Report of Diamond Grinding on Cells 7 & and 8 MnROAD Mainline Interstate Highway 1-94

Draft Final Report

Prepared by:

Bernard Igbafen Izevbekhai, P.E, M.Eng, MSISE,
Research Operations Engineer,
Minnesota Department of Transportation

November 2007

Published by:

Minnesota Department of Transportation
Research Services Section
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

This report represents the results of research conducted by the author and does not necessarily represent the views or policies of the Minnesota Department of Transportation and/or the Center for Transportation Studies. This report does not contain a standard or specified technique.

Caveat

The authors and the Minnesota Department of Transportation and/or Center for Transportation Studies do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to this report

ACKNOWLEDGEMENTS

Author expresses gratitude to Diamond Surface Incorporated (DSI) in general and Terry Kraemer Owner and Chief Executive of DSI in particular and for providing the actual grinding of Cells 7 and 8 and 37 and bearing all the grinding cost to facilitate this study.
Acknowledgement s are also due to and Texas Department of Transportation, Minnesota Department of Transportation (Lead State)and Federal Highway Administration for participating in the transportation pooled fund TPF 5-(134) relevant to this study.
Author is grateful to Larry Scofield Director of Environmental services ACPA for arranging all the field validation process and performing most of the Sound testing. Author is indebted to International Grooving and Grinding Association (IGGA) and American Concrete Paving Association (ACPA for their immeasurable roles in this study.

Bernard I Izevbekhai, P.E.
Lead State Technical Contact
Nov 2007

Executive Summary

With increased understanding of surface characteristics it was expedient re-examine on how diamond grinding process and performance can be improved to enhance quietness, safety and ride comfort. An attempt to define the scope without re-inventing the wheel led to a collaboration of Center for Quiet Safe and Durable Highways (SQDH) Purdue, Federal Highway Administration (FHWA), American Concrete paving Association (ACPA), International Grinding and Grooving Association (IGGA) towards a laboratory development of a quieter grinding configuration. It was determined at that juncture that MnROAD studies would create an opportunity to validate the Purdue results. Some meetings were held with IGGA local Minnesota and Concrete Paving Association of Minnesota towards this objective.

The study was posted as solicitation 1048 in the Transportation Pooled Fund (TPF website and responses were obtained from Mn/DOT (Lead state), TXDOT and FHWA (Mark Swanlund). It was subsequently cleared by FHWA and assigned TPF # (TPF 5-(134)... However, to fulfill the required 20% percent match for the Federal participation, some non-Federal source for a minimum of $25,000 was required... ACPA and IGGA agreed to perform the Diamond grinding as an in-kind match. Mn/DOT developed a partnership agreement with ACPA pursuant to the diamond grinding. Mn/DOT made 2 cells available in MnROAD Mainline for this study. Subsequently ACPA requested to do a proof-of-concept at MnROAD Low Volume Road to increase the comfort level of performing unconventional grind before proceeding to the mainline. Mn/DOT provided cell 37 in the low volume loop for the proof of concept or initial validation test.

The proof of concept grinding was performed in the week of June 18 2007. Noise (OBSI) measurements were performed by Larry Scofield of ACPA and the texture, ride, and friction measurements were performed by Mn/DOT Concrete Research and MnROAD Operations. In the pooled fund meeting held on the 18th of July member states expressed the need to see the performance of the grinding configurations in full lane width as against the 2' test strips in the low volume road. The group agreed on the following points:

- The grinding of the mainline has to be done. Bernard and Ben Worel met with IGGA and fully explored the original option of industry grinding the mainline. Diamond Surface Incorporated (DSI) agreed to construct the cells at their expense. In consequence Mn/DOT elected to perform the Monitoring of the ground pavement.
- The scope of works includes monitoring of friction, noise, texture and ride quality. Development of a protocol for splash and spray will not be included in the scope of works. A consultant will be hired however to provide an advisory role. Consultant shall in the advisory role make recommendation for other research needs, perform statistical analysis on our data in relation to data from other surface characteristics initiatives.
- In this role the consultant will participate in meetings and render construction and periodic reports. Such a consultant will be proficient in surface characteristics work and should be knowledgeable in the interpreting analyzing data on texture, noise, ride and friction. Durability and benefit /cost will also be documented and reported.

The Proof of concept grinding validated the feasibility of producing the innovative grind at a production level. Although it was not a full width grinding exercise four test strips were created. 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. 0.120 groove Kerf, depth configuration TS1 and TS2 represented the innovative configuration with the difference of the number of passes to achieve each configuration. TS4 was the original non-uniform transverse tine that was in the entire lane before grinding. ACPA measured on Board sound intensity on each strip and Mn/DOPT measured Ride quality, Friction, and Texture before and after grinding. The results showed a Friction number distribution of ribbed tire friction for the innovative grind ranging from the 48 to the 54. The disparity between ribbed and smooth tire friction was less than 5 in the innovative configurations. This is a significant issue in the interpretation of non correlative texture degradation and Friction degradation observations and lends credence to the hysterisis theory of tire pavement Suction enhanced by better contact

Ride quality measurements were difficult to establish within the strips as the vertical acceleration of the wheel track was not representative of the single laser response that bounced from kerf to grove and vice versa. This resulted in higher ride quality measurements after grinding. Ride quality before grinding was averaged at 64in/mile but ride quality ranged from 89 inches per mile in the Right wheel path to 160 inches per mile in the innovative grind. A triple laser measurement was also done. Texture measurements indicated greatly improved texture depths with the conventional grind and improved texture depths in the innovative grind, after grinding. Onboard sound intensity tests showed that the innovative grind achieved a high level of quietness surpassing previously known configurations of grinding. At 98.5 Db(A) the Innovative grind was much quieter than the conventional grind 102 Db(A) and than the un-ground tine 104 Db(A).

After the pregrind measurements the mainline Cells 7 and 8 grinding was done by DSI forces between 10/18/07 and 1020/07 and the respective testing for post grind friction texture ride and noise followed shortly after. Cell 7 had the innovative grind while cell 8 had the conventional grind. By the strategy described in section 4, a separate sub cell was created in the left shoulder of cell 8. In that portion, partial tine removal was performed by DSI.

Results showed improved ride quality in the innovative and conventional grinding partly because DSI performed some corrective grinding in portions of extreme faulting. The innovative grinding resulted in IRI improvement from 128 inches per mile to 72 inches per mile in the driving lane. The passing lane showed the same percentage improvement in IRI after grinding in each cell while the driving lane showed a different percentage improvement but similar in both cells. Each Lane therefore had the same percentage improvement in spite of the configuration.

Prior to grinding, texture measurements ranged from .3 mm to .5 mm. In Cell 8 shoulder texture measurements indicated that original textures 0.8 mm had been original textures were maintained over time. This was partially removed by grinding but the macro and micro texture of the diamond grind resulted in improved texture to 1 mm or greater after partial tine removal. Texture improved in the conventional grind to a 1.2mm to 1.5mm range. The innovative grind textures improved to a range of .9mm to 1.1mm. This was more uniform and unlike the conventional grind, the texture was durable and could not be easily damaged by oblique impacts. Friction measurements in the Mainline were similar to results obtained in cell 37. Once again, the difference between the smooth and ribbed tire friction was small. OBSI noise levels for the conventional grind measured by Mn/DOT at 102 and 103 DBA and the innovative grind was 98.5 db(A)

These cells will be monitored for a minimum of 5 years to determine durability and time related texture/ friction decay of the innovative grinds and the noise trends over the study period.

Section 1 deals with the histrionics preceding this grinding activity and how we got here. Section2 discusses cell 37 proof of concept grinding in detail. Section 3 discusses the results and testing of the configurations in cell 37. Section 3 discusses the testing of cell 37. Section 4 discuses the Grinding activities for cells 7 and 8 MnROAD Mainline and section5 discusses the results of testing. Section 6 concludes that the innovative grind is actually a quiet pavement innovation that should be monitored for many years to observe performance with time

Index

List of Tables

List of Figures

Appendix

F4. Noise data From Cell 37

1 INTRODUCTION

1.1 MnRoad Facility

The Minnesota Department of Transportation (Mn/DOT) constructed the Minnesota Road Research Project (MnROAD) between 1990 and 1994. MnROAD is located along Interstate 94 forty miles northwest of Minneapolis/St.Paul and is an extensive pavement research facility consisting of two separate roadway segments containing 51 distinct test cells. Each MnROAD test cell is approximately 500 feet long. Subgrade, aggregate base, and surface materials, as well as, roadbed structure and drainage methods vary from cell to cell. All data presented herein, as well as historical sampling, testing, and construction information, can be found in the MnROAD database and in various publications. Layout and designs used for the Mainline and Low Volume Road are shown in appendix E

Additional information on MnROAD:
http://mnroad.dot.state.mn.us/research/mnresearch.asp.

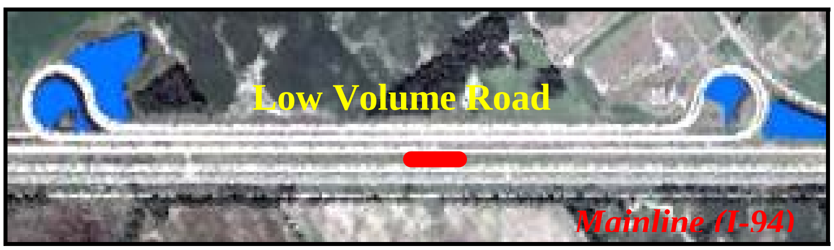


Figure 1 – MnROAD Mainline and Low Volume Road Indicating Cells 7 and 8 as Red Solid Line

1.2 Low Volume Road

Parallel and adjacent to Interstate 94 and the Mainline is the Low Volume Road (LVR). The LVR is a 2-lane, 2½-mile closed loop that contains 20 test cells. Traffic on the LVR is restricted to an MnROAD operated vehicle, which is an 18-wheel, 5-axle, tractor/trailer with two different loading configurations. The "heavy" load configuration results in a gross vehicle weight of 102 kips (102K configuration). The “legal” load configuration has a gross vehicle weight of 80 kips (80K configuration). On Wednesdays, the tractor/trailer operates in the 102Kconfiguration and travels in the outside lane of the LVR loop. The tractor/trailer travels on the inside lane of the LVR loop in the 80K configuration on all other weekdays. It was hypothesized at the inception of MnROAD that the 2 load spectra would yield similar damage ESALs on the LVR are determined by the number of laps (80 per day on average) for each day and are entered into the MnROAD database.

1.3 MnROAD Mainline

The mainline consists of a 3.5-mile 2-lane interstate roadway carrying “live” traffic. Cell design/layout can be found in Appendix-E. The Mainline consists of both 5-year and 10-year pavement designs. The 5-year cells were completed in 1992 and the 10-year cells were completed in 1993. Originally, a total of 23 cells were constructed consisting of 14 HMA cells and 9 Portland Cement Concrete (PCC) test cells.

Traffic on the mainline comes from the traveling public on westbound I-94. Typically the mainline traffic is switched to the old I-94 westbound lanes once a month for three days to allow MnROAD researchers to safely collect data. The mainline ESALs are determined from an IRD hydraulic load scale was installed in 1989 and a Kistler quartz sensor installed in 2000. Currently the mainline has received roughly 7. million flexible Equivalent Single Axle Loads (ESALS) and 10 million Rigid ESALS as of December 31, 2006

1.4 MnROAD Instrumentation and Performance Database

Data collection at MnROAD is accomplished with a variety of methods to help describe the layers, the pavement response to loads and the environment, and actual pavement performance. Layer data is collected from a number of different types of sensors located throughout the pavement surface and sub-layers, which initially numbered 4,572. Since then researchers have added to this total with additional installations and sensors types. Data flows from these sensors to several roadside cabinets, which are connected by a fiber optic network that is feed into the MnROAD database for storage and analysis. Data can be requested from the MnROAD database for each sensor along with the performance data that is collected thought the year. This includes ride, distress, rutting, faulting, friction, forensic trenches, material laboratory testing and the sensors measure variables such as temperature, moisture, strain, deflection, and frost depth in the pavement along with so much more**.**

1.5 Histrionics of The Diamond Grinding Initiative

With increased understanding of surface characteristics it was expedient re-examine on how diamond grinding process and performance can be improved to enhance quietness, safety and ride comfort. An attempt to define the scope without re-inventing the wheel led to a collaboration of Center for Quiet Safe and Durable Highways (SQDH) Purdue, Federal Highway Administration (FHWA), American Concrete paving Association (ACPA), International Grinding and Grooving Association (IGGA) towards a laboratory development of a quieter grinding configuration. It was determined at that juncture that MnROAD studies would create an opportunity to validate the Purdue results. Some meetings were held with IGGA local Minnesota and Concrete Paving Association of Minnesota towards this objective.

The study was posted as solicitation 1048 in the Transportation Pooled Fund (TPF website and responses were obtained from Mn/DOT (Lead state), TXDOT and FHWA (Mark Swanlund). It was subsequently cleared by FHWA and assigned a TPF # (TPF 5-(134)... However, to fulfill the required 20% percent match for the Federal participation, some non-Federal source for a minimum of $25,000 was required... ACPA and IGGA agreed to perform the Diamond grinding as an in-kind match. Mn/DOT developed a partnership agreement with ACPA pursuant to the diamond grinding. Mn/DOT made 2 cells available in MnROAD Mainline for this study. Subsequently ACPA requested to do a proof-of-concept at MnROAD Low Volume Road to increase the comfort level of performing unconventional grind before proceeding to the mainline. Mn/DOT provided cell 37 in the low volume loop for the proof of concept or initial validation test.

The proof of concept grinding was performed in the week of June 18 2007. Noise (OBSI) measurements were performed by Larry Scofield of ACPA and the texture, ride, and friction measurements were performed by Mn/DOT Concrete Research and MnROAD Operations. In the pooled fund meeting held on the 18th of July member states expressed the need to see the performance of the grinding configurations in full lane width as against the 2' test strips in the low volume road. The group agreed on the following points:

- The grinding of the mainline has to be done. Bernard and Ben Worel met with IGGA and fully explored the original option of industry grinding the mainline. Diamond Surface Incorporated (DSI) agreed to construct the cells at their expense. In consequence Mn/DOT elected to perform the Monitoring of the ground pavement.
- The scope of works includes monitoring of friction, noise, and texture and ride quality. Development of a protocol for splash and spray will not be included in the scope of works. A consultant will be hired however to provide an advisory role. Consultant shall in the advisory role make recommendation for other research needs, perform statistical analysis on our data in relation to data from other surface characteristics initiatives.
- In this role the consultant will participate in meetings and render construction and periodic reports. Such a consultant will be proficient in surface characteristics work and should be knowledgeable in the interpreting analyzing data on texture, noise, ride and friction. Durability and benefit /cost will also be documented and reported.

2. Grinding Proof of Concept in Cell 37

2.1 Background

The IGGA and ACPA have been working with Purdue University to develop a diamond grinding texture with improved noise characteristics. The research began by attempting to optimize blade width and spacer configurations. Traditionally, this had been thought to control resulting noise characteristics. However, the Purdue work indicated that fin profile was the controlling variable and not the blade/spacer configuration.

2.2 Laboratory Development of Innovative Grinding Textures

Work then began to produce fin profiles that were essentially uniform on top. After experimentation, two different techniques appeared to work best. The use of three chopper blades utilized as spacers placed between two 0.125 inch conventional diamond grinding blades, and a "flush" grind with grooving. The flush grind was produced by using 0.090 inch width blades with 0.090 inch spacers to lightly grind the surface. The Purdue grinding head was then offset slightly to grind a second time to remove the fins. The flush ground texture was then grooved with 0.125 inch diamond grinding blades spaced on 0.50 inch centers. The grooves produced measured 0.012 inches deep. The chopper blade configuration used chopper blades that were dressed to 0.08 inches shorter in radius than the 0.125 inch blades.

The Purdue research uses the Purdue Tire Pavement Test Apparatus (TPTA) to evaluate the various textures. This laboratory based device, shown in Figure 2.1, consists of a twelve foot diameter drum upon which six cast segments are placed around the circumference as shown. The IGGA developed grinding head was used to grind the various textures and is shown in the right hand side of Figure 2.1

.

Figure 2.1a and b Laboratory Diamond Grinder and Top Track Purdue Testing Wheel

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. The diamond ground surface, although resembling actual field grinding had not been produced using actual diamond grinding equipment in practice. The flush grind surface was produced on the TPTA by offsetting the head and making a second pass such that the fins were ground off.

2.3 Diamond Grinding Configurations on the low volume Road

Field validation was a two-part process. First the "proof of concept" intended to prove or disprove that textures created and measured on the TPTA reflect diamond ground textures on the MnROAD Low Volume Road. The second stage was the actual full width-production-based construction operation. These configurations were tested for noise, friction characteristics as well as ride quality and texture in each case.

On May 24, 2007 sections 37, 38, and 39 of the Mn ROAD low volume concrete test sections were reviewed by ACPA (Larry Scofield). It was noted that cell 38 had significant cracking and distress. Section 37 and 39 both appeared useable but one large transverse crack existed in section 39. All the sections had surface textures in good condition with well sealed joints. The existing texture was a random transverse tine pattern installed at right angles to the roadway direction. The transverse joints were skewed. The joints appeared to be approximately 3/8 to ½ inch in width with an approximate 3/16 inch recess in the silicone sealant.

In the eastbound direction two inch cores had been retrieved across two joint locations. This requires that the WB directions be used for the testing to avoid these joints. The WB sections, however, included instrumentation access covers in the wheel path locations.

The field validation experiment consisted of grinding two wheel tracks, each 18 inches wide by 500 ft long, and one wheel track 24 inches wide by 500 ft long. One wheel track was ground using 0.125 inch blades with 0.120 inch spacers. This was TS3 and Similar to a conventional grind. This wheel track was considered the "control" and used as a benchmark to evaluate the other two strips. Each strip was ground to 24 inches wide to eliminate the need to restack the equipment head as its current configuration is 24 inches wide.

In a second strip the grinders used the triple chopper blades in combination with 0.125 inch conventional blades. A third track used a technique to produce a flush grind condition similar to the Purdue work and then groove it with 0.125 blades spaced on 0.50 inch centers. The Purdue work used 0.090 inch blades and spacers to produce this texture and then offset and reground to remove the fins. An alternative technique will be required in the field to produce the flush grind condition. Anticipating that the existing random transverse tined texture may have impact on the On Board Sound Intensity (OBSI) levels, flush grinding was performed in part to eliminate current random tine texture. Uniformity of removal of the existing tine was an issue of concern.

The diamond grinding configurations were arranged in cell 37 as shown in figure 2.3.1. Three test sections, two 18 inches wide and one 24 inches wide were constructed leaving a strip (TS4) of existing random transverse tine on the right wheel path.

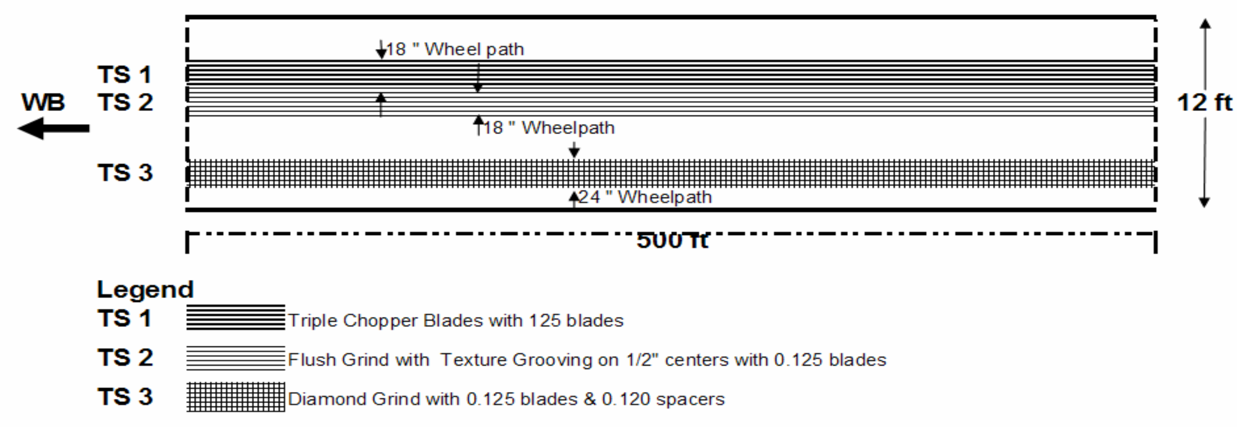


Figure 2.4 Diamond Grinding Test Section Layout in Cell 37

3 Post Grind Testing in the Low Volume Road

3.1 OBSI Noise Testing Sequence

OBSI testing was conducted on the existing random transverse tining in each of the four strips prior to grinding. Upon completion of the diamond grinding, the surface of each of the three test grind wheel tracks were tested again. Subsequently, the joint seal were removed using a joint plow or other suitable device. Upon completion of sealant removal, OBSI testing was conducted again on the four strips. The intent was to validate both the Purdue TPTA recommended surfaces and to validate the Purdue TPTA predicted joint effects for one joint width level.

For each test on each of the four strips, four replicate runs were conducted with the ACPA OBSI equipment. This resulted in 12 tests for each of wheel tracks 1-3 and 8 tests for wheel track 4 for a total of 44 OBSI tests. Since the wheel track is only 18 inches wide, guidance of the test vehicle (e.g. Chevy Malibu) was carefully performed during OBSI testing. This was accomplished by painting dots on the PCCP surface to use for guidance. A separate set of dots will be needed for each wheel track. The markings will need to extend through the test areas and beyond to allow adequate alignment. OBSI testing was conducted by the ACPA using the dual probe configuration at 60 mph with the 16 inch ASTM SRTT tire.

Upon completion of the MnRoad testing, the ACPA OBSI test tire and wheel (e.g. ASTM SRTT tire mounted on Chevy Malibu Wheel) was dismounted from the Malibu and mounted on the Purdue TPTA and used to retest the original TPTA texture samples (e.g. triple chopper and flush grind). The recently calibrated ACPA Cal Tone was used to calibrate the Purdue equipment. This will remove as much tire bias and microphone calibration bias as possible between the field and laboratory comparisons. Mn/DOT Conducted Ride, Friction, and Texture measurements. Results of the Proof of concept experiment in the low volume road are shown in Appendix F

3 Results of Testing on Cell 37

Detailed test results are shown in appendix F.

3.2 Friction Testing

Mn DOT conducted ASTM E-274 Locked-Wheel Skid testing with the ASTM smooth tire. Friction testing will be conducted two times during the experiment: (1) After completion of the initial (e.g. prior to grinding) OBSI testing on test sections TS1, TS2 and TS3; and a second time on these same sections after the joint seal has been removed and the final OBSI test measurements obtained. This sequencing eliminated the possibility of contamination of the textures by the skid tester while still obtaining before and after measurements to evaluate frictional changes.

3.3 Ride Testing

Ride measurements were accomplished with the AMES LISA Light weight profiler operated at 10 mph. To ensure measurements were within the cell auto start and stop commands were used.

TS3

TS1 TS2 TS4

Fig 3.2.1 Configurations in Cell 37

Fig 3.2.2 Close-up View of the Quiet Configurations TS1 and TS 2 With Original Transverse tine texturing sandwiched between.

Fig 3.2.3 A Panoramic View of the texture Strips Looking West on Cell 37 MnROAD

Fig 3.2.4 Close-up View Of TS1 Innovative Grind in one pass Cell 37 MnROAD

Fig 3.2 .5 Grinding Head and Spacers

Fig 3.2.6 Grinding Shaft before assemblage of Cutters and spacers

4 MAINLINE (Cells 7 and 8) GRINDING ACTIVITIES

The Details of the construction activities are shown in Appendix Table a 4.2.
Grinding of the Surface was preceded by an identification of the configurations to which the two cells would be ground. The strategy chosen included

- Conventional grinding on Cell 8
- Innovative grinding on cell 7
- Partial grind on Tied Concrete shoulder of cell 8

The layout is shown in table 4.1

Table 4.1 Layout of Grinding Activities

Diamond Services Incorporated performed the Grinding. Equipment on site included the Diamond grinding equipment, consisting of the actual cutting equipment with an articulated water receptacle. DSI performed longitudinal grinding in minimally overlapping longitudinal strips. This resulted in 4 passes per 12 ft lane. The 2 cells were ground with the conventional grinding . That was the full grind for cell 8 and the primary grind for cell 7. The secondary grind for cell 7 is the innovative diamond grinding configuration that is the subject of this study.

DSI Performed the Grinding in the sequence recorded below. Prior to the mainline closure that commenced on the 15th of October, Mn/DOT Concrete Research Team had conducted Pregrind OBSI, and Ride Quality tests on Cells 7 and 8. The proceeding is the sequence of activities during the actual lane closure that spanned from the 15th of October to the 23rd of October.

October 15 2007:
7:00 AM : MnROAD Operations closed mainline traffic switch to allow testing prior to the grinding.

- 10:00AMMn/DOT Concrete research mark the spots (BX 1 to BX 13 representing 52 spots) for pre and post grind texture measurements on the right shoulder on both cells such that the prescribed test spots are the locations where lines Drawn from the shoulder spots parallel to the skew joints intersect the 4 wheel path. Mn/DOT Concrete Research (Series BX 14 to BX21 representing 18 spots were also made on the shoulder of Cell 8.
- 12:00 noon Mn/DOT Concrete Research Operations conducts a visual survey and observes sensor caps predominantly on cell 7 wheel path and assess the extent to which that would affect statistical pass by noise measurements.

October 16 2007 :

- Weather was overcast and characterized by intermittent drizzles Mn/DOT Concrete research conducted some Sand Volumetric Technique (Sand patch tests and confirmatory Circular track meter tests on some location. Concrete Research Operations requested for possible removal of sensor shaft capping that was on the pavement surface predominantly on cell 7 due to the anticipation that it may cause transient effects on the noise spectrum particularly in the Statistical Pass By measurements. MnROAD Operations promised to work on the caps to minimize influence on grinding and accuracy of noise measurement.

- October 17 2007 : Overcast , intermittent drizzles. 55- 60 Deg.
- 7:30 AM MnROAD Operations secure water meter and Hydrant in Otsego for the grinding.

- 12:00 noon Mn/DOT Concrete Research performs the final pregrind texture measurements To ASTM E-965 and ASTM E-2153 Standards. DSI brings equipment to site. Equipment included Diamond Grinder, Water Truck. Crew consisted of a supervisor, an Operator and the water truck driver. DSI Terry Kraemer confers with Mn/DOT Concrete Research Operations to confirm location and configuration of Grinding.

October 18 2007

- 6:30 am: DSI Commences Grinding from Driving lane left edge and performs 4 ft wide conventional grinding strips non stop from East end of Cell 8 to west end of cell 7.
- 9:30AM: DSI performs corrective grinding to remove prominent bumps from cell 8. The bumps were removed in 6 parallel runs though the 300ft portion of the Cell that was faulted and fraught with bumps and dips. Original construction records indicated that this correction was suggested during the initial testing of the original pavement but was not done at that time.
- 12:00 Noon: DSI resumes conventional grind in parallel strips from east end of cell 8 to west end of cell 7.

- 6:00pm DSI Closes for the Day after grinding the entire driving lane and half of the Passing Lane.

10/19/07 Weather Overcast Intermittently clear temp55-60 degrees

- <u>6:00AM</u> DSI commences grinding of the Remaining strip of the passing Lane.
- <u>12:00 Noon</u> DSI Completes conventional grinding of cells 7 and 8 and partial texture removal grind of cell 8 Shoulder. Cell 8 Shoulder was ground to a lesser groove depth than the conventional grind as requested by ACPA.

- 1:00PM DSI disassembles the blades for the conventional grind and sets up the blades for the single pass innovative grind.
- 4:00PM DSI commences the innovative grinding on cell 7.
- 6:30PM. DSI completes the Innovative grinding of Cell 7 Driving Lane.

10/ 20/07 (Saturday) clear 55-60 degrees

- 6:00 AM DSI Commences innovative grinding of passing lane.12:00 noon DSI completes grinding of the passing Lane thus completing the entire grinding.

Fig 4.1 DSI Diamond Grinding equipment complete with cutter and articulated water truck

Fig 4.2 Conventional Grind Configuration (0.125X 0.125x.0.120)

Fig 4.3 Conventional Grind and Innovative Grind

Fig 4.4 Conventional Grind Cell 8 And Previous Texturing (Transverse Tine)

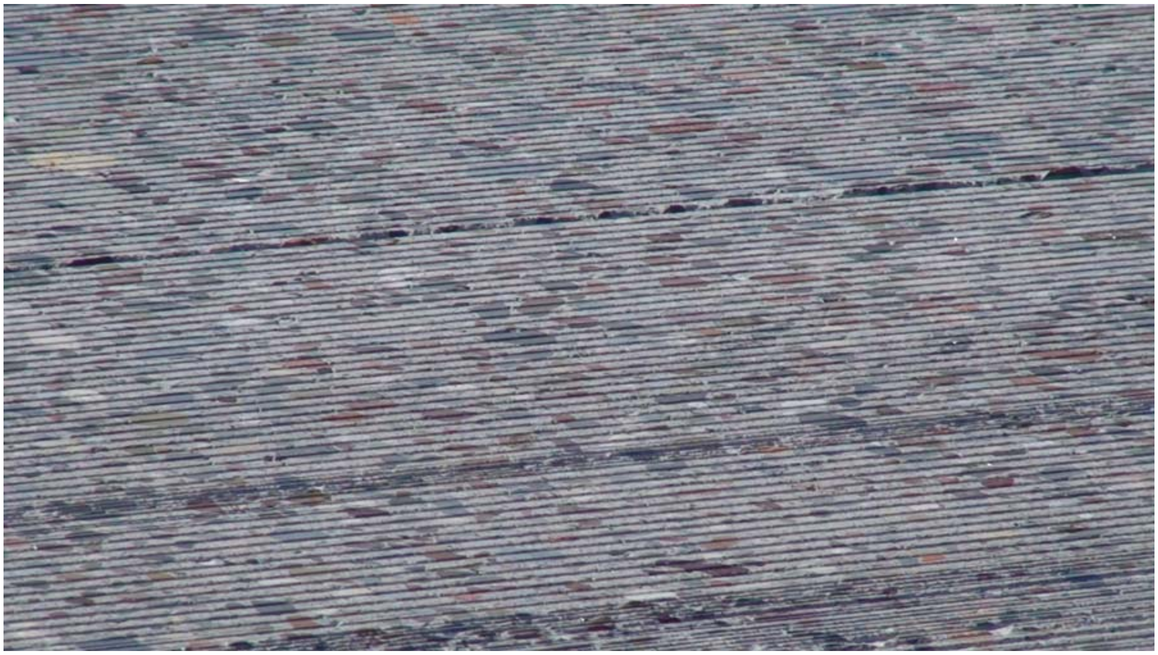


Fig 4.5   Innovative Grind with Skid Marks After Friction Testing

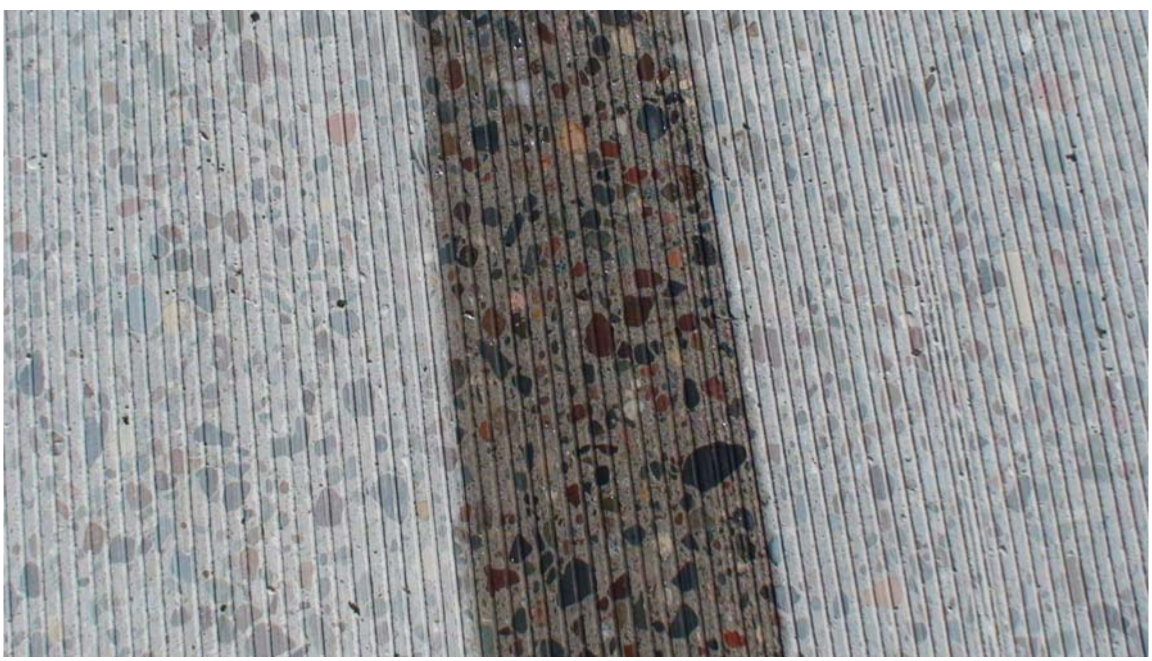


Fig 4.6 Wet Tracks on Innovative Grind After Friction Testing

Fig 4.7 Statistical-Pass-By Set-Up Beside Cell 7 (Measurement by Illingworth and Rodkin)

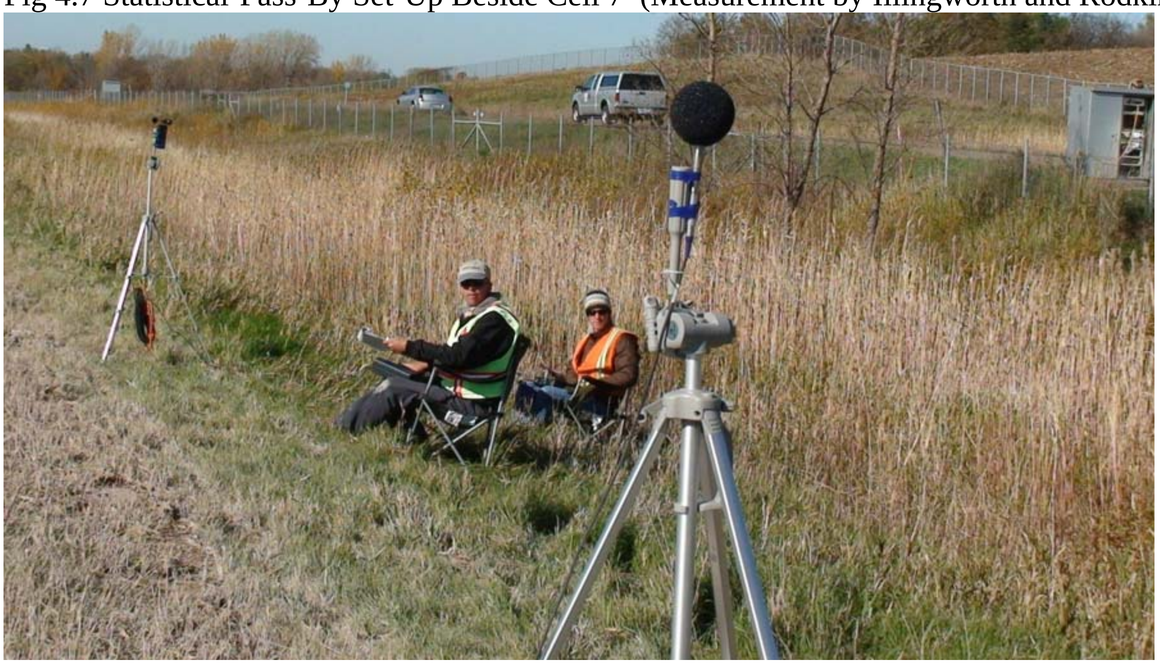


Fig 4.8 Statistical-Pass-By Showing Radar Measuring Speed Microphone and Weather Station Near cell 8


Fig 4.9 ASTM E 2157-01 Circular Track Meter Texture Testing on cell 8


Fig 4.10 Close-up view of the Diamond Cutter

Fig 4.11 DSI Equipment Worked adequately under the Rain

4 POST GRIND TESTING RESULTS

Table 4.1 POST GRIND VS PREGRIND Mainline Ride Quality Cells 7 and 8

Cell Location	Lane	Wheel Path	Pre-Grind IRI (inch/Mile)	Post Grind IRI (inch/Mile)
Cell 7	Driving	LWP	72.8	48.3
		LWP		44.5
		LWP		46.5
		RWP	78.5	51.9
		RWP		55.4
		RWP		44.2
Cell 8	Driving	LWP	123.1	70.4
		LWP		74.1
		LWP		74.9
		RWP	104.8	74.2
		RWP		75.4
		RWP		75.3
Cell 7	Passing	LWP	68	53.7
		LWP		47.5
		LWP		50
		RWP	128.7	81.7
		RWP		84.9
		RWP		73.7
Cell 8	Passing	LWP	107.9	70.7
		LWP		55.9
		LWP		66
		RWP	128	81.7
		RWP		84.9
		RWP		73.7

Table 4.2 OBSI SUMMARY POST GRINDING

O.B.S.I. Data Sheet

Date:10/22/2007

Operator: J.P. & T.S.

Location	Test No.	Leading Edge	Trailing Edge	Average
Cell 8 D.L.	1	103.6	102.6	**103.1**
	3	104.0	103.0	**103.5**
	5	103.7	102.9	**103.3**
Cell 7 D.L.	2	98.8	99.7	**99.3**
	4	98.1	98.8	**98.5**
	6	98.5	99.0	**98.7**
Cell 7 Midlane	7	98.6	99.0	**98.8**
	8	98.4	99.0	**98.7**
	9	98.2	98.7	**98.5**
Cell 8 P.L.	10	103.4	102.5	**103.0**
	12	103.5	102.6	**103.1**
	14	104.1	103.3	**103.7**
C ell 7 P.L.	11	98.2	99.2	**98.7**
	13	98.2	99.2	**98.7**
	15	98.7	99.6	**99.2**

Table 4.3 Pre-grind OBSI (Illingworth and Rodkin)

TABLE 4.4 HISTORICAL PREGRIND FRICTION DATA

			Cell 7				
Driving Ribbed		**RTF**		**PASSING Ribbed**		**RTF**	
		D lane RTF				**Plane RTF**	
ML-Driving-RL	23-Jun-94	60	Ribbed	ML-Passing-LL	23-Jun-94	58.7	Ribbed
ML-Driving-RL	29-Oct-97	55.1	Ribbed	ML-Passing-LL	23-Jun-94	58.7	Ribbed
ML-Driving-RL	20-Oct-98	47.7	Ribbed	ML-Passing-LL	20-Sep-94	52.5	Ribbed
ML-Driving-RL	31-Oct-01	38.1	Ribbed	ML-Passing-LL	4-May-95	60.1	Ribbed
ML-Driving-RL	3-Nov-04	57.7	Ribbed	ML-Passing-LL	20-Jun-95	63.6	Ribbed
ML-Driving-RL	24-May-05	53.3	Ribbed	ML-Passing-LL	29-Oct-97	58.3	Ribbed
ML-Driving-RL	19-Apr-06	55.7	Ribbed	ML-Passing-LL	20-Oct-98	53.4	Ribbed
ML-Driving-RL	24-Oct-06	59.5	Ribbed	ML-Passing-LL	31-Oct-01	42.1	Ribbed
ML-Driving-RL			Ribbed	ML-Passing-LL	3-Nov-04	56.9	Ribbed
ML-Driving-RL			Ribbed	ML-Passing-LL	24-May-05	58.8	Ribbed
ML-Driving-RL			Ribbed	ML-Passing-LL	19-Apr-06	57.5	Ribbed
ML-Driving-RL			Ribbed	ML-Passing-LL	24-Oct-06	59.4	Ribbed
				ML-Passing-LL	14-Oct-98	56.7	Ribbed
Driving Smooth		**STF**	**Passing Smooth**			**STF**	
		D Lane STF				**P Lane STF**	
ML-Driving-RL	14-Oct-98	31	Smooth		14-Oct-98	46	Smooth
ML-Driving-RL	20-Oct-98	36.2	Smooth	ML-Passing-LL	20-Oct-98	41.9	Smooth
ML-Driving-RL	19-Apr-06	26.2	Smooth	ML-Passing-LL	3-Nov-04	43.3	Smooth
ML-Driving-RL	24-Oct-06	35.9	Smooth	ML-Passing-LL	19-Apr-06	40.4	Smooth
			Cell 8				
Driving Ribbed		**RTF**		**PASSING Ribbed**		**RTF**	
		D lane RTF				**P Lane RTF**	
ML-Driving-RL	23-Jun-94	54.3	Ribbed	ML-Passing-LL	23-Jun-94	56.4	Ribbed
ML-Driving-RL	20-Sep-94	54.9	Ribbed	ML-Passing-LL	20-Sep-94	47	Ribbed
ML-Driving-RL	4-May-95	54.8	Ribbed	ML-Passing-LL	4-May-95	57.7	Ribbed
ML-Driving-RL	20-Jun-95	48.5	Ribbed	ML-Passing-LL	20-Jun-95	55.4	Ribbed
ML-Driving-RL	29-Oct-97	44.5	Ribbed	ML-Passing-LL	29-Oct-97	52.8	Ribbed
ML-Driving-RL	14-Oct-98	46.2	Ribbed	ML-Passing-LL	14-Oct-98	54.4	Ribbed
ML-Driving-RL	20-Oct-98	37.7	Ribbed	ML-Passing-LL	20-Oct-98	39.9	Ribbed
ML-Driving-RL	31-Oct-01	38.7	Ribbed	ML-Passing-LL	31-Oct-01	41.2	Ribbed
ML-Driving-RL	3-Nov-04	47.5	Ribbed	ML-Passing-LL	3-Nov-04	50.4	Ribbed
ML-Driving-RL	24-May-05	42.6	Ribbed	ML-Passing-LL	24-May-05	46.8	Ribbed
ML-Driving-RL	19-Apr-06	60.7	Ribbed	ML-Passing-LL	19-Apr-06	52.6	Ribbed
ML-Driving-RL	24-Oct-06	48	Ribbed	ML-Passing-LL	24-Oct-06	47	Ribbed
Driving Smooth		**STF**	**Passing Smooth**			STF	
		D Lane STF				Plane STF	
ML-Driving-RL	14-Oct-98	25.9	Smooth	ML-Passing-LL	14-Oct-98	41.3	Smooth
ML-Driving-RL	20-Oct-98	22.6	Smooth	ML-Passing-LL	20-Oct-98	24.3	Smooth
ML-Driving-RL	19-Apr-06	30.2	Smooth	ML-Passing-LL	3-Nov-04	29.7	Smooth
ML-Driving-RL	19-Apr-06	30.2	Smooth	ML-Passing-LL	19-Apr-06	28	Smooth
ML-Driving-RL	24-Oct-06	20.9	Smooth				

Table 4.5 POST GRIND FRICTION MEASUREMENT

CELL	LANE	DAY	TIME	FN	SPEED	AIR_TEMP	TIRE_TYPE	EQUIPMENT	STA	DATE_UPDA	Texture E-274	Type
7	Driving	Tuesday	10:32 AM	53.6	40.4	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	0.56	Innovative
7	Driving	Tuesday	10:32 AM	54.7	40.3	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	0.53	Innovative
7	Driving	Tuesday	10:32 AM	51.2	42.1	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	0.53	Innovative
7	Driving	Tuesday	10:32 AM	47.4	41.4	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	0.53	Innovative
7	Passing	Tuesday	11:08 AM	47.4	42	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	0.64	Innovative
7	Passing	Tuesday	11:08 AM	49.3	41.4	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	0.61	Innovative
7	Passing	Tuesday	11:08 AM	48.8	41.2	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	0.61	Innovative
7	Passing	Tuesday	11:08 AM	44.6	40.8	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	0.64	Innovative
8	Driving	Tuesday	10:32 AM	85.9	40.3	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	0.86	Conventional
8	Driving	Tuesday	10:32 AM	80.2	41.3	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	0.81	Conventional
8	Driving	Tuesday	10:32 AM	63.5	41.4	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	0.81	Conventional
8	Driving	Tuesday	10:32 AM	62.7	40.4	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	0.81	Conventional
8	Passing	Tuesday	11:08 AM	62.6	40.4	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	1.24	Conventional
8	Passing	Tuesday	11:08 AM	65.2	41.2	52	Ribbed	Mn/DOT - 1295 Friction		22-Oct-07	1.24	Conventional
8	Passing	Tuesday	11:08 AM	64.2	41	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	1.02	Conventional
8	Passing	Tuesday	11:08 AM	73.1	40.2	52	Smooth	Mn/DOT - 1295 Friction		22-Oct-07	0.89	Conventional

5 Brief Discussion of Results

The Proof of concept grinding v alidated the feasibility of producing the innovatiovew grind at a production level. Although it was not a full width grinding exercise four test strips were created. 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 .125X .125 X.120 g4rrove Ke4rf, depth configuration TS1 and TS2 represented the innovative configuration with the difference of the number of passes to achieve each configuration. TS4 was the original non-uniform transverse tine that was in the entire lane before grinding. ACPA measured on Board sound intensity on each strip and Mn/DOPT measured Ride quality, Friction, and Texture before and after grinding. The results showed a Friction number distribution of ribbed tire friction for the innovative grind ranging from the upper 40s to the mid 50s. The disparity between ribbed and smooth tire friction was less than 5 in the innovative configurations. This is a significant issue in the interpretation of non correlative texture degradation and Friction degradation observations and lends credence to the hysterisis theory of tire pavement suction enhanced by better contact

Ride quality measurements were difficult to establish within the strips as the vertical acceleration of the wheel track was not representative of the single laser response that bounced from kerf to grove and vice versa. This resulted in higher ride quality measurements after grinding. Ride quality before grinding was averaged at 64in/mile but ride quality ranged from 89 inches per mile in the Right wheel path to 160 inches per mile in the innovative grind. A triple laser measurement was also done. Texture measurements indicated greatly improved texture depths with the conventional grind and improved texture depths in the innovative grind, after grinding. Onboard sound intensity tests showed that the innovative grind achieved a high level of quietness surpassing previously known configurations of grinding. At 98.5 Db(A) the Innovative grind was much quieter than the conventional grind 102 Db(A) and than the Un-ground Tie 104 Db(A).

After Mn/DOT had performed pre-grind measurements the mainline Cells 7 and 8 grinding was done by DSI forces between 10/18/07 and 1020/07 and the respective testing for post grind friction texture ride and noise followed shortly after. Cell 7 had the innovative grind while cell 8 had the conventional grind. By the strategy described in section 4, a separate sub cell was created in the left shoulder of cell 8. In that portion, partial tine removal was performed by DSI. Tables 4.1 to 4.5 show the Pregrind and post Grind test results. More detailed results are shown in Appendix A to D.
The Mn/DOT Standard equipment of a Bruel and Kjaer front end, a rig system developed by Illingworth and Rodkin, the Inventor of the OBSI method and a set of sophisticated microphones supplied by BRC Engineering. The Rig is installed on the Standard Reference Test Tire and connected to the frontend through a series of communication cables. The front-end is also linked to a laptop that allows direct analysis of the noise data. The Mn/DOT equipment is installed on a Chevrolet Impala as shown in figure 1. Installations, training and test runs were completed in July 2007 and the Mn/DOT proficient operators are John Pantelis, Bernard Izevbekhai Ted Snyder, and Jack Herndon.

In the OBSI procedure, a convenient logarithm scale is used to mimic the human hearing spectrum. This is the A-weighted scale that is simply explained by the following expatiation.
If "n" similar sources generate a noise level i db (A), the total Noise level is given by

$$dB(A)_t = 10 * \log [10^{\{dB(A)_1/10\}} + 10^{\{dB(A)_2/10\}} + \ldots . + 10^{\{dB(A)_n/10\}}]$$

Consequently, if there are 2 sources with the same sound intensity, the cumulative intensity is thus 3 db (A) higher than the individual intensity as shown below. This implies that a reduction of the sound intensity by 3dba is equivalent in effect to a traffic reduction to 50 % of original ADT.

$$DB(A)_{i2} = 10* \log [10^{(dB(A)i/10)} + 10^{(dB)Ai/10)}] \text{ for 2 sources}$$

$$= 10 \log [2 * 10^{(dB(A)/10)}] \text{ for 2 sources}$$
$$= 10*(\text{Log } 2 + dB(A)i)$$
$$= (i + 3) dB(A)$$

Similarly In the A weighted metric a reduction of 4.7 d B(A) is equivalent to a 70% reduction in the overall noise level. OBSI noise levels for the conventional grind measured by Mn/DOT at 102 and 103 DBA and the innovative grind was 98.5 db(A)

Results showed improved ride quality in the innovative and conventional grinding partly because DSI performed some corrective grinding in portions of extreme faulting. The innovative grinding resulted in IRI improvement from 128 inches per mile to 72 inches per mile in the driving lane. The passing lane showed the same percentage improvement in IRI after grinding in each cell while the Driving lane showed a different percentage improvement built similar in both cells. Each Lane therefore had the same percentage improvement in spite of the configuration.

Texture measurements ranges from .3 mm to .5 mm prior to grinding. In Cell 8 shoulder texture measurements indicated that original textures 0.8 mm had been original textures were maintained over time. This was partially removed by grinding but the macro and microtexture of the diamond grind resulted in improved texture to 1 mm or greater after partial tine removal. Texture improved in the conventional grind to a 1.3mm to 1.8 mm range. The innovative grind textures improved to a range of .9mm to 1.1mm. This was more uniform and unlike the conventional grind, the texture was durable and could not be easily damaged by oblique impacts on Friction measurements in the Mainline were similar to results obtained in cell 37. Once again, the difference between the smooth and ribbed tire friction was small.

These cells will be monitored for a minimum of 5 years to determine durability and time related texture/ friction decay of the innovative grinds and the noise trends over the study period.

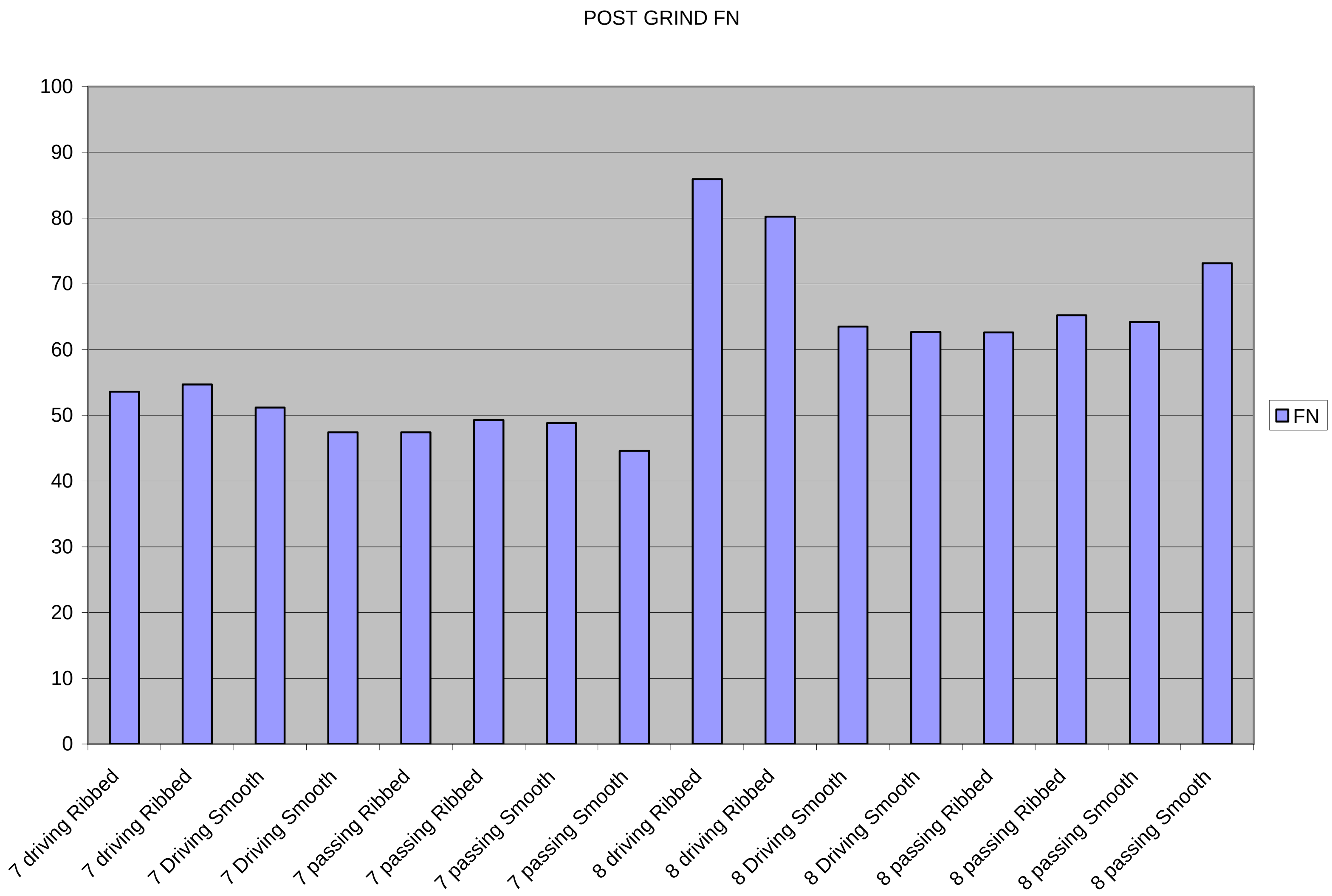


Fig 5.1 Measured FN post grind

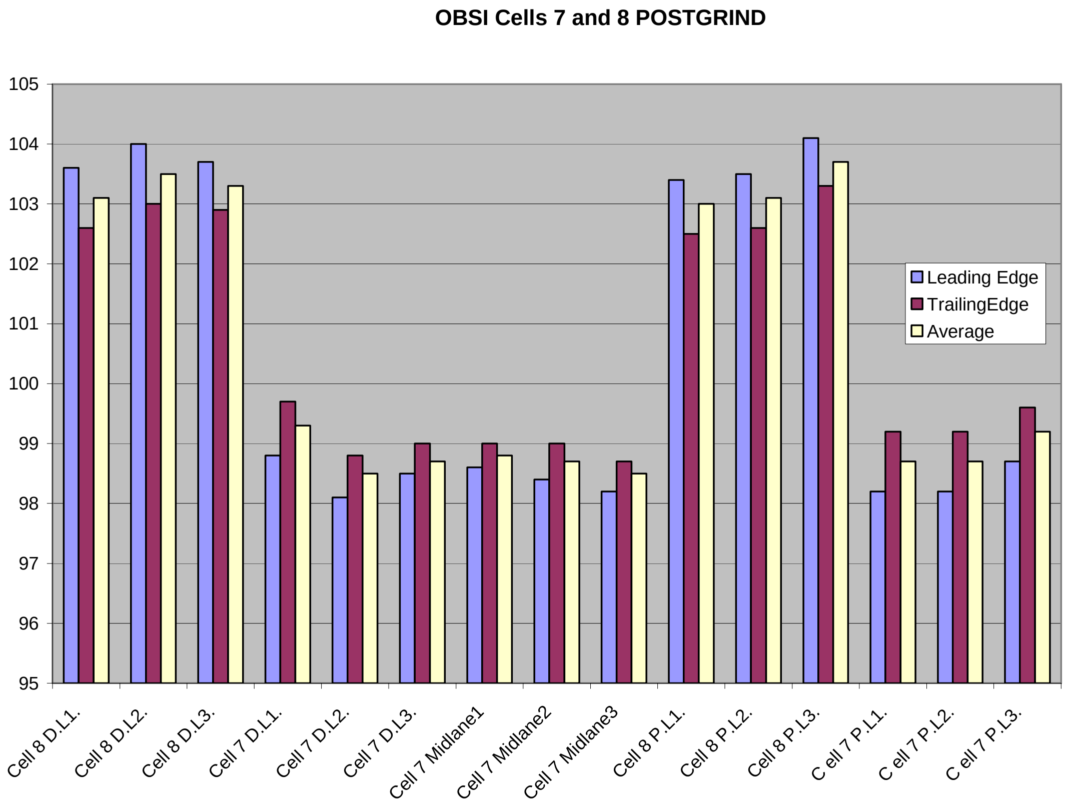


Fig 5.2 OBSI Cells 7 and 8 Post Grind

6 CONCLUSION

- The grinding configuration produced by the Purdue SQDH laboratory is an innovative a quiet pavement solution. At 98.5 Db(A) it rep[resents the quietest diamond ground pavement in the United States. It provides lesser ribbed tire friction than the conventional grind but higher smooth tire friction comparable to the ribbed tire friction numbers. This is an interesting phenomenon as it provides higher than expected friction numbers for worn tires.

- Successful placement of the innovative configuration in the MnROAD mainline confirms the feasibility of performing the innovative grinding in a single pass.

- Improved ride quality was not validated in the low volume road due to difficulty in measuring ride quality is strips thinner than the light weight profiler. However both the conventional and innovative grind resulted in improved ride quality in the mainline where full width grinding was done.

- The test sections will be monitored for many years to study the durability of the surface characteristics of the innovative grinding

Appendix A
DETAILS OBSI TEST
Table A1 Post Grind Tables

OBSI SUMMARY

O.B.S.I. Data Sheet

Date:10/22/2007

Operator: J.P. & T.S.

Location	Test No.	Leading Edge	Trailing Edge	Average
Cell 8 D.L.	1	103.6	102.6	**103.1**
	3	104.0	103.0	**103.5**
	5	103.7	102.9	**103.3**
Cell 7 D.L.	2	98.8	99.7	**99.3**
	4	98.1	98.8	**98.5**
	6	98.5	99.0	**98.7**
Cell 7 Midlane	7	98.6	99.0	**98.8**
	8	98.4	99.0	**98.7**
	9	98.2	98.7	**98.5**
Cell 8 P.L.	10	103.4	102.5	**103.0**
	12	103.5	102.6	**103.1**
	14	104.1	103.3	**103.7**
C ell 7 P.L.	11	98.2	99.2	**98.7**
	13	98.2	99.2	**98.7**
	15	98.7	99.6	**99.2**

Table A2 Cell 7 Passing lane Run 1

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	83.3	1.6	0.4	83.2	2.8	0.4	83.3
315	81.1	2.4	0.6	84.8	1.1	0.6	83.3
400	79.7	4.0	0.8	80.1	4.5	0.7	79.9
500	81.3	2.4	0.9	78.8	5.4	0.8	80.2
630	83.7	2.4	1.0	81.6	3.3	0.9	82.8
800	90.4	0.8	1.0	89.2	1.2	1.0	89.8
1000	94.5	0.6	1.0	95.3	0.9	1.0	94.9
1250	89.0	0.7	1.0	92.2	0.7	1.0	90.9
1600	88.5	1.0	1.0	88.4	0.9	1.0	88.5
2000	88.2	1.0	1.0	86.9	1.0	1.0	87.6
2500	85.6	1.1	1.0	85.9	0.9	1.0	85.8
3150	80.6	0.9	0.9	81.3	0.8	0.9	81.0
4000	77.3	1.2	0.8	78.1	1.2	0.9	77.7
5000	74.0	1.7	0.7	73.8	1.7	0.7	73.9
A-wtd	98.5			99.0			98.7

Table A3 Cell 7 Passing lane Run 2

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	74.6	10.3	0.5	83.6	3.6	0.5	81.1
315	#NUM!	#NUM!	0.6	85.5	1.2	0.6	#NUM!
400	80.5	3.2	0.8	77.6	7.9	0.6	79.3
500	81.9	2.3	0.9	77.5	7.3	0.8	80.2
630	83.2	2.6	1.0	82.3	3.1	0.9	82.8
800	87.9	1.4	1.0	88.9	1.4	1.0	88.4
1000	94.3	0.6	1.0	94.8	0.9	1.0	94.6
1250	90.1	0.5	1.0	93.7	0.7	1.0	92.2
1600	88.6	1.1	1.0	88.8	1.1	1.0	88.7
2000	88.0	1.3	1.0	87.7	1.2	1.0	87.9
2500	85.4	1.1	1.0	86.4	0.9	1.0	85.9
3150	80.6	0.9	0.9	81.0	0.9	0.9	80.8
4000	76.5	1.7	0.8	77.4	1.6	0.8	77.0
5000	73.2	2.1	0.7	73.3	2.0	0.7	73.2
A-wtd	98.2			99.2			98.7

Table A3 Cell 7 Passing lane Run 3

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	81.3	4.8	0.5	85.8	2.3	0.4	84.1
315	#NUM!	#NUM!	0.6	84.5	3.4	0.6	#NUM!
400	79.4	5.5	0.8	85.1	1.5	0.6	83.1
500	82.6	2.4	0.9	81.6	4.6	0.8	82.1
630	83.5	2.7	1.0	82.6	3.8	0.9	83.1
800	88.3	1.5	1.0	89.1	1.4	1.0	88.7
1000	95.1	0.7	1.0	95.5	1.0	1.0	95.3
1250	90.9	0.6	1.0	93.8	0.8	1.0	92.6
1600	89.0	1.1	1.0	89.0	1.1	1.0	89.0
2000	88.0	1.3	1.0	87.9	1.3	1.0	87.9
2500	85.5	1.2	1.0	86.5	0.9	1.0	86.0
3150	80.8	1.0	0.9	81.3	1.0	0.9	81.1
4000	76.9	1.7	0.8	78.0	1.5	0.8	77.5
5000	73.9	2.1	0.7	73.8	2.0	0.7	73.8
A-wtd	98.7			99.6			99.2

Table A4 Cell 7 Mid lane Post Grind
Run 1

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	87.0	-0.9	0.4	77.9	9.1	0.5	84.5
315	81.0	3.6	0.5	85.1	1.1	0.6	83.5
400	83.2	1.4	0.7	82.3	2.5	0.7	82.7
500	82.3	1.9	0.9	79.5	4.8	0.8	81.1
630	83.1	2.2	1.0	81.1	4.0	0.9	82.3
800	88.1	1.2	1.0	88.4	1.4	1.0	88.3
1000	93.9	0.8	1.0	93.5	0.9	1.0	93.7
1250	89.8	0.7	1.0	92.9	0.7	1.0	91.6
1600	88.9	1.1	1.0	88.8	1.0	1.0	88.8
2000	88.6	1.2	1.0	88.9	1.0	1.0	88.7
2500	86.2	1.1	1.0	87.6	0.6	1.0	87.0
3150	80.9	0.8	1.0	82.1	0.6	0.9	81.5
4000	77.3	1.3	0.8	78.6	0.9	0.9	78.0
5000	74.1	1.6	0.7	74.1	1.2	0.8	74.1
A-wtd	98.2			98.7			98.5

Table A5Cell 7 Midlane Run 2

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	83.4	1.7	0.5	82.0	4.1	0.5	82.8
315	81.1	2.6	0.6	70.8	14.3	0.6	78.5
400	82.2	2.1	0.8	81.4	3.3	0.7	81.8
500	82.3	2.4	0.9	81.6	3.4	0.9	81.9
630	84.5	1.9	1.0	83.4	2.7	0.9	84.0
800	88.7	1.0	1.0	88.9	1.1	1.0	88.8
1000	93.8	0.8	1.0	93.5	0.9	1.0	93.7
1250	90.2	0.8	1.0	93.2	0.7	1.0	92.0
1600	89.6	1.1	1.0	88.9	1.1	1.0	89.3
2000	88.6	1.2	1.0	88.9	1.0	1.0	88.8
2500	86.3	1.1	1.0	87.7	0.6	1.0	87.0
3150	80.9	0.8	1.0	82.8	0.4	1.0	82.0
4000	77.1	1.3	0.9	78.6	0.9	0.9	77.9
5000	73.7	1.6	0.8	73.8	1.2	0.8	73.8
A-wtd	98.4			99.0			98.7

Table A6 Cell 7 Midlane Run 3

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	87.0	-0.9	0.4	77.9	9.1	0.5	84.5
315	81.0	3.6	0.5	85.1	1.1	0.6	83.5
400	83.2	1.4	0.7	82.3	2.5	0.7	82.7
500	82.3	1.9	0.9	79.5	4.8	0.8	81.1
630	83.1	2.2	1.0	81.1	4.0	0.9	82.3
800	88.1	1.2	1.0	88.4	1.4	1.0	88.3
1000	93.9	0.8	1.0	93.5	0.9	1.0	93.7
1250	89.8	0.7	1.0	92.9	0.7	1.0	91.6
1600	88.9	1.1	1.0	88.8	1.0	1.0	88.8
2000	88.6	1.2	1.0	88.9	1.0	1.0	88.7
2500	86.2	1.1	1.0	87.6	0.6	1.0	87.0
3150	80.9	0.8	1.0	82.1	0.6	0.9	81.5
4000	77.3	1.3	0.8	78.6	0.9	0.9	78.0
5000	74.1	1.6	0.7	74.1	1.2	0.8	74.1
A-wtd	98.2			98.7			98.5

Table A7 CELL 8 PL
Run 1

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	87.1	0.3	0.7	89.8	-1.5	0.6	88.6
315	83.4	3.9	0.8	86.1	2.3	0.7	85.0
400	88.6	1.3	0.9	86.5	1.7	0.8	87.7
500	90.9	1.2	1.0	89.0	2.0	0.9	90.0
630	95.2	1.3	1.0	92.7	1.7	1.0	94.2
800	99.6	0.5	1.0	97.1	0.8	1.0	98.6
1000	95.8	1.1	1.0	96.9	1.0	1.0	96.4
1250	93.1	0.6	1.0	95.0	0.8	1.0	94.1
1600	90.0	0.8	1.0	90.4	0.9	1.0	90.2
2000	87.8	1.2	1.0	87.4	1.2	1.0	87.6
2500	84.7	1.2	1.0	84.4	1.2	1.0	84.5
3150	80.2	1.0	0.9	79.8	1.3	0.9	80.0
4000	76.2	1.6	0.8	75.9	2.1	0.8	76.1
5000	73.7	1.8	0.7	72.8	2.2	0.7	73.3
A-wtd	103.4			102.5			103.0

TABLE A8 CELL 8 PL Run 2

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	88.0	-0.3	0.7	88.8	0.4	0.7	88.4
315	83.5	4.2	0.8	87.8	2.7	0.8	86.1
400	89.6	1.2	1.0	89.4	2.4	0.9	89.5
500	91.4	1.4	1.0	90.7	1.7	1.0	91.1
630	95.5	1.3	1.0	92.9	1.6	1.0	94.4
800	99.7	0.6	1.0	97.1	0.8	1.0	98.6
1000	96.1	1.1	1.0	97.2	1.0	1.0	96.7
1250	93.1	0.6	1.0	94.8	0.8	1.0	94.0
1600	89.5	0.9	1.0	90.1	0.9	1.0	89.8
2000	87.7	1.2	1.0	87.2	1.2	1.0	87.4
2500	84.7	1.1	1.0	84.5	1.1	1.0	84.6
3150	80.2	0.8	0.9	79.7	1.1	0.9	79.9
4000	76.2	1.3	0.8	75.7	1.8	0.8	76.0
5000	73.5	1.6	0.7	72.5	1.9	0.7	73.0
A-wtd	103.5			102.6			103.1

TABLE A9 Cell 8 PL Run 3

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	75.8	11.8	0.7	90.1	-1.9	0.6	87.2
315	85.6	2.0	0.8	82.3	6.3	0.7	84.3
400	89.1	1.4	1.0	86.5	2.1	0.8	88.0
500	91.7	1.3	1.0	89.8	1.9	1.0	90.8
630	96.3	1.2	1.0	93.5	1.4	1.0	95.1
800	100.4	0.5	1.0	97.9	0.8	1.0	99.3
1000	96.5	1.0	1.0	97.9	1.0	1.0	97.3
1250	93.5	0.6	1.0	95.6	0.8	1.0	94.7
1600	90.2	0.9	1.0	90.7	0.8	1.0	90.5
2000	88.1	1.1	1.0	87.5	1.2	1.0	87.8
2500	84.9	1.1	1.0	84.8	1.1	1.0	84.8
3150	79.9	1.0	0.9	79.7	1.2	0.9	79.8
4000	75.9	1.7	0.8	75.6	2.1	0.8	75.7
5000	73.7	1.7	0.7	72.4	2.1	0.7	73.1
A-wtd	104.1			103.3			103.7

Table A10 Cell 8 DL Run 1

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	82.8	4.5	0.6	82.4	5.1	0.5	82.6
315	87.0	1.4	0.8	89.2	-0.8	0.7	88.2
400	90.3	0.9	1.0	88.2	0.5	0.8	89.4
500	91.5	1.3	1.0	89.7	1.6	1.0	90.7
630	95.8	1.2	1.0	92.9	1.6	1.0	94.6
800	100.3	0.4	1.0	97.5	0.5	1.0	99.1
1000	95.3	0.9	1.0	96.9	0.8	1.0	96.2
1250	92.7	0.5	1.0	94.6	0.8	1.0	93.8
1600	89.4	0.8	1.0	90.1	0.8	1.0	89.7
2000	86.8	1.1	1.0	85.9	1.2	1.0	86.4
2500	83.9	1.1	1.0	83.3	1.3	1.0	83.6
3150	80.2	1.0	0.9	79.4	1.2	0.9	79.8
4000	76.4	1.3	0.8	75.8	1.6	0.8	76.1
5000	73.8	1.8	0.7	72.6	2.0	0.7	73.2
A-wtd	103.6			102.6			103.1

Table A11 Cell 8 DL Run 2

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	78.0	9.2	0.7	86.5	1.2	0.6	84.0
315	88.0	0.4	0.9	86.8	1.0	0.8	87.5
400	90.5	1.1	1.0	88.1	0.8	0.9	89.4
500	92.1	1.0	1.0	89.3	1.8	1.0	90.9
630	96.5	1.2	1.0	93.5	1.6	1.0	95.2
800	100.6	0.4	1.0	97.9	0.6	1.0	99.5
1000	96.1	1.0	1.0	97.4	0.9	1.0	96.8
1250	93.1	0.6	1.0	95.1	0.8	1.0	94.2
1600	89.3	0.8	1.0	90.4	0.8	1.0	89.9
2000	87.2	1.1	1.0	86.6	1.1	1.0	86.9
2500	83.9	1.1	1.0	83.6	1.1	1.0	83.8
3150	80.0	0.9	0.9	79.5	1.1	0.9	79.7
4000	76.3	1.4	0.8	75.6	1.6	0.8	75.9
5000	73.9	1.8	0.7	72.5	1.8	0.7	73.2
A-wtd	104.0			103.0			103.5

Table A12 Cell 8 DL Run 3

	Leading Edge			Trailing Edge			AVG
	IL	PI	Coh	IL	PI	Coh	IL
250	85.4	0.6	0.7	86.9	-0.4	0.6	86.2
315	85.3	2.4	0.9	83.0	4.1	0.8	84.3
400	89.7	1.1	1.0	86.2	1.8	0.9	88.3
500	91.1	0.9	1.0	88.8	1.5	1.0	90.1
630	95.8	1.3	1.0	93.1	1.5	1.0	94.6
800	100.3	0.4	1.0	97.9	0.5	1.0	99.3
1000	95.6	1.0	1.0	97.4	0.9	1.0	96.6
1250	93.1	0.5	1.0	95.0	0.7	1.0	94.1
1600	88.9	0.8	1.0	90.2	0.8	1.0	89.6
2000	87.1	1.1	1.0	86.5	1.1	1.0	86.8
2500	83.7	1.1	1.0	83.5	1.1	1.0	83.6
3150	79.6	0.9	0.9	79.6	1.0	0.9	79.6
4000	75.8	1.3	0.8	75.6	1.4	0.8	75.7
5000	73.3	1.7	0.7	72.1	1.8	0.7	72.8
A-wtd	103.7			102.9			103.3

APPENDIX B POST GRIND & PREGRIND Mainline Ride Quality

TABLE B1 POST GRIND VS PREGRIND Mainline Ride Quality

Cell Location	Lane	Wheel Path	Pre-grind Record (erd file ref) 9/8/07	Pre-Grind IRI (inch/Mile)	Post Grind IRI (inch/Mile)	Post Grind record (10/22/07) (erd file ref)
Cell 7	Driving	LWP		72.8	48.3	
		LWP			44.5	
		LWP			46.5	
		RWP		78.5	51.9	
		RWP			55.4	
		RWP			44.2	
Cell 8	Driving	LWP		123.1	70.4	
		LWP			74.1	
		LWP			74.9	
		RWP		104.8	74.2	
		RWP			75.4	
		RWP			75.3	
Cell 7	Passing	LWP		83.3	53.7	
		LWP			47.5	
		LWP			50	
		RWP		68	81.7	
		RWP			84.9	
		RWP			73.7	
Cell 8	Passing	LWP		107.9	70.7	
		LWP			55.9	
		LWP			66	
		RWP		128	81.7	
		RWP			84.9	
		RWP			73.7	

Appendix B2 Pregrind Ride Data

Cell7LFLNlwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	83.3	134.7	3.56

Cell7LFLNrwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	68.0	117.1	3.72

Cell7RTLNlwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	72.8	127.4	3.62

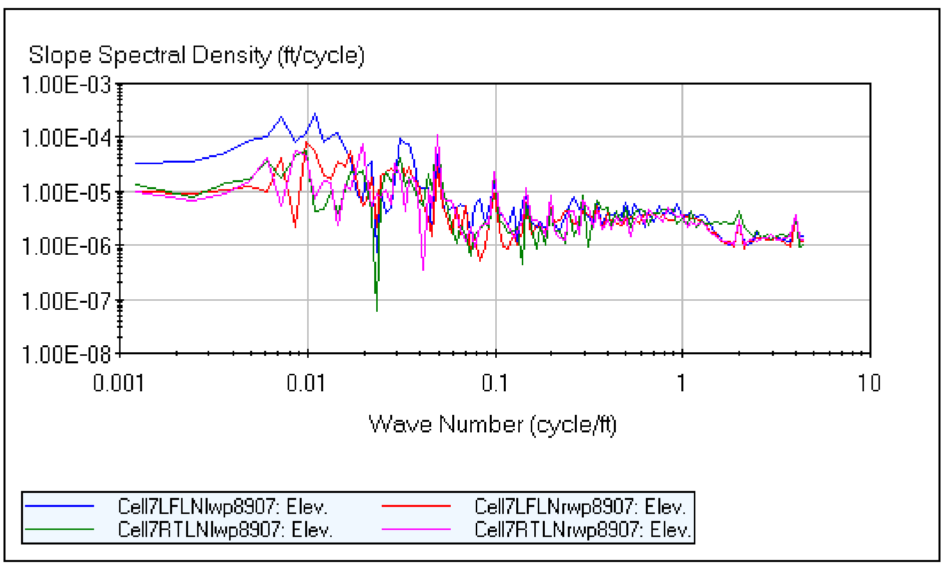
Cell7RTLNrwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	78.5	123.7	3.66

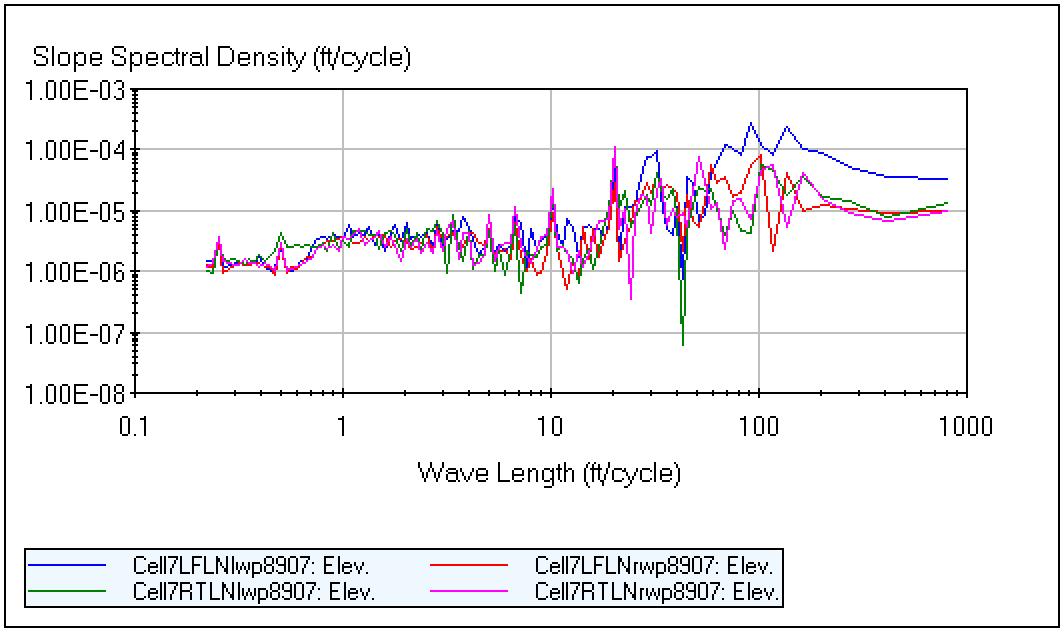
Analysis - Power Spectral Density

Input	Value	Unit
PSD Calculation	Slope	
Use Point Reset	No	
Frequency Averaging	Yes	
Bands Per Octave	12	
Pre-Processor Filter	None	

Wave Number

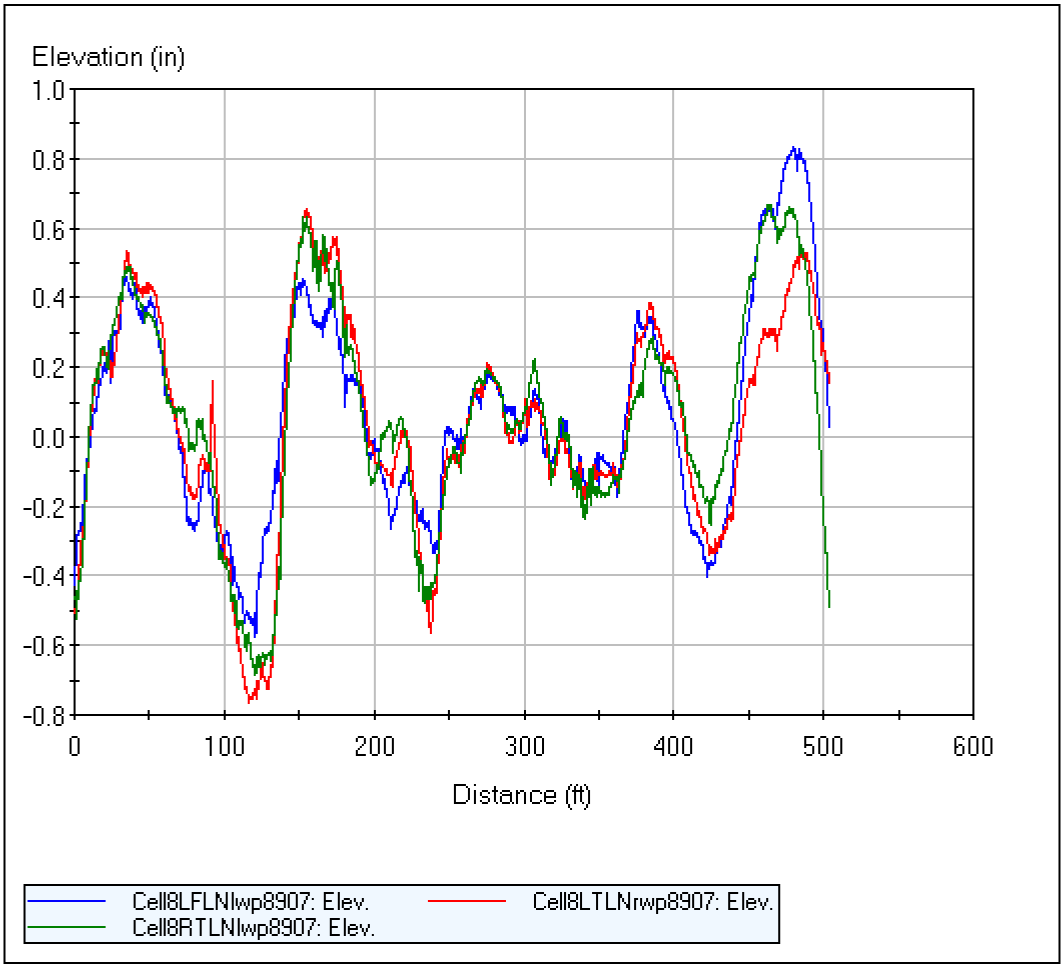


Wave Length



Slope Spectral Density (ft/cycle)
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
0.1
1
10
100
1000
Wave Length (ft/cycle)
Cell7LFLNlwp8907: Elev.
Cell7LFLNrwp8907: Elev.
Cell7RTLNlwp8907: Elev.
Cell7RTLNrwp8907: Elev.

Cell 8 Proval Report Pregrind



Cell8LFLNlwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	107.9	173.2	3.23

Cell8LTLNrwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	123.0	176.6	3.20

Cell8RTLNlwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	123.1	186.0	3.13

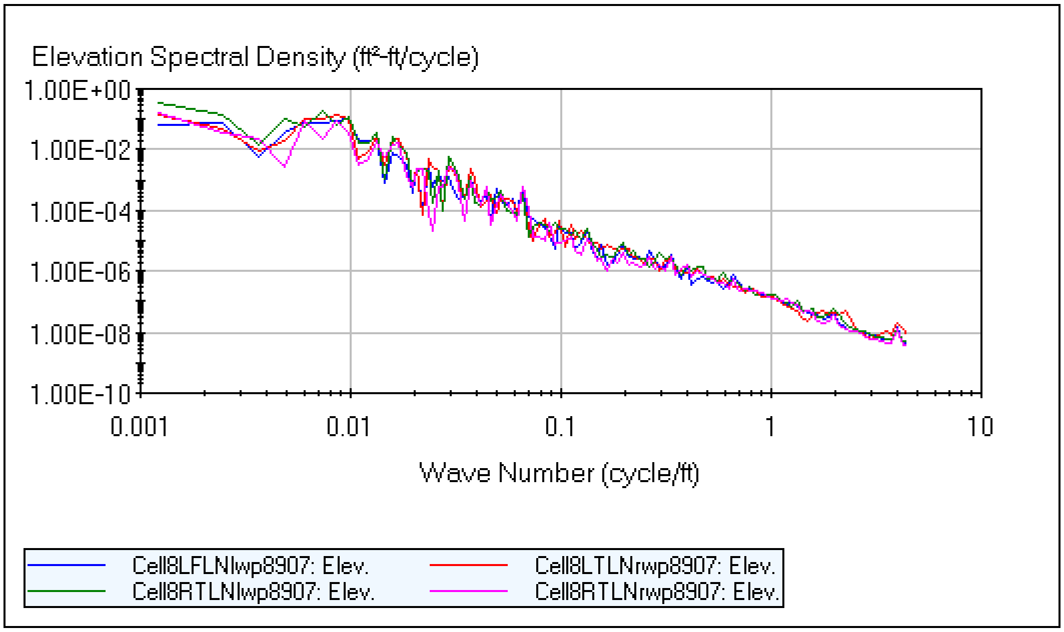
Cell8RTLNrwp8907

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	104.8	169.0	3.26

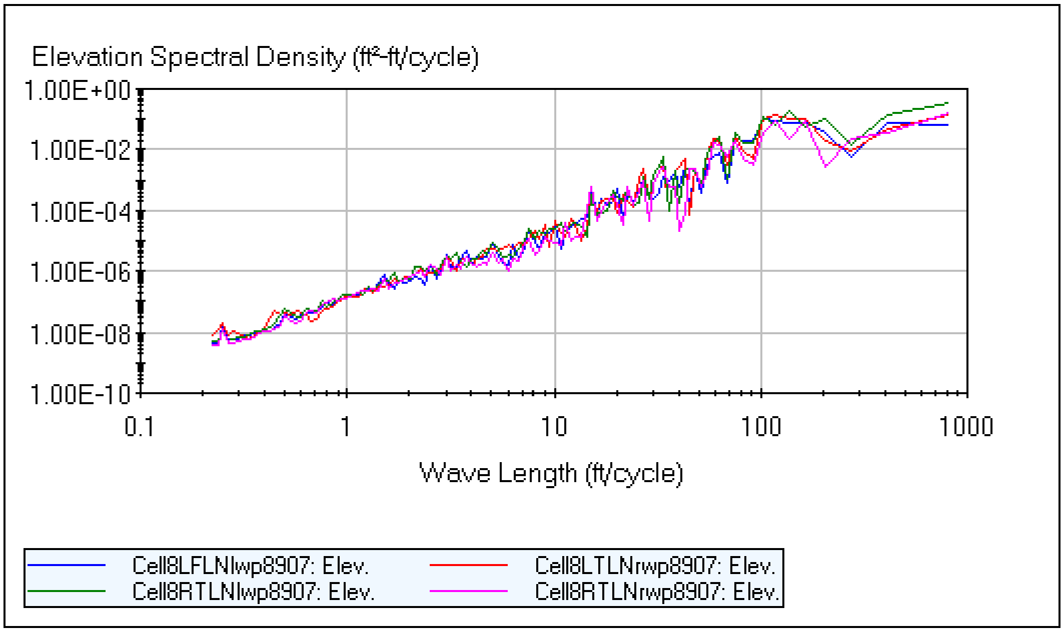
Analysis - Power Spectral Density

Input	Value	Unit
PSD Calculation	Elevation	
Use Point Reset	No	
Frequency Averaging	Yes	
Bands Per Octave	12	
Pre-Processor Filter	None	

Wave Number

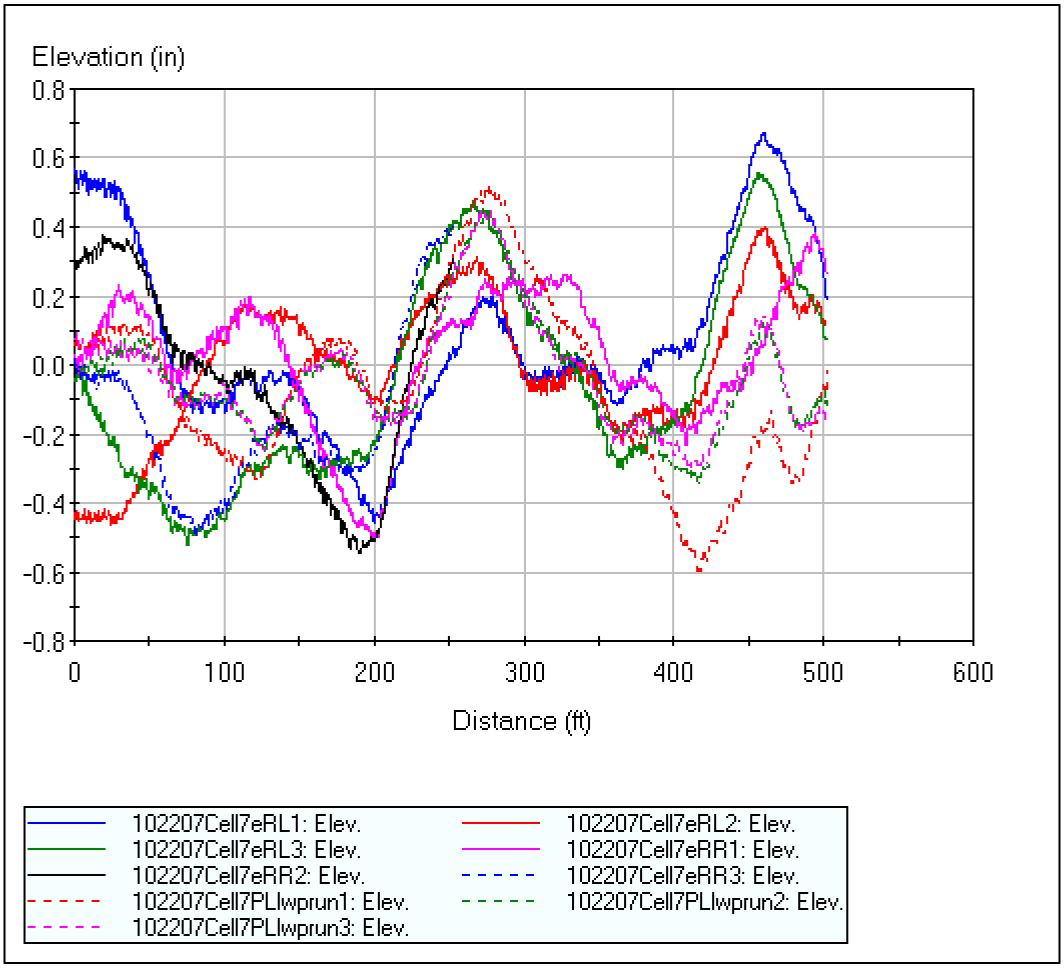


Wave Length



Elevation Spectral Density (ft²-ft/cycle)
1.00E+00
1.00E-02
1.00E-04
1.00E-06
1.00E-08
1.00E-10
0.1
1
10
100
1000
Wave Length (ft/cycle)
Cell8LFLNlwp8907: Elev.
Cell8LTLNrwp8907: Elev.
Cell8RTLNlwp8907: Elev.
Cell8RTLNrwp8907: Elev.

Appendix B3 Post Grind Report



102207Cell7eRL1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	48.3	115.3	3.74

102207Cell7eRL2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	44.5	112.5	3.76

102207Cell7eRL3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	46.5	100.5	3.88

102207Cell7eRR1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	51.9	119.8	3.69

102207Cell7eRR2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	55.4	117.8	3.71

102207Cell7eRR3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	44.2	118.4	3.71

102207Cell7PLlwprun1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	53.7	108.1	3.81

102207Cell7PLlwprun2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	47.5	95.1	3.93

102207Cell7PLlwprun3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	50.0	103.9	3.85

102207Cell7PLrwprun1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	49.9	95.7	3.93

102207Cell7PLrwprun1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	49.9	95.7	3.93

102207Cell7PLrwprun2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	43.2	87.8	4.01

102207Cell7PLrwprun3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	45.7	94.0	3.94

102207Cell8PLlwprun1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	70.7	173.1	3.23

102207Cell8PLlwprun2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	75.9	180.8	3.17

102207Cell8PLlwprun3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	66.0	184.2	3.14

102207Cell8PLrwprun1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	81.7	202.8	3.00

102207Cell8PLrwprun2

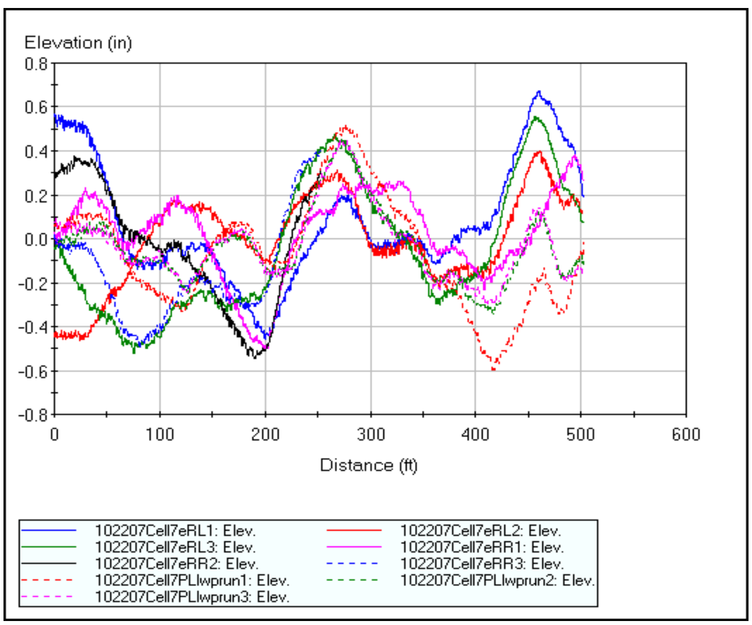
Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	84.9	166.1	3.29

102207Cell8PLrwprun3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	73.7	213.3	2.92

102207Cell8RL1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	70.4	167.7	3.27



102207Cell8RR3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	75.3	189.8	3.10

102207Cell8PLlwprun3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	66.0	184.2	3.14

102207Cell8PLrwprun1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	81.7	202.8	3.00

102207Cell8PLrwprun2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	84.9	166.1	3.29

102207Cell8PLrwprun3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	73.7	213.3	2.92

102207Cell8RL1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	70.4	167.7	3.27

102207Cell8RL2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	74.1	166.6	3.28

102207Cell8RL3

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	74.9	207.8	2.96

102207Cell8RR1

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	74.2	198.7	3.03

102207Cell8RR2

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	75.4	188.6	3.11

Appendix C ADDITIONAL FRICTION DATA

Table C1 Pregrind Friction data

CELL	CONSTRUCT	LANE	DAY	TIME	FN	PEAK	SPEED	AIR_TEMP	PVMT_TEMP	TIRE_TYPE	EQUIPMENT STA	DATE_UPDA	LATITUDE	LONGITUDE
7	1	ML-Driving	23-Jun-94		60					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Passing	23-Jun-94		58.7					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Driving	20-Sep-94		6.7					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Passing	20-Sep-94		52.5					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Driving	4-May-95		1.5					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Passing	4-May-95		60.1					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Driving	20-Jun-95		0.4					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Passing	20-Jun-95		63.6					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Driving	29-Oct-97	12:17	55.1	74.2	40.3	50	51	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Passing	29-Oct-97	12:22	58.3	79.7	39.4	48	51	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Driving	14-Oct-98	14:11	31	66.5	48.3	40.2	51	Smooth	WSDOT	5-May-06		
7	1	ML-Passing	14-Oct-98	14:24	46	64	40.3	51		Smooth	WSDOT	5-May-06		
7	1	ML-Passing	14-Oct-98	15:01	56.7	87.8	40.3	44		Ribbed	WSDOT	5-May-06		
7	1	ML-Driving	20-Oct-98	10:10	36.2	39.6	40.2	51		Smooth	WSDOT	5-May-06		
7	1	ML-Passing	20-Oct-98	10:27	41.9	63.1	40	46		Smooth	WSDOT	5-May-06		
7	1	ML-Passing	20-Oct-98	9:48	53.4	76.4	40.1	41		Ribbed	WSDOT	5-May-06		
7	1	ML-Driving	20-Oct-98	9:33	47.7	69.8	39.7	44		Ribbed	WSDOT	5-May-06		
7	1	ML-Driving	31-Oct-01	13:49	38.1	57.2	40.2	69	55	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Passing	31-Oct-01	14:39	42.1	64.4	40.3	60	55	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Driving	3-Nov-04	11:12	57.7	83.3	39.5	30		Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1657	09343.434910W
7	1	ML-Passing	3-Nov-04	10:42	56.9	85.6	39.7	29		Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1644	09343.437853W
7	1	ML-Passing	3-Nov-04	10:58	43.3	72.4	40.2	30		Smooth	Mn/DOT - 1295 Paven	5-May-06	4516.1611	09343.431128W
7	1	ML-Driving	24-May-05	10:47	53.3	69.7	40.5	72	114.9	Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1626	09343.429433W
7	1	ML-Passing	24-May-05	10:27	58.8	77.9	40.3	71	108.4	Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1642	09343.436711W
7	1	ML-Driving	19-Apr-06	11:32	26.2	45.26	40.5	60		Smooth	Mn/DOT - 1295 Paven	5-May-06	4516.1712	09343.445986W
7	1	ML-Passing	19-Apr-06	11:49	57.5	81.56	40.4	60		Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Driving	19-Apr-06	11:08	55.7	82.81	40.4	59		Ribbed	Mn/DOT - 1295 Paven	5-May-06		
7	1	ML-Passing	19-Apr-06	12:10	40.4	78.95	40.2	62		Smooth	Mn/DOT - 1295 Paven	5-May-06	4516.1695	09343.446519W
7	1	ML-Driving	24-Oct-06	1404	35.9	51.97	40.2	43	63	Smooth	Mn/DOT - 1295 Paven	1-Nov-06	4516.1592	09343.426354W
7	1	ML-Driving	24-Oct-06	1348	59.5	78.6	40	42	62.8	Ribbed	Mn/DOT - 1295 Paven	1-Nov-06	4516.1647	09343.436862W
7	1	ML-Passing	24-Oct-06	1419	59.4	75.81	40	45	64	Ribbed	Mn/DOT - 1295 Paven	1-Nov-06	4516.1588	09343.430087W
8	1	ML-Driving	23-Jun-94		54.3					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Passing	23-Jun-94		56.4					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Driving	20-Sep-94		54.9					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Passing	20-Sep-94		47					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Driving	4-May-95		54.8					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Passing	4-May-95		57.7					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Driving	20-Jun-95		48.5					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Passing	20-Jun-95		55.4					Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Driving	29-Oct-97	12:17	44.5	74.1	40.1	50	51	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Passing	29-Oct-97	12:21	52.8	76.7	40.4	48	51	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Driving	14-Oct-98	14:11	25.9	18.7	56.6	40.2	55	Smooth	WSDOT	5-May-06		
8	1	ML-Passing	14-Oct-98	15:01	54.4	72.8	39.8	44		Ribbed	WSDOT	5-May-06		
8	1	ML-Passing	14-Oct-98	14:23	41.3	48	40.2	50		Smooth	WSDOT	5-May-06		
8	1	ML-Driving	14-Oct-98	14:47	46.2	66.7	40.2	51		Ribbed	WSDOT	5-May-06		
8	1	ML-Driving	20-Oct-98	10:10	22.6	30.1	40.4	46		Smooth	WSDOT	5-May-06		
8	1	ML-Passing	20-Oct-98	9:48	39.9	70.5	40.1	42		Ribbed	WSDOT	5-May-06		
8	1	ML-Driving	20-Oct-98	9:33	37.7	66.7	40.1	39		Ribbed	WSDOT	5-May-06		
8	1	ML-Passing	20-Oct-98	10:27	24.3	45.5	40.2	46		Smooth	WSDOT	5-May-06		
8	1	ML-Driving	31-Oct-01	13:50	38.7	57	40.3	69	55	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Passing	31-Oct-01	14:39	41.2	61.2	40.4	60	55	Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Passing	3-Nov-04	10:42	50.4	85.8	40.1	29		Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1110	09343.339638W
8	1	ML-Passing	3-Nov-04	10:58	29.7	41.6	40.5	30		Smooth	Mn/DOT - 1295 Paven	5-May-06	4516.1080	09343.333602W
8	1	ML-Driving	3-Nov-04	11:12	47.5	73.6	40.5	30		Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1122	09343.336604W
8	1	ML-Passing	24-May-05	10:27	46.8	65.7	40.6	73	106.6	Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1101	09343.337046W
8	1	ML-Driving	24-May-05	10:47	42.6	60.4	40.6	72	112.8	Ribbed	Mn/DOT - 1295 Paven	5-May-06	4516.1084	09343.329791W
8	1	ML-Passing	19-Apr-06	12:09	28	81.77	39.9	62		Smooth	Mn/DOT - 1295 Paven	5-May-06	4516.1279	09343.370323W
8	1	ML-Passing	19-Apr-06	11:48	52.6	80.73	40	61		Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Driving	19-Apr-06	11:32	30.2	37.58	40.5	61		Smooth	Mn/DOT - 1295 Paven	5-May-06	4516.1236	09343.358663W
8	1	ML-Driving	19-Apr-06	11:08	60.7	81.89	40.5	59		Ribbed	Mn/DOT - 1295 Paven	5-May-06		
8	1	ML-Driving	24-Oct-06	1404	20.9	28.87	40.6	43	61	Smooth	Mn/DOT - 1295 Paven	1-Nov-06	4516.1056	09343.327768W
8	1	ML-Passing	24-Oct-06	1419	47	68.09	40.1	44	63.3	Ribbed	Mn/DOT - 1295 Paven	1-Nov-06	4516.1051	09343.331460W
8	1	ML-Driving	24-Oct-06	1348	48	64.14	40.3	42	61.7	Ribbed	Mn/DOT - 1295 Paven	1-Nov-06	4516.1052	09343.327272W

Appendix D Texture data

Table D1Pre-Grind Texture Data

		PREGRIND									
	Measured By Bernard Izevbekhai					Sand Patch ASTM E-965					
						Cell 7 &8					
		10/15/07, 10/16/07				Time 12:00pm		Temp 55 Deg F			
	LOCATION	WHEELPATH	RUN 1	RUN 2	RUN 3	Average	Vol mm3	Texture (m	ASTM E-2	CTM Check	
			482.6	457.2	482.6	474.1	68300	0.39		0.42	0.43
Cell 8	BX1	RR	482.6	482.6	482.6	482.6	68300	0.37		0.5	
Cell 8	BX1	RL	431.8	431.8	431.8	431.8	68300	0.47		0.51	
Cell 8	BX1	LR	431.8	457.2	457.2	448.7	68300	0.43		0.52	
Cell 8	BX1	LL	431.8	406.4	431.8	423.3	68300	0.49			
Cell 8	BX2	RR	457.2	457.2	482.6	465.7	68300	0.40		0.42	
Cell 8	BX2	RL	457.2	457.2	457.2	457.2	68300	0.42		0.5	
Cell 8	BX2	LR	431.8	457.2	431.8	440.3	68300	0.45		0.45	
Cell 8	BX2	LL	431.8	431.8	431.8	431.8	68300	0.47		.	
Cell 8	BX3	RR	482.6	482.6	457.2	474.1	68300	0.39			
Cell 8	BX3	RL	457.2	482.6	254	397.9	68300	0.55			
Cell 8	BX3	LR	431.8	482.6	431.8	448.7	68300	0.43			
Cell 8	BX3	LL	431.8	457.2	431.8	440.3	68300	0.45			
Cell 8	BX4	RR	508	482.6	457.2	482.6	68300	0.37		0.45	
Cell 8	BX4	RL	482.6	482.6	482.6	482.6	68300	0.37		0.42	
Cell 8	BX4	LR	431.8	406.4	406.4	414.9	68300	0.51		0.49	
Cell 8	BX4	LL	431.8	431.8	431.8	431.8	68300	0.47		0.45	
Cell 8	BX5	RR	431.8	406.4	431.8	423.3	68300	0.49			
Cell 8	BX5	RL	457.2	457.2	457.2	457.2	68300	0.42			
Cell 8	BX5	LR	431.8	482.6	431.8	448.7	68300	0.43			
Cell 8	BX5	LL	482.6	431.8	431.8	448.7	68300	0.43			
Cell 8	BX6	RR	482.6	508	533.4	508.0	68300	0.34			
Cell 8	BX6	RL	508	508	457.2	491.1	68300	0.36			
Cell 8	BX6	LR	457.2	457.2	457.2	457.2	68300	0.42			
Cell 8	BX6	LL	457.2	457.2	457.2	457.2	68300	0.42			
Cell 8	Bx7	RR	457.2	431.8	431.8	440.3	68300	0.45			
Cell 8	Bx7	RL	457.2	457.2	457.2	457.2	68300	0.42			
Cell 8	Bx7	LR	406.4	406.4	457.2	423.3	68300	0.49			
Cell 8	Bx7	LL	457.2	457.2	431.8	448.7	68300	0.43			
Cell 7	BX8	RR	508	508	457.2	491.1	68300	0.36		0.35	0.39
Cell 7	BX8	RL	482.6	431.8	431.8	448.7	68300	0.43		0.45	
Cell 7	BX8	LR	431.8	457.2	457.2	448.7	68300	0.43		0.54	
Cell 7	BX8	LL	457.2	457.2	482.6	465.7	68300	0.40		0.54	
Cell 7	BX9	RR	508	508	508	508.0	68300	0.34			
Cell 7	BX9	RL	482.6	457.2	457.2	465.7	68300	0.40			
Cell 7	BX9	LR	406.4	406.4	457.2	423.3	68300	0.49			
Cell 7	BX9	LL	406.4	406.4	406.4	406.4	68300	0.53			
Cell 7	BX10	RR	508	508	482.6	499.5	68300	0.35		0.39	
Cell 7	BX10	RL	508	508	482.6	499.5	68300	0.35		0.45	
Cell 7	BX10	LR	431.8	457.2	457.2	448.7	68300	0.43		0.55	
Cell 7	BX10	LL	431.8	431.8	431.8	431.8	68300	0.47		0.55	
Cell 7	BX11	RR	508	508	508	508.0	68300	0.34			
Cell 7	BX11	RL	482.6	482.6	482.6	482.6	68300	0.37			
Cell 7	BX11	LR	508	482.6	482.6	491.1	68300	0.36			
Cell 7	BX11	LL	457.2	457.2	508	474.1	68300	0.39			
Cell 7	BX12	RR	482.6	533.4	533.4	516.5	68300	0.33			
Cell 7	BX12	RL	482.6	508	508	499.5	68300	0.35			
Cell 7	BX12	LR	508	533.4	533.4	524.9	68300	0.32			
Cell 7	BX12	LL	457.2	508	304.8	423.3	68300	0.49			
Cell 7	Bx13	RR	482.6	482.6	508	491.1	68300	0.36			
Cell 7	Bx13	RL	482.6	508	508	499.5	68300	0.35			
Cell 7	Bx13	LR	482.6	457.2	457.2	465.7	68300	0.40			
Cell 7	Bx13	LL	508	482.6	482.6	491.1	68300	0.36			
Cell 8SH	Bx14	RR	330.2	304.8	304.8	313.3	68300	0.89		0.91	
Cell 8SH	Bx14	RL	330.2	25.4	279.4	211.7	68300	1.94			
Cell 8SH	Bx15	RR	330.2	50.8	304.8	228.6	68300	1.66			
Cell 8SH	Bx15	RL	304.8	304.8	304.8	304.8	68300	0.94			
Cell 8SH	Bx16	RR	304.8	330.2	304.8	313.3	68300	0.89			
Cell 8SH	Bx16	RL	330.2	304.8	228.6	287.9	68300	1.05			
Cell 8SH	BX17	RR	355.6	304.8	304.8	321.7	68300	0.84		0.74	1.03
Cell 8SH	BX17	RL	330.2	279.4	304.8	304.8	68300	0.94			
Cell 8SH	Bx18	RR	330.2	304.8	330.2	321.7	68300	0.84			
Cell 8SH	Bx18	RL	304.8	279.4	330.2	304.8	68300	0.94			
Cell 8SH	BX19	RR	330.2	304.8	304.8	313.3	68300	0.89			
Cell 8SH	BX19	RL	330.2	304.8	304.8	313.3	68300	0.89		0.77	
Cell 8SH	Bx20	RR	304.8	304.8	254	287.9	68300	1.05			
Cell 8SH	Bx20	RL	304.8	533.4	254	364.1	68300	0.66			
Cell 8SH	BX21	RR	304.8	279.4	254	279.4	68300	1.11			
Cell 8SH	BX21	RL	330.2	304.8	304.8	313.3	68300	0.89		0.81	

Appendix D Texture data

Table D2 Post Grind Textures

POSTGRIND										
	Measured By Bernard Izevbekhai					Sand Patch ASTM E-965				
						Cell 7 & 8				
		10/23/2007				Time 12:00pm		Temp 50 Deg F	ASTM 2157	Mean
			RUN 1	RUN 2	RUN 3	Average	Vol mm3	Texture (mm)	CTM	E-965
			254	254	254	254.0	68300	1.35	**1.35**	1.54
Cell 8	Cell 8	RR	228.6	228.6	254	237.1	68300	1.55	1.43	
	BX1	RL	228.6	228.6	228.6	228.6	68300	1.66	1.45	
		LR	203.2	228.6	228.6	220.1	68300	1.80	1.53	
		LL	254	228.6	228.6	237.1	68300	1.55		
Cell 8	BX2	RR	254	254	254	254.0	68300	1.35	1.45	
		RL	254	254	254	254.0	68300	1.35	1.2	
		LR	254	254	254	254.0	68300	1.35	1.32	
		LL	254	254	254	254.0	68300	1.35	1.43	
Cell 8	BX3	RR	254	254	254	254.0	68300	1.35		
		RL	228.6	228.6	254	237.1	68300	1.55		
		LR	228.6	228.6	279.4	245.5	68300	1.44		
		LL	228.6	228.6	254	237.1	68300	1.55		
Cell 8	BX4	RR	254	254	228.6	245.5	68300	1.44	1.42	
		RL	254	254	228.6	245.5	68300	1.44	1.3	
		LR	254	228.6	228.6	237.1	68300	1.55	1.52	
		LL	228.6	228.6	228.6	228.6	68300	1.66	1.4	
Cell 8	BX5	RR	228.6	228.6	228.6	228.6	68300	1.66		
		RL	228.6	228.6	228.6	228.6	68300	1.66		
		LR	228.6	228.6	228.6	228.6	68300	1.66		
		LL	228.6	228.6	228.6	228.6	68300	1.66		
Cell 8	BX6	RR	228.6	228.6	228.6	228.6	68300	1.66		
		RL	228.6	228.6	228.6	228.6	68300	1.66		
		LR	228.6	228.6	228.6	228.6	68300	1.66		
		LL	228.6	228.6	228.6	228.6	68300	1.66		
Cell 8	Bx7	RR	228.6	228.6	228.6	228.6	68300	1.66		
		RL	228.6	228.6	228.6	228.6	68300	1.66		
		LR	228.6	228.6	228.6	228.6	68300	1.66		
		LL	228.6	203.2	228.6	220.1	68300	1.80		
Cell 7	BX8	RR	304.8	304.8	304.8	304.8	68300	0.94	1.1	0.96
		RL	304.8	304.8	304.8	304.8	68300	0.94	1.24	
		LR	304.8	304.8	279.4	296.3	68300	0.99	1.09	
		LL	304.8	330.2	304.8	313.3	68300	0.89	1.09	
Cell 7	BX9	RR	304.8	330.2	304.8	313.3	68300	0.89		
		RL	279.4	304.8	304.8	296.3	68300	0.99		
		LR	304.8	304.8	304.8	304.8	68300	0.94		
		LL	304.8	304.8	304.8	304.8	68300	0.94		
Cell 7	BX10	RR	304.8	279.4	279.4	287.9	68300	1.05	1.03	
		RL	304.8	279.4	279.4	287.9	68300	1.05	1.11	
		LR	304.8	304.8	304.8	304.8	68300	0.94	0.94	
		LL	304.8	304.8	279.4	296.3	68300	0.99	1.11	
Cell 7	**BX11**	RR	304.8	279.4	279.4	287.9	68300	1.05		
		RL	279.4	279.4	279.4	279.4	68300	1.11		
		LR	304.8	304.8	304.8	304.8	68300	0.94		
		LL	279.4	304.8	330.2	304.8	68300	0.94		
Cell 7	BX12	RR	304.8	304.8	330.2	313.3	68300	0.89		
		RL	304.8	304.8	330.2	313.3	68300	0.89		
		LR	304.8	304.8	279.4	296.3	68300	0.99		
		LL	330.2	304.8	304.8	313.3	68300	0.89		
Cell 7	Bx13	RR	279.4	304.8	304.8	296.3	68300	0.99		
		RL	304.8	304.8	304.8	304.8	68300	0.94		
		LR	330.2	304.8	304.8	313.3	68300	0.89		
		LL	279.4	279.4	304.8	287.9	68300	1.05		
Cell 8SH	Bx14	RR	228.6	254	228.6	237.1	68300	1.55	1.7	
		RL	228.6	228.6	228.6	228.6	68300	1.66		
Cell 8SH	Bx15	RR	228.6	228.6	228.6	228.6	68300	1.66		
		RL	228.6	228.6	228.6	228.6	68300	1.66		
Cell 8SH	Bx16	RR	228.6	228.6	228.6	228.6	68300	1.66		
		RL	228.6	228.6	228.6	228.6	68300	1.66		
Cell 8SH	BX17	RR	228.6	228.6	228.6	228.6	68300	1.66	1.72	1.54
		RL	254	254	203.2	237.1	68300	1.55		
Cell 8SH	Bx18	RR	228.6	228.6	254	237.1	68300	1.55		
		RL	228.6	254	254	245.5	68300	1.44		
Cell 8SH	BX19	RR	228.6	254	254	245.5	68300	1.44		
		RL	228.6	228.6	254	237.1	68300	1.55	1.52	
Cell 8SH	Bx20	RR	228.6	254	254	245.5	68300	1.44		
		RL	254	228.6	228.6	237.1	68300	1.55		
Cell 8SH	BX21	RR	228.6	228.6	254	237.1	68300	1.55		
		RL	228.6	228.6	228.6	228.6	68300	1.66	1.5	

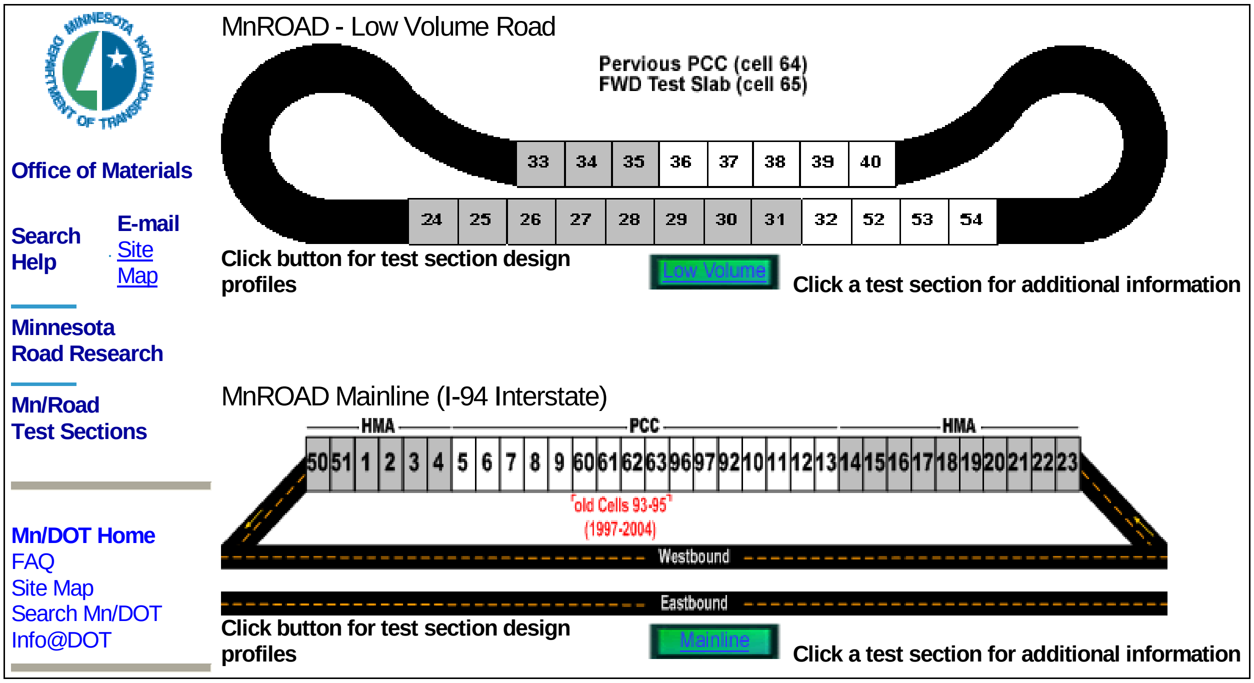
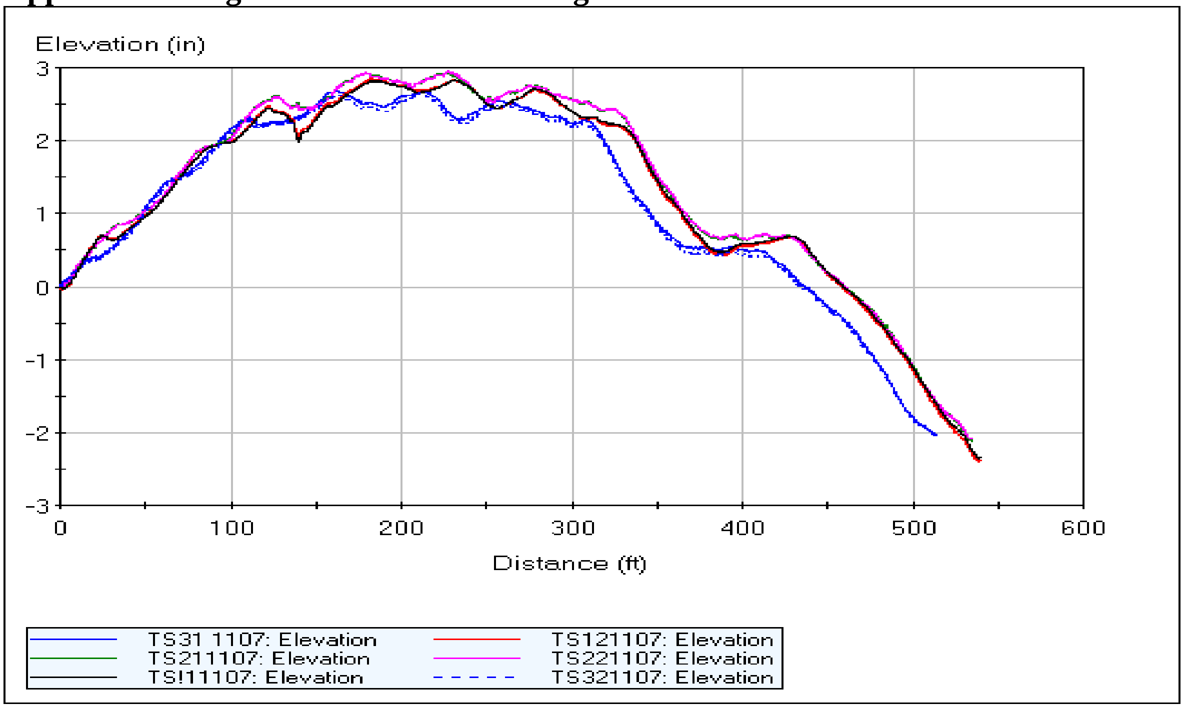


Figure E1 MnROAD Mainline and Low Volume Road

APPENDIX F DATA FROM CELL 37

Appendix F1 Fig 1 Ride Data and Profilograms of TS1 TS2 and TS3



Analysis - Ride Statistics

TS31 1107

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elevation	63.5	88.7	4.00

TS111107

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elevation	70.8	85.7	4.03

TS121107

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elevation	70.9	97.5	3.91

TS211107

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elevation	65.6	89.1	3.99

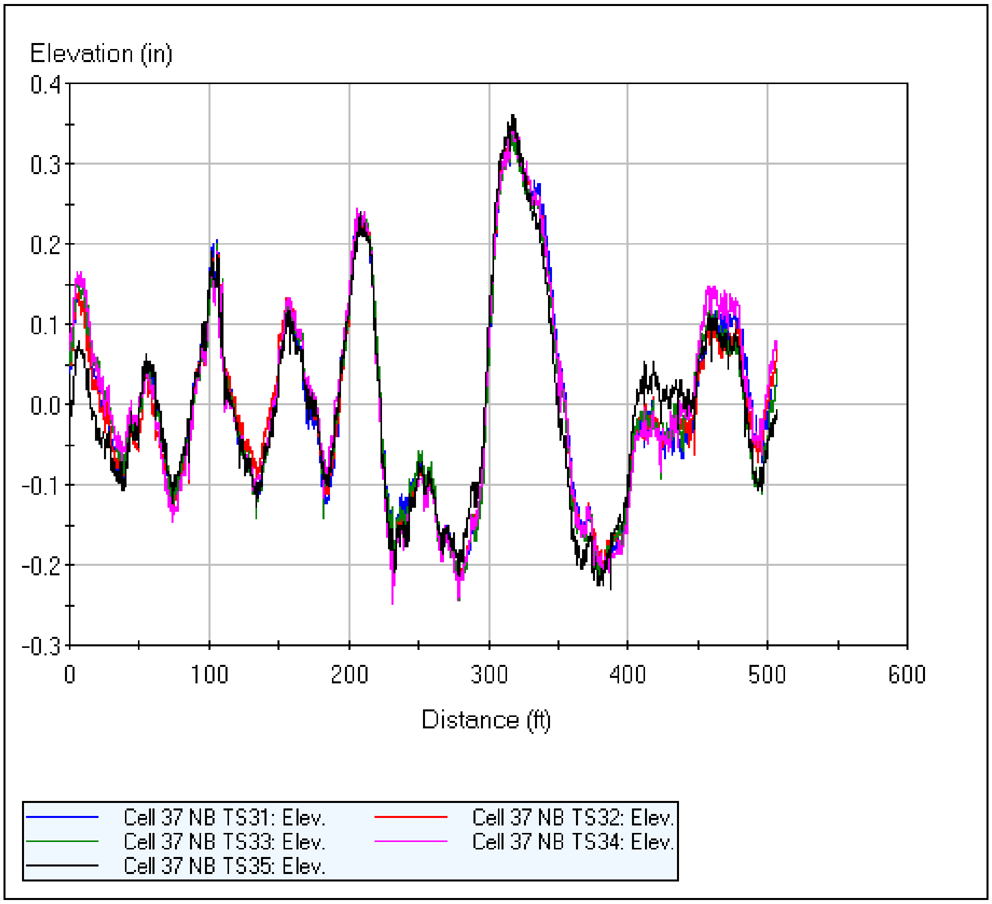
TS221107

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elevation	67.2	94.2	3.94

TS321107

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elevation	63.6	94.3	3.94

Cell 37 Pregrind REPORT (TESTED 6/18/07)



Cell 37 NB TS31

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	65.6	126.6	3.63

Cell 37 NB TS32

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	64.9	128.9	3.61

Cell 37 NB TS33

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	64.7	127.5	3.62

Cell 37 NB TS34

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	64.7	128.0	3.62

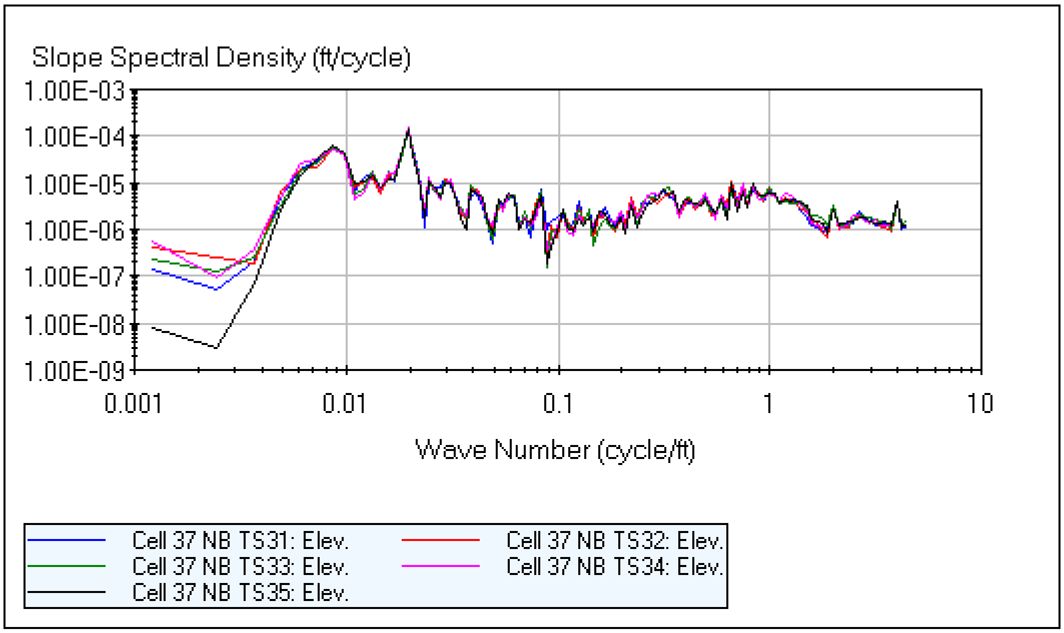
Cell 37 NB TS35

Channel Title	IRI (in/mi)	PTRN (in/mi)	RN
Elev.	63.9	125.2	3.64

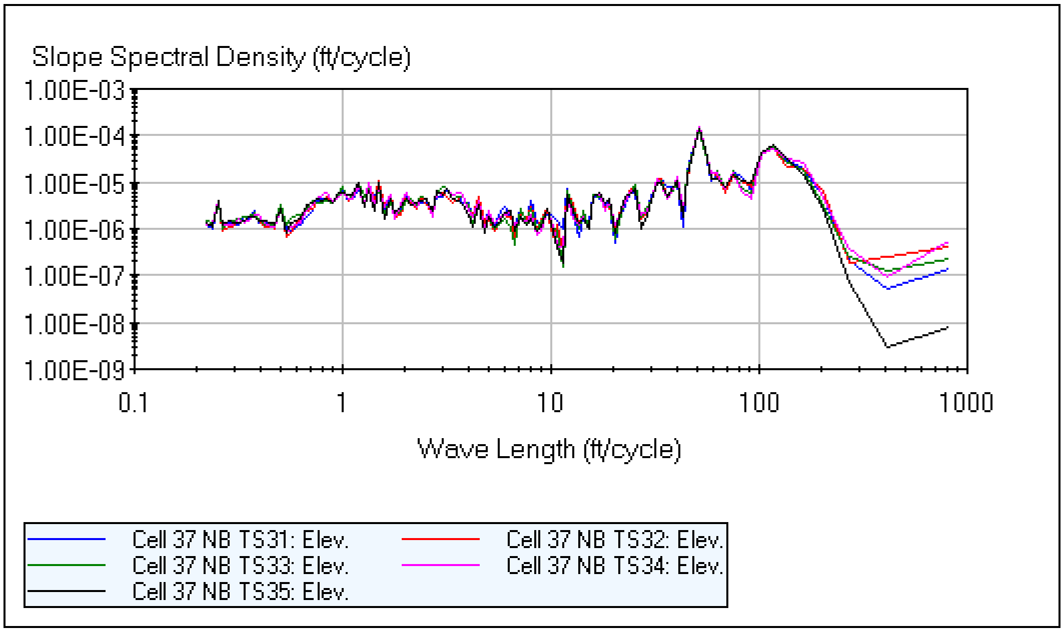
Analysis - Power Spectral Density

Input	Value	Unit
PSD Calculation	Slope	
Use Point Reset	No	
Frequency Averaging	Yes	
Bands Per Octave	12	
Pre-Processor Filter	None	

Wave Number



Wave Length



Slope Spectral Density (ft/cycle)
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
0.1
1
10
100
1000
Wave Length (ft/cycle)
Cell 37 NB TS31: Elev.
Cell 37 NB TS32: Elev.
Cell 37 NB TS33: Elev.
Cell 37 NB TS34: Elev.
Cell 37 NB TS35: Elev.

Appendix Table F2 Texture Data Cell 37

Measured By Bernard Izevbekhai
Arash Moin
Date 6/19/07

Sand Patch ASTM E-965
Cell 37
Time 10:00am **Temp 65 Deg F**

Station	DIA1	DIA 2	DIA 3	RUN 1	RUN 2	RUN 3	Average	Vol mm3	Texture (mm)	REMARKS
TX9 TS3	**16**	**16**	**15**	**408**	**408**	**382.5**	399.5	68300	0.545	
TX9 TS1	13	14	15	**331.5**	**357**	**382.5**	357	68300	0.683	
TX8TS1	13	13	12	**331.5**	**331.5**	**306**	323	68300	0.834	
TX7 TS1	12.5	13	14	**318.75**	**331.5**	**357**	335.75	68300	0.772	
TX6 TS1	17	15	14	**433.5**	**382.5**	**357**	391	68300	0.569	
TX5 TS1	17.5	19.5	19.5	**446.25**	**497.25**	**497.25**	480.25	68300	0.377	
TX4 TS1	14	15	16	**357**	**382.5**	**408**	382.5	68300	0.595	
TX3 TS1	12	15	14	**306**	**382.5**	**357**	348.5	68300	0.716	
TX2 TS1	13	14	15	**331.5**	**357**	**382.5**	357	68300	0.683	
TX 1TS1	15	16	16	**382.5**	**408**	**408**	399.5	68300	0.545	
									0.632	

Arash Moin
Date 6/22/07 **Sand Patch Test** **Time 11:10 AM**
Cell 37

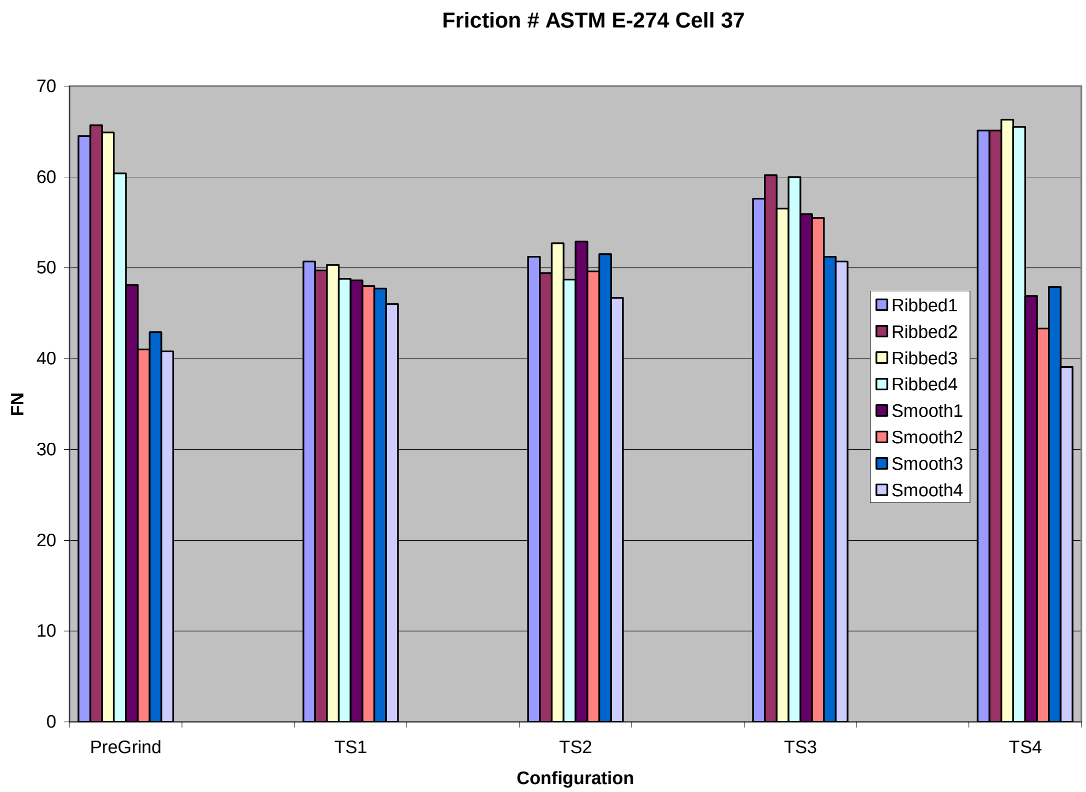
Station	DIA1	DIA 2	DIA 3	RUN 1	RUN 2	RUN 3	Average	Vol mm3	Texture (mm)	REMARKS
TX9 TS3	11	11	10.5	280.5	280.5	267.75	276.25	68300	1.140	Closest to middle yellow line
TX8 TS3	11.5	11.5	12	293.25	293.25	306	297.5	68300	0.983	
TX7 TS3	11	10.5	10.5	280.5	267.75	267.75	272	68300	1.176	
TX6 TS3	10	11	10.5	255	280.5	267.75	267.75	68300	1.214	
TX5 TS3	10.5	10.5	9	267.75	267.75	229.5	255	68300	1.338	
TX4 TS3	10.5	10	10.5	267.75	255	267.75	263.5	68300	1.253	
TX3 TS3	10	9	9	255	229.5	229.5	238	68300	1.536	
TX2 TS3	10	9	8.5	255	229.5	216.75	233.75	68300	1.592	
TX1 TS3	9	10	10	229.5	255	255	246.5	68300	1.432	
									1.296	

Station	DIA1	DIA 2	DIA 3	RUN 1	RUN 2	RUN 3	Average	Vol mm3	Texture (mm)	REMARKS
TX9 TS2	11	12	12.5	280.5	306	318.75	301.75	68300	0.956	
TX8 TS2	9	9.5	9.5	229.5	242.25	242.25	238	68300	1.536	2nd closest to middle yellow line
TX7 TS2	9	9	9	229.5	229.5	229.5	229.5	68300	1.652	
TX6 TS2	9.5	10.5	10.5	242.25	267.75	267.75	259.25	68300	1.295	
TX5 TS2	10	11	11.5	255	280.5	293.25	276.25	68300	1.140	
TX4 TS2	12	12	12.5	306	306	318.75	310.25	68300	0.904	
TX3 TS2	10.5	10	10	267.75	255	255	259.25	68300	1.295	
TX2 TS2	11	10	10	280.5	255	255	263.5	68300	1.253	
TX1 TS2	10	9	9.5	255	229.5	242.25	242.25	68300	1.483	
									1.279	

Station	DIA1	DIA 2	DIA 3	RUN 1	RUN 2	RUN 3	Average	Vol mm3	Texture (mm)	REMARKS
TX9 TS1	12	13	12.5	306	331.5	318.75	318.75	68300	0.856	3rd closest to middle yellow line
TX8 TS1	12	12	13	306	306	331.5	314.5	68300	0.880	
YX7 TS1	12	12.5	12.5	306	318.75	318.75	314.5	68300	0.880	
TX6 TS1	12	13	13	306	331.5	331.5	323	68300	0.834	
TX5 TS1	12	12.5	12.5	306	318.75	318.75	314.5	68300	0.880	
TX4 TS1	12	12	12	306	306	306	306	68300	0.929	
TX3 TS1	12	12	12.5	306	306	318.75	310.25	68300	0.904	
TX2 TS1	13	12.5	13	331.5	318.75	331.5	327.25	68300	0.812	
TX1 TS1	13	12.5	12.5	331.5	318.75	318.75	323	68300	0.834	
									0.868	

Station	DIA1	DIA 2	DIA 3	RUN 1	RUN 2	RUN 3	Average	Vol mm3	Texture (mm)	REMARKS
TX9 TS4	13	13.5	13	331.5	344.25	331.5	335.75	68300	0.772	4th closest to(furthest from middle yellow line
TX8 TS4	13.5	13.5	14	344.25	344.25	357	348.5	68300	0.716	
TX7 YS4	13	12.5	13	331.5	318.75	331.5	327.25	68300	0.812	
TX6 TS4	12.5	12.5	13	318.75	318.75	331.5	323	68300	0.834	
TX5 TS4	15	15	15.5	382.5	382.5	395.25	386.75	68300	0.582	
TX4 TS4	14	15	14.5	357	382.5	369.75	369.75	68300	0.636	
TX3 TS4	12	11.5	12	306	293.25	306	301.75	68300	0.956	
TX2 TS4	12	10	12	306	255	306	289	68300	1.042	
TX1 TS4	14	13	13	357	331.5	331.5	340	68300	0.753	
									0.789	

Appendix F 3   Friction Data For cell 37



Appendix TABLE F3   Friction Data from Cell 37

			FRICTION #							
Condition	**Date**	**Test Code**	**Ribbed1**	**Ribbed2**	**Ribbed3**	**Ribbed4**	**Smooth1**	**Smooth2**	**Smooth3**	**Smooth4**
Pre -Grind	6/18/2007	**PreGrind**	64.5	65.7	64.9	60.4	48.1	41	42.9	40.8
Post Grind	6/22/2007	**TS1**	50.7	49.7	50.3	48.8	48.6	48	47.7	46
Post Grind	6/22/2007	**TS2**	51.2	49.4	52.7	48.7	52.9	49.6	51.5	46.7
Post Grind	6/22/2007	**TS3**	57.6	60.2	56.5	60	55.9	55.5	51.2	50.7
Post Grind	6/22/2007	**TS4**	65.1	65.1	66.3	65.5	46.9	43.3	47.9	39.1

Appendix Table F4 Texture measurements from Skid Truck

	TEXTURE X 10 mm												
Test Code	Location1	Location2	Location3	Location4	Location5	Location6	Location7	Location8	Location9	Location10	Location11	Location12	Mean
PreGrind Ribbed	0.610	0.610	0.635	0.711	0.635	0.660	0.991	0.889	1.016	0.762	0.660	1.168	**0.779**
PregrindSmooth	0.889	0.889	0.889	1.067	1.168	1.397	0.838	0.762	0.762	0.838	0.686	0.762	**0.912**
TS1 Ribbed	0.787	0.483	0.432	0.483	0.483	0.356	0.686	0.813	0.660	0.559	0.483	0.508	**0.561**
TS1Smooth	0.838	0.838	0.711	0.432	0.483	0.533	0.711	0.686	0.610	0.610	0.610	0.635	**0.641**
TS2 Ribbed	0.838	0.838	0.838	0.483	0.406	0.406	0.635	0.610	0.457	0.533	0.406	0.406	**0.572**
TS2 Smooth	0.737	0.737	0.737	0.711	0.787	0.737	0.711	0.914	0.940	0.762	0.660	0.711	**0.762**
TS3 Ribbed	0.635	0.406	0.406	0.406	0.483	0.508	0.559	0.533	0.737	0.762	0.660	0.533	**0.552**
TS3 Smooth	0.965	0.940	1.397	0.584	0.711	0.711	0.838	0.864	0.838	0.711	0.660	1.041	**0.855**
TS4 Ribbed	1.143	1.041	1.397	0.584	0.559	0.686	0.787	0.787	0.838	0.838	0.483	0.483	**0.802**
TS4 Smooth	1.118	1.118	0.991	0.991	0.838	0.762	0.940	1.016	1.067	1.118	0.711	0.686	**0.946**