PCC SURFACE CHARACTERISTICS
MNROAD STUDIES
DATA ANALYSIS

Year 1 Annual Report

Task 4: Submit Annual Reports

DRAFT

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The purpose of this study is to analyze the long term performance of different diamond grinding patterns ground on Portland Cement Concrete Pavement. The testing area is located at the MnROAD cold weather test facility. There are three cells on the MnROAD mainline that are involved with this test. Cells 7 and 9 are Next Generation Concrete Surface grinds (NGCS) and cell 8 is a conventionally ground surface. The objective of NGCS surfaces is to reduce the tire/pavement noise while maintaining good friction, ride, and wear characteristics. The grinding of cells 7 (Innovative) and 8 (conventional) was done in October of 2007 with the grinding of cell 9 (Ultimate) occurring in October of 2008. These cells will be monitored for a minimum of five years to determine durability and time-related texture and friction decay of the innovative grinds and the noise trends over the study period.

The data collection on this project is conducted by Mn/DOT at the MnROAD facility near Albertville, Minnesota. For this first annual report, data is included through late 2010. This section describes the data that has been collected and the dates and times of its collection.

Table 1. Dates and Types of MnROAD Testing Conducted.

	Characteristics Measured			
Testing Date	**Noise**	**Friction**	**Texture**	**Ride**
17 Aug 2007	X			
8 Sep 2007				X
10 Sep 2007	X			
15 Oct 2007			X	
22 Oct 2007	X			X
23 Oct 2007			X	
6 Nov 2007		X		
2 Apr 2008	X			
28 May 2008		X		
25 Oct 2008			X	
31 Oct 2008		X		
2 Nov 2008			X	
19 Nov 2008				X
20 Nov 2008	X			
5 Dec 2008	X			
15 Mar 2009			X	
16 Mar 2009	X			
16 Jun 2009		X		
21 Jul 2009	X			
15 Sep 2009	X			
17 Nov 2009	X			
8 Mar 2010	X			X
1 Jun 2010			X	
28 Jul 2010	X			
17 Sep 2010	X			
20 Sep 2010		X		
17 Nov 2010	X			

Throughout this report, references to the cells included in the study are as follows.

- Conventional Grind

    Cell 8

    Grinding conducted on 20 October 2007

- Innovative Grind
  Cell 7
  Grinding conducted on 20 October 2007
- Ultimate Grind
  Cell 9
  Grinding conducted on or about 22 October 2008

Noise

Noise testing was conducted using the On Board Sound Intensity (OBSI) method. The OBSI method uses two microphones to collect sound data from both the leading edge and the trailing edge of the tire. A standardized tire referred to as the Standard Reference Test Tire is also used as per ASTM standards. After the initial grinding on each cell, there was a significant reduction in noise from the innovative grind compared to the conventional grind. In fact, after the grinding was performed in October 2007 on cells 7 and 8, there was a 4.5 decibel difference between the innovative grind on cell 7 and the conventional grind on cell 8.

Cell 9 was ground in October of 2008, approximately 1 year after cells 7 and 8. Figure 1 and Figure 2 show the OBSI noise level measurements for the driving lane and passing lane of all three of these cells, respectively, tested on the dates provided in Table 1.

It is important to note that these tests were performed at different times of the year, and at various times during the day. The temperature of the road surface and of the tire will have varied among the different testing periods. Since the temperature of the road surface and of the tire affects the noise measurement, it is important for the noise measurements to be adjusted for these differences. While the temperatures have been recorded for all of the tests, an adjustment function has not been developed at the current time. A testing program will be conducted in the spring of 2011 to produce this adjustment function. This testing program will involve a full-day testing session where OBSI testing will be conducted many times throughout the day, at different surface and tire temperatures to determine the effect of temperature on pavement noise. Thus, currently, the data analysis may be modified at the time of the next annual report to reflect these adjustments.

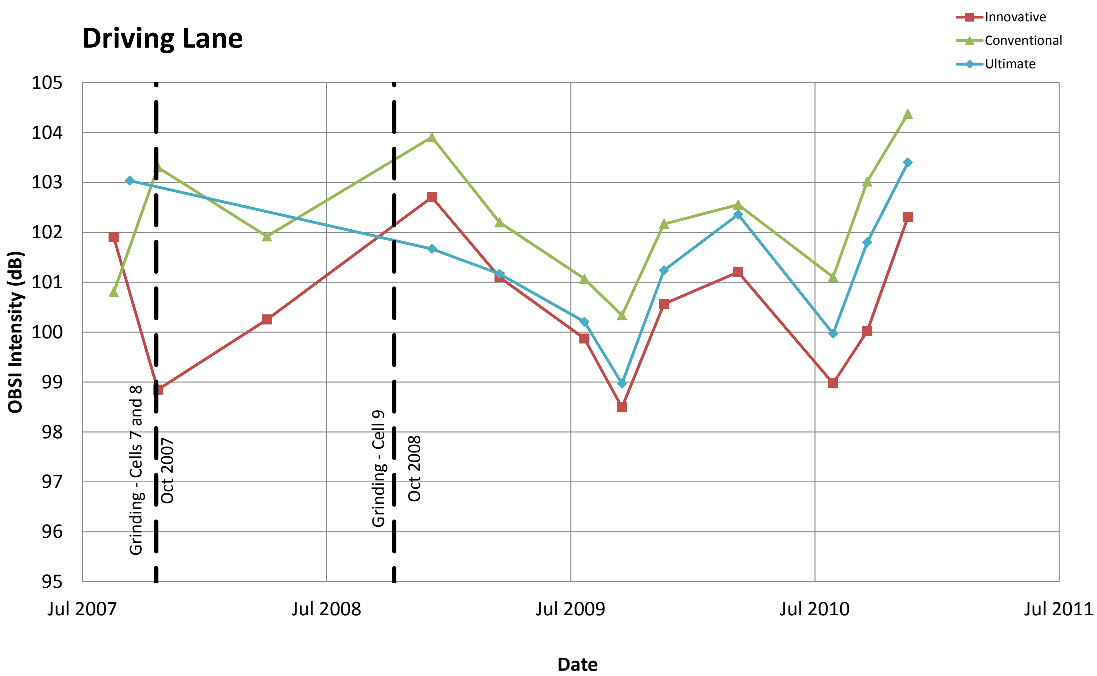

Figure 1. OBSI Measurements – Driving Lane.

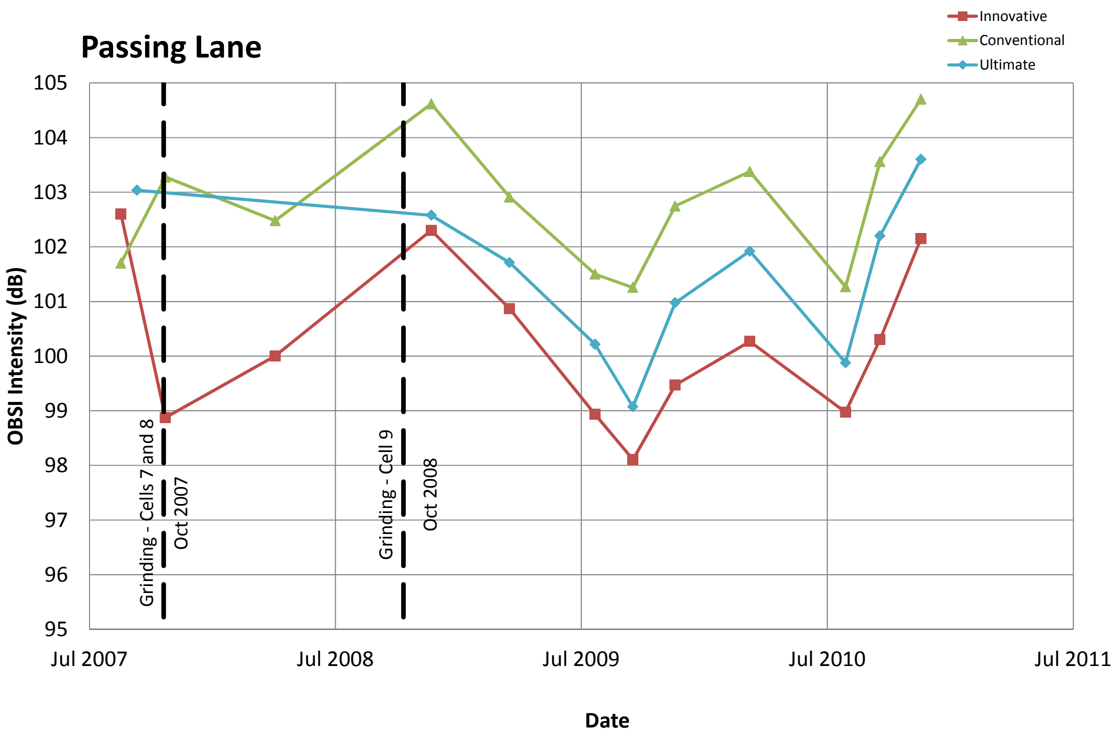

Figure 2. OBSI Measurements – Passing Lane.

No OBSI testing was conducted immediately following the grinding of cell 9. Table 2 shows the OBSI measurements in the driving lane, and the relative differences between the sound measurements on cell 8 (conventional grind), cell 7 (innovative grind) and cell 9 (ultimate grind). Table 3 show the same results for the passing lane, which are similar to those in the driving lane.

The differences between the measurements are shown in Figure 3 and Figure 4 for the driving and passing lanes, respectively. Initially there is a significant difference between the innovative and conventional grinds. Soon afterward, however, those differences seem to decrease significantly. These differences then appear to increase slightly beginning about 18 months after the initial grind.

Table 2. Comparison of OBSI Measurements – Driving Lane.

				Difference (Cell 7 to 8) Conventional - Innovative		Difference (Cell 9 to 8) Conventional - Ultimate		Difference (Cell 7 to 9) Ultimate - Innovative	
Date	Conventional (Cell 8)	Innovative (Cell 7)	Ultimate (Cell 9)	dB Difference	% Difference	dB Difference	% Difference	dB Difference	% Difference
10/22/07	103.3	98.8	-	4.5	4.5%	-	-	-	-
4/2/08	101.9	100.3	-	1.7	1.7%	-	-	-	-
12/5/08	103.9	102.7	101.7	1.2	1.2%	2.2	2.2%	-1.0	-1.0%
3/16/09	102.2	101.1	101.2	1.1	1.1%	1.0	1.0%	0.1	0.1%
7/21/09	101.1	99.9	100.2	1.2	1.2%	0.9	0.9%	0.3	0.3%
9/15/09	100.3	98.5	99.0	1.8	1.9%	1.4	1.4%	0.5	0.5%
11/17/09	102.2	100.6	101.2	1.6	1.6%	0.9	0.9%	0.7	0.7%
3/8/10	102.6	101.2	102.4	1.4	1.3%	0.2	0.2%	1.2	1.1%
7/28/10	101.1	99.0	100.0	2.1	2.2%	1.1	1.1%	1.0	1.0%
9/17/10	103.0	100.0	101.8	3.0	3.0%	1.2	1.2%	1.8	1.8%
11/17/10	104.4	102.3	103.4	2.1	2.0%	1.0	0.9%	1.1	1.1%

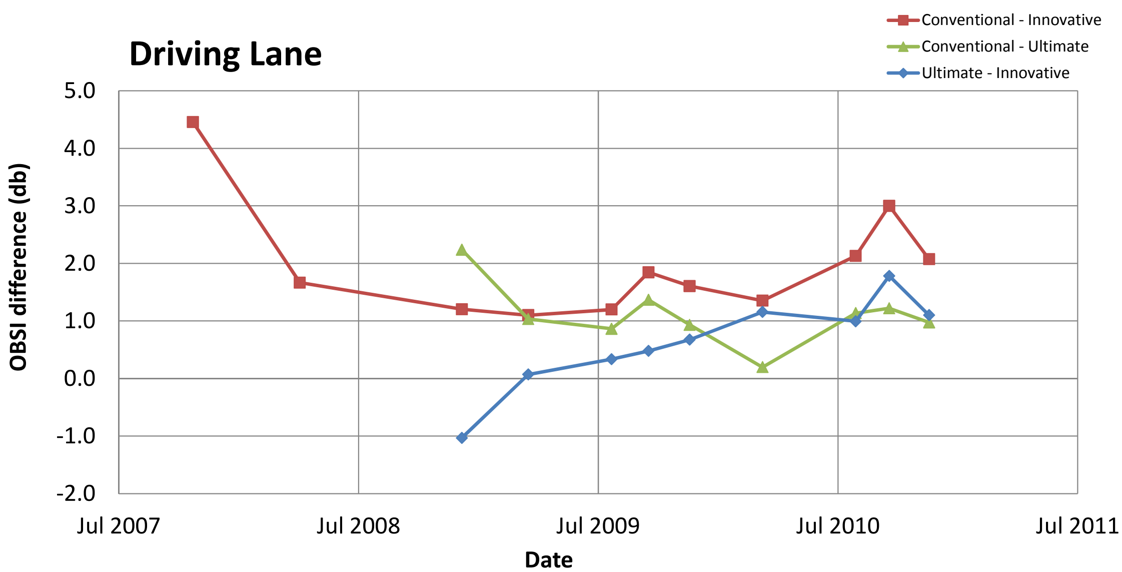

Figure 3. Difference in OBSI Measurements – Driving Lane.

Table 3. Comparison of OBSI Measurements – Passing Lane.

				Difference (Cell 7 to 8) Conventional - Innovative		Difference (Cell 9 to 8) Conventional - Ultimate		Difference (Cell 7 to 9) Ultimate - Innovative	
Date	Conventional (Cell 8)	Innovative (Cell 7)	Ultimate (Cell 9)	dB Difference	% Difference	dB Difference	% Difference	dB Difference	% Difference
10/22/07	103.3	98.9	-	4.4	4.5%	-	-	-	-
4/2/08	102.5	100.0	-	2.5	2.5%	-	-	-	-
11/20/08	104.6	102.3	102.6	2.3	2.3%	2.0	2.0%	0.3	0.3%
3/16/09	102.9	100.9	101.7	2.0	2.0%	1.2	1.2%	0.8	0.8%
7/21/09	101.5	98.9	100.2	2.6	2.6%	1.3	1.3%	1.3	1.3%
9/15/09	101.3	98.1	99.1	3.1	3.2%	2.2	2.2%	1.0	1.0%
11/17/09	102.7	99.5	101.0	3.3	3.3%	1.8	1.8%	1.5	1.5%
3/8/10	103.4	100.3	101.9	3.1	3.1%	1.5	1.4%	1.7	1.6%
7/28/10	101.3	99.0	99.9	2.3	2.3%	1.4	1.4%	0.9	0.9%
9/17/10	103.6	100.3	102.2	3.3	3.2%	1.4	1.3%	1.9	1.9%
11/17/10	104.7	102.2	103.6	2.6	2.5%	1.1	1.1%	1.5	1.4%

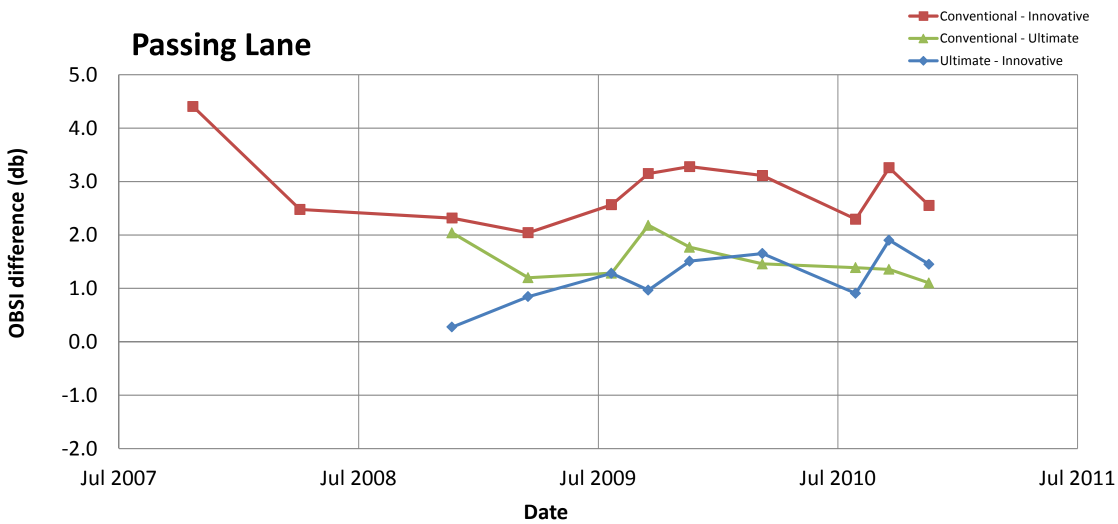

Figure 4. Difference in OBSI Measurements – Passing Lane.

The rate of change in the differences does not seem to follow a trend at this point when comparing the innovative and ultimate to the conventional grinds, but these trends will be monitored over time. The difference in OBSI measurements between the innovative and ultimate grinds, however, shows a consistent increase (the ultimate grind becoming louder, more quickly than the innovative grind.)

It is important to quantify the significance of the difference in OBSI levels for the three surfaces. The following formula is used to calculate the total noise level from several point sources.

$$dB_{total} = 10 \cdot \log\left(10^{\frac{OBSI_1}{10}} + 10^{\frac{OBSI_2}{10}} + 10^{\frac{OBSI_3}{10}} + \ldots + 10^{\frac{OBSI_n}{10}}\right) \qquad \text{Eq. 1}$$

where:

dB_{total} = total noise level from all point sources

$OBSI_i$ = sound from individual point source i (tire-pavement interface)

The test conducted on 9 September 2010 shows a difference of 3 dB from the Innovative grind to the Conventional grind on the driving lane. Initially, a 3-dB difference in the sound pressure level may not seem significant. In fact, a 3 dB change in sound pressure levels at the tire pavement interface is equivalent to cutting the traffic volume in half. Figure 5 shows that 8 cars at 100 dB each is equivalent to 4 cars at 103 dB each. This was calculated using the equation above.

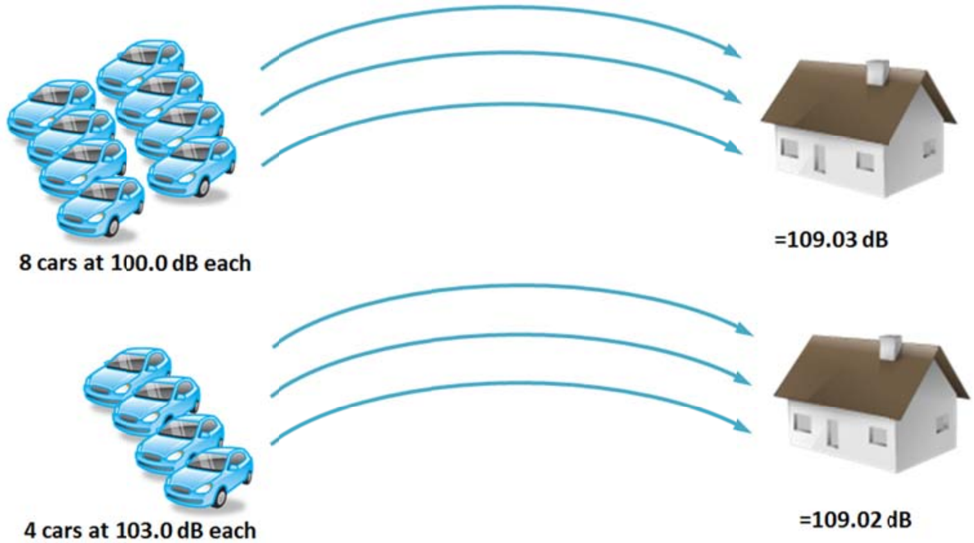

Figure 5. Relationship Between Noise Increase and Traffic Volume.

Figure 6 shows the perceived traffic reduction for both of the NGCS surfaces from the Conventional grind on the driving lane. This was calculated using Equation 1above. Note that this refers to the instantaneous traffic volume.

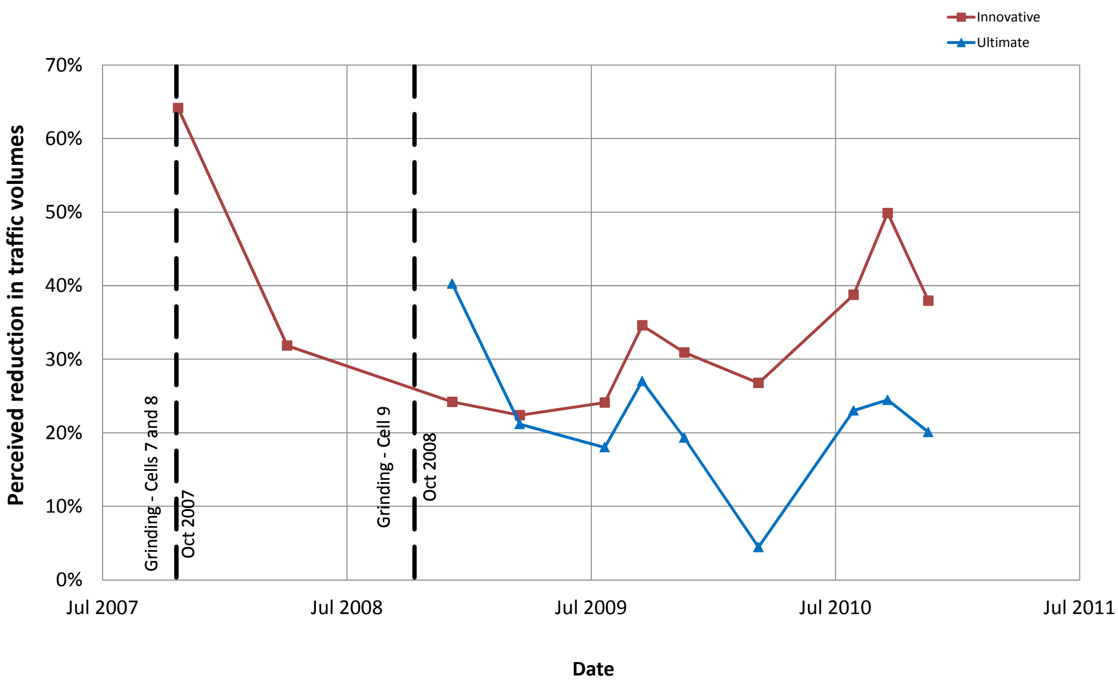

Figure 6. Perceived Reduction of Traffic Volume from the Conventional Grind on the Driving Lane.

When comparing the noise levels between the grinding methods by age since the grinding was conducted, the data are more erratic. One fortunate coincidence is that the grinding on cell 9 occurred almost exactly one year after the grinding on cells 7 and 8. Also, there are three testing dates subsequent to cell 9 grinding that fall one year after testing at the same age on cells 7 and 8 within a few days. This information is shown below, in Figure 7 and Figure 8. The comparison for cells 7 and 8 are the same as in the previous figures since they were ground and measured at the same time. Since the three cells were tested within days of the one-year mark from each other, the air and surface temperatures would have been similar, and thus any corrections may not be as significant as if they were conducted in different seasons. Note, however, that this data still needs to be corrected for temperature, which will be conducted in the spring of 2011. In the figures below, the legend indicates the comparison made. For example, when comparing the conventional to the innovative grind in Figure 7, the “Conventional – Innovative” notation indicates that the conventional grind is louder by the ordinate of the line at the particular time.

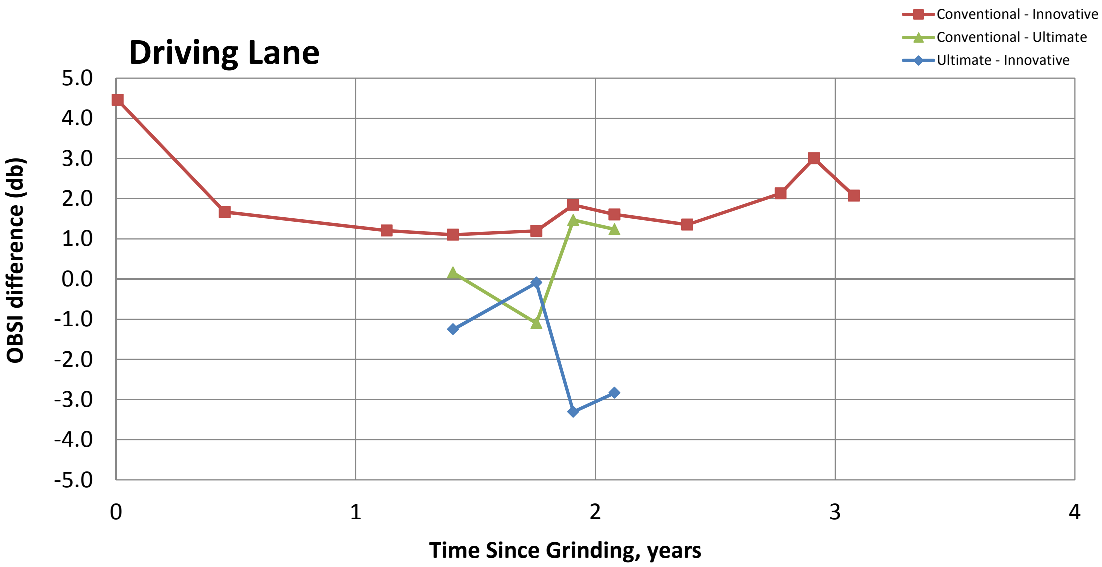

Figure 7. Difference in OBSI Measurements by Time Since Grinding – Driving Lane.

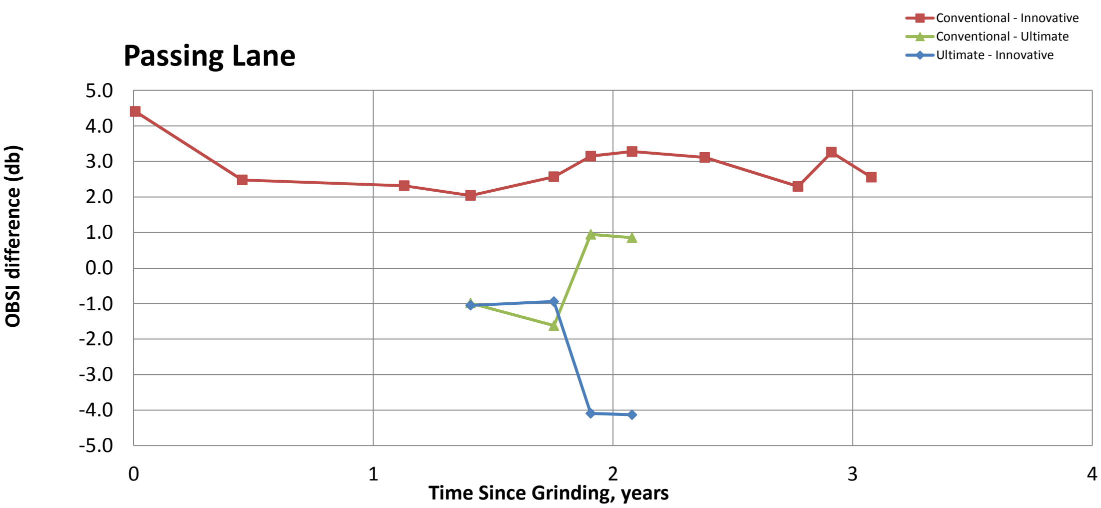

Figure 8. Difference in OBSI Measurements by Time Since Grinding – Passing Lane.

Figure 9 shows the OBSI measurement for both the leading edge and trailing edge from each test, in the Driving Lane. There is one key piece of information that can be extracted from the data in this figure, which is that the trailing edge of the two NGCS surfaces (Innovative and Ultimate) produces a higher sound pressure level initially after grinding, and that the conventional grind produces the opposite result. The leading edge is higher immediately after grinding than the trailing edge. The reason for this is likely due to the grinding procedure. The grinding of the conventional surface leaves brittle tines or kerfs with positive or upward texture that eventually breaks off or “wear in” and becomes smoother. The NGCS procedure involves grinding of the entire surface creating no positive or upward texture. Passing lane data showed ultimately the same result.

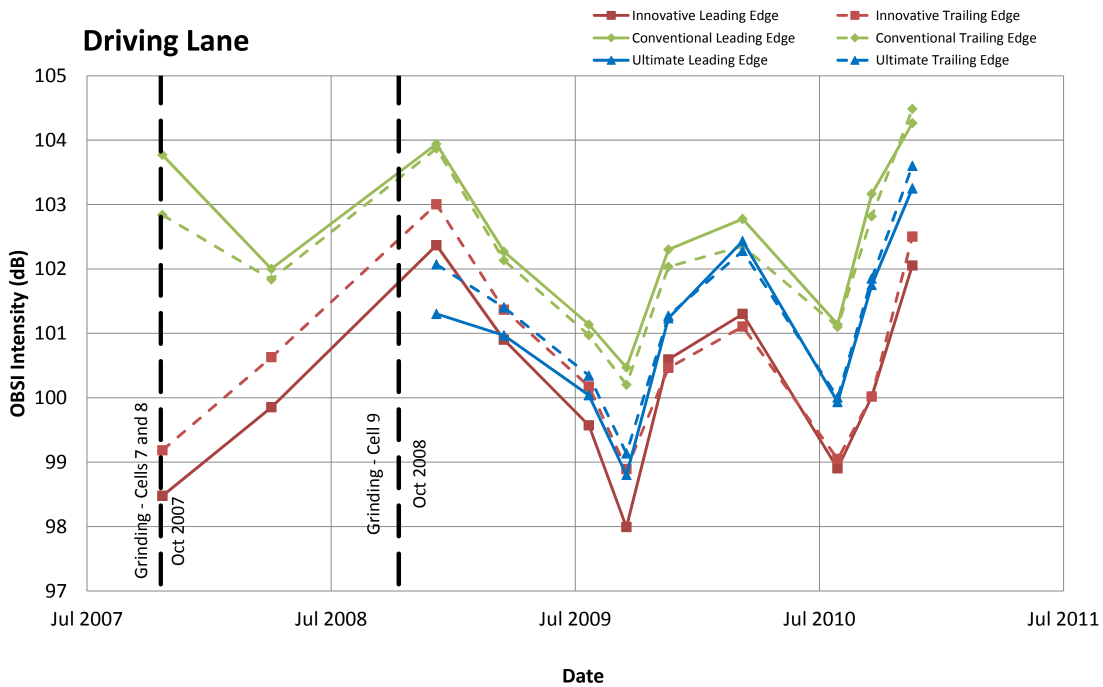

Figure 9. Leading Edge and Trailing Edge Comparison

As more data becomes available, it is hoped that the trends in the noise measurements will become more meaningful. For some statistical trend analysis methods, a minimum of 10 data points is required. In most cases, this level of data will be achieved in the next year.

Friction

The purpose of friction testing is to compare how the performance of the three surface grinding methods maintain their friction characteristics over time. It is important to evaluate each point and adjust for climatic conditions such as surface temperature and others when comparing individual test results. After the initial pavement grinding, the friction number was higher for the conventional grind than for the innovative grind using both a ribbed and smooth tire. The ultimate grind was performed on cell 9 approximately one year after the conventional and innovative grind. The results of the friction testing in the driving and passing lanes (using the ribbed tire) are shown in Figure 10 through Figure 13. The same results for the smooth tire testing are shown in Figure 14 through Figure 17.

Ribbed Tire

After cells 7 and 8 were ground, it appears that the friction on cell 8 (conventional) increases while the friction of cell 7 (conventional) decreases between the first and second tests. In the initial period after grinding, the fins remaining on the conventional grind break down and the overall friction decreases, whereas for the innovative grind, these fins are not left behind in the grinding process. It is possible that the difference in surface temperatures from one testing date to the next may have an effect on the friction measurements. The air temperature was 37° F on 16 November 2007, and 66° F on 28 May 2008 – a difference of 29° F. The surface temperature was about 53° F greater in the May 2008 testing than in November 2007. The conventional surface outperformed the Innovative grind by a friction number of almost 10, initially, and increased to a difference of about 12 by the time of the second test in May 2008.

After its high point measured at about seven or eight months after grinding, the conventional grind decreased at approximately a constant rate for about a year, and then has remained almost constant for two testing periods. The innovative grind held a relatively constant friction number for the first two years after grinding, and has shown a slight decrease at the most recent testing (20 September 2010).

In the first six months after the grinding of cell 9 (ultimate), in October 2008, the friction number decreased slightly between the first and second testing dates (31 October 2008 and 16 June 2009). This period of "wearing in" may actually occur in less than six months, but this cannot be determined due to the quarterly data collection frequency. The friction number has remained nearly constant between that time and the third testing date (20 September 2010).

Using the most recent data it seems that the conventional grind outperforms the two NGCS surfaces for longevity of friction number, using the test with the ribbed tire. Over time, additional testing will provide additional information regarding this trend. As mentioned with the noise data, as more data is obtained, additional analysis of a more statistical nature will be conducted.

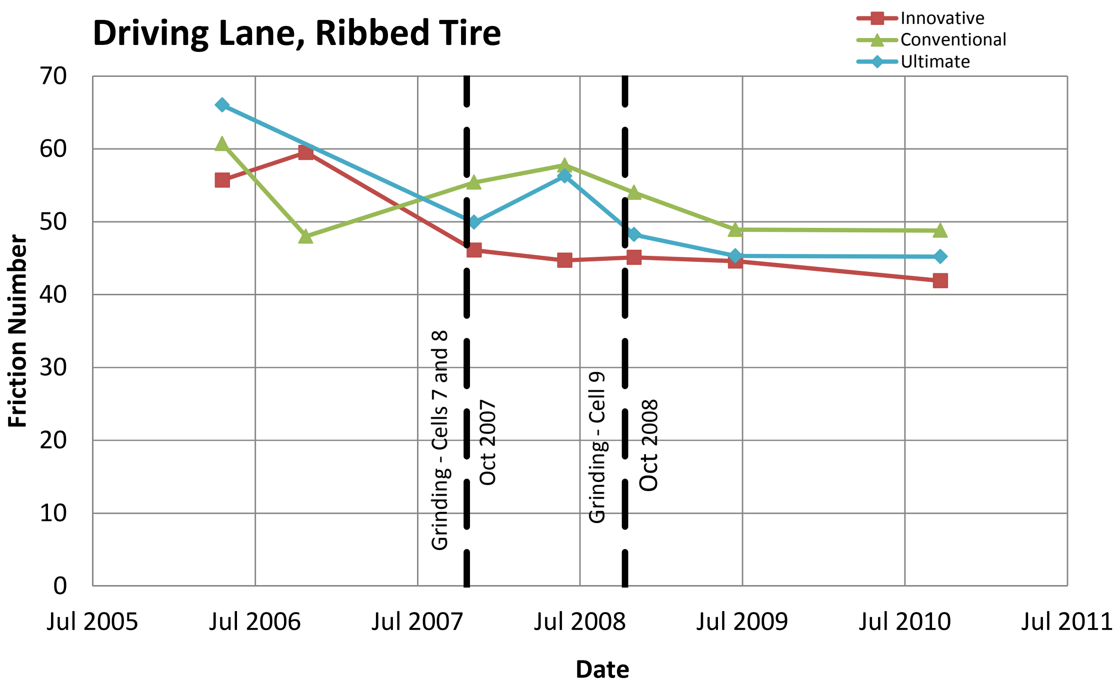

Figure 10. Friction Test – Driving Lane, Ribbed Tire by Test Date.

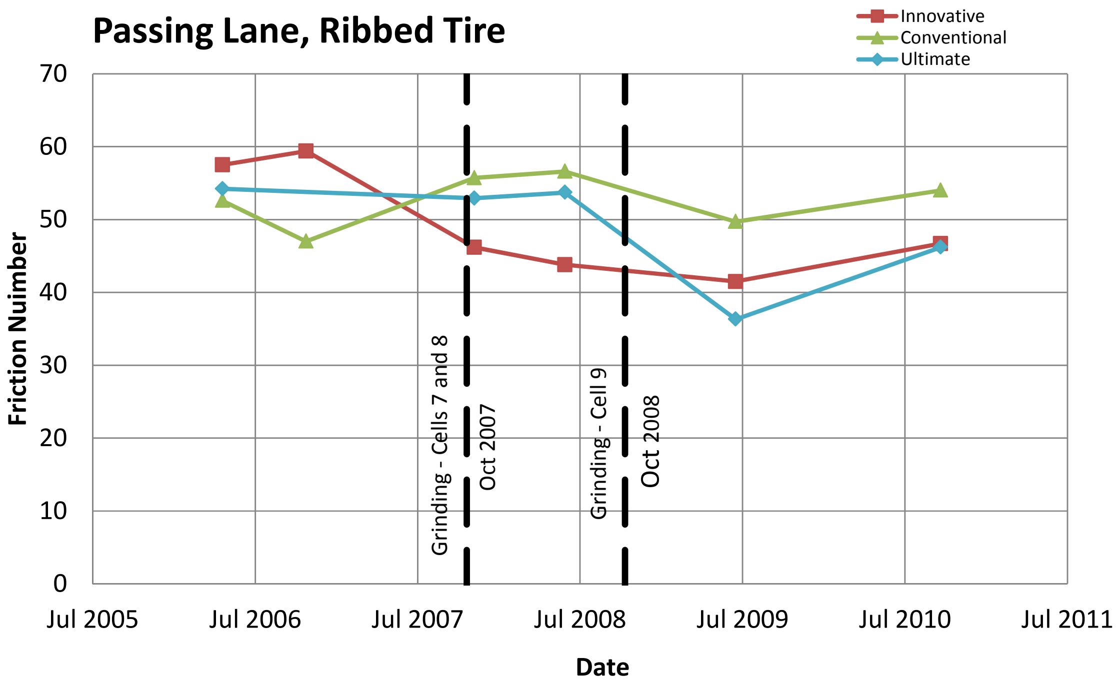

Figure 11. Friction Test – Passing Lane, Ribbed Tire by Test Date.

Comparisons can be made easier by comparing the surfaces by the elapsed time since they were ground, instead of by date. Figure 12 and Figure 13 are made up of the same friction data as Figure 10 and Figure 11, but are shown in terms of the age, or time since grinding. Essentially, the Ultimate grind data is offset so that it can be directly compared to the others which were ground one year earlier.

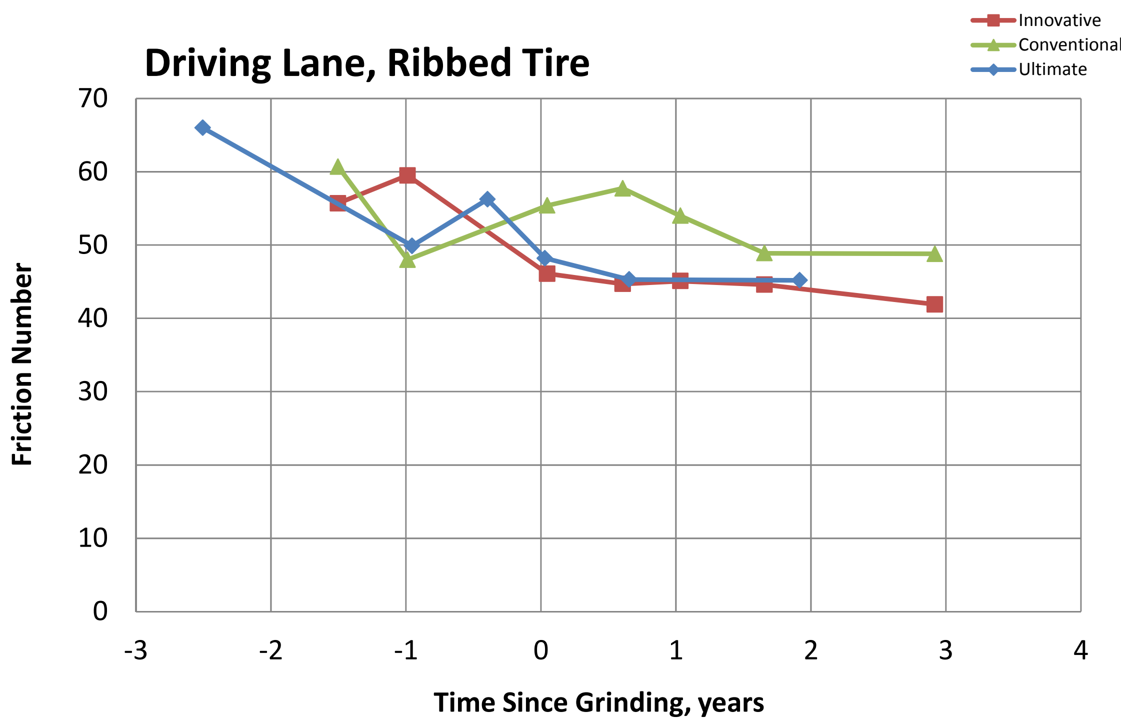

Figure 12. Friction – Driving Lane, Ribbed Tire by Time Since Grinding.

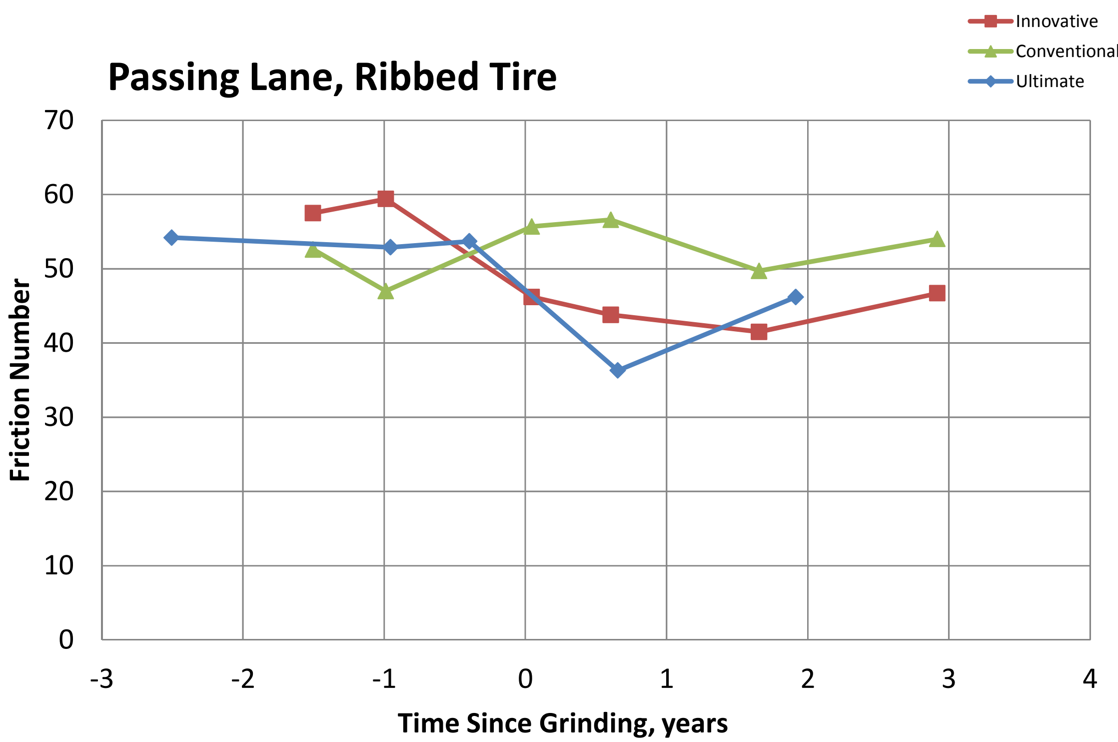

Figure 13. Friction – Passing Lane, Ribbed Tire by Time Since Grinding.

Smooth Tire

Using the smooth tire, the friction number of cells 7 and 8 increased between the initial test after grinding and the next test, about seven months later. The two cells began a decrease at a constant rate for about one year. The conventional grind on cell 8 however, continues to show a decrease at about the same rate, and at the most recent testing date, shows a lower friction number than both the Innovative and Ultimate grinds. As discussed above, the ultimate grind is not at the same "age" as the other two types, and so the testing conducted in September 2010 cannot be compared directly between the ultimate grind and the others tested at the same time. At the age of approximately 1.5 to 2 years, however, the friction number of the ultimate grind is at or lower than that of the other two.

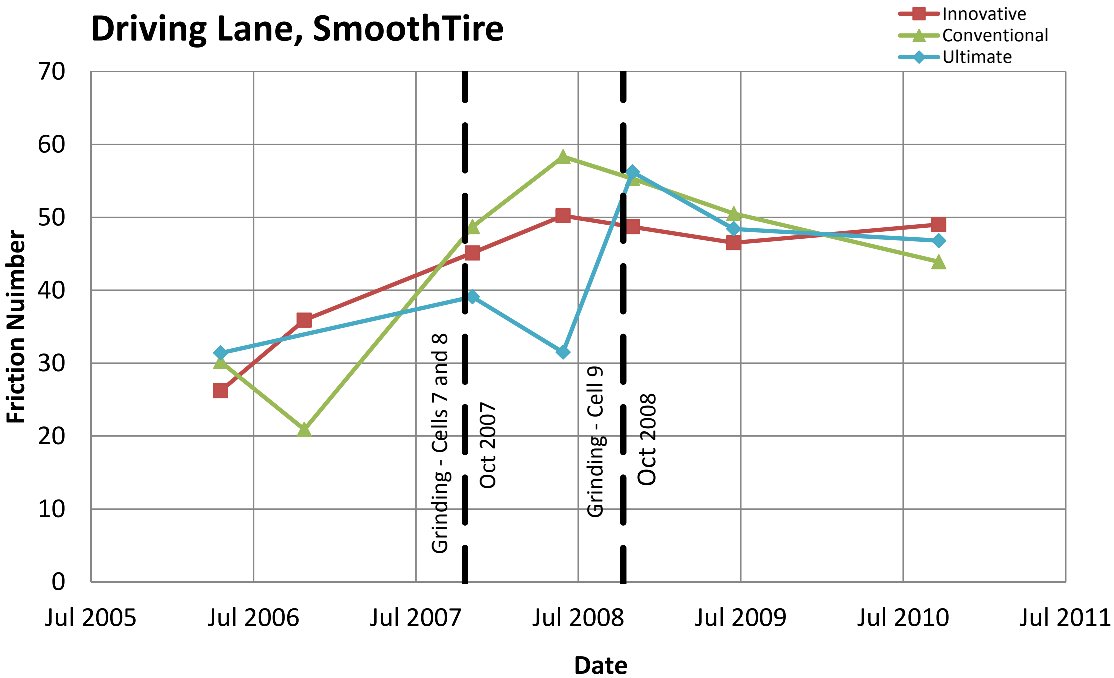

Figure 14. Friction Test – Driving Lane, Smooth Tire by Test Date.

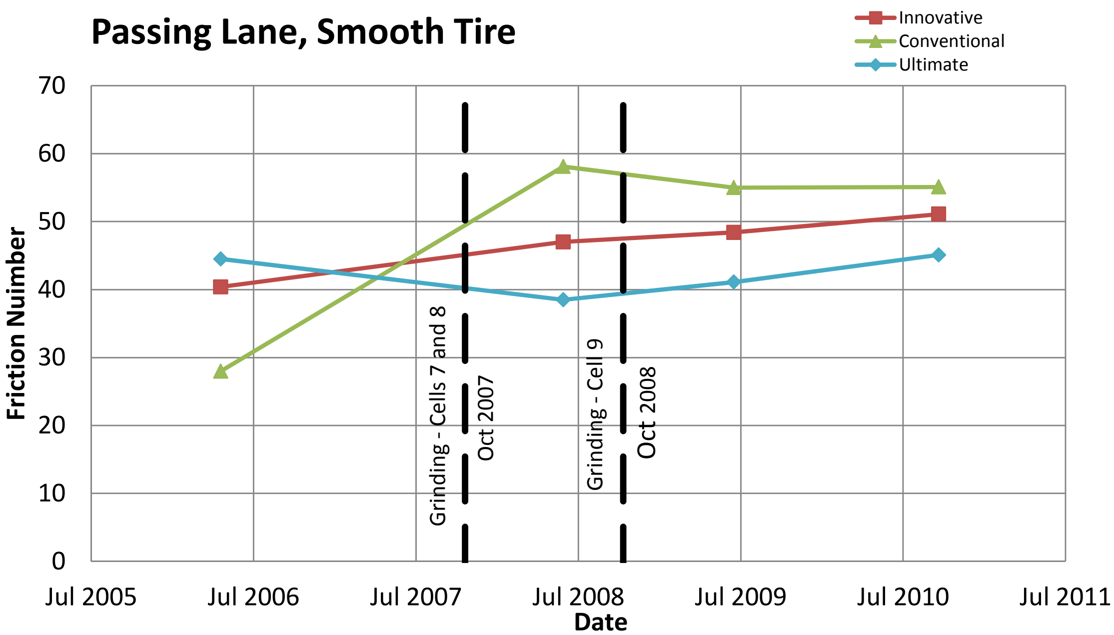

Figure 15. Friction Test – Passing Lane, Smooth Tire by Test Date.

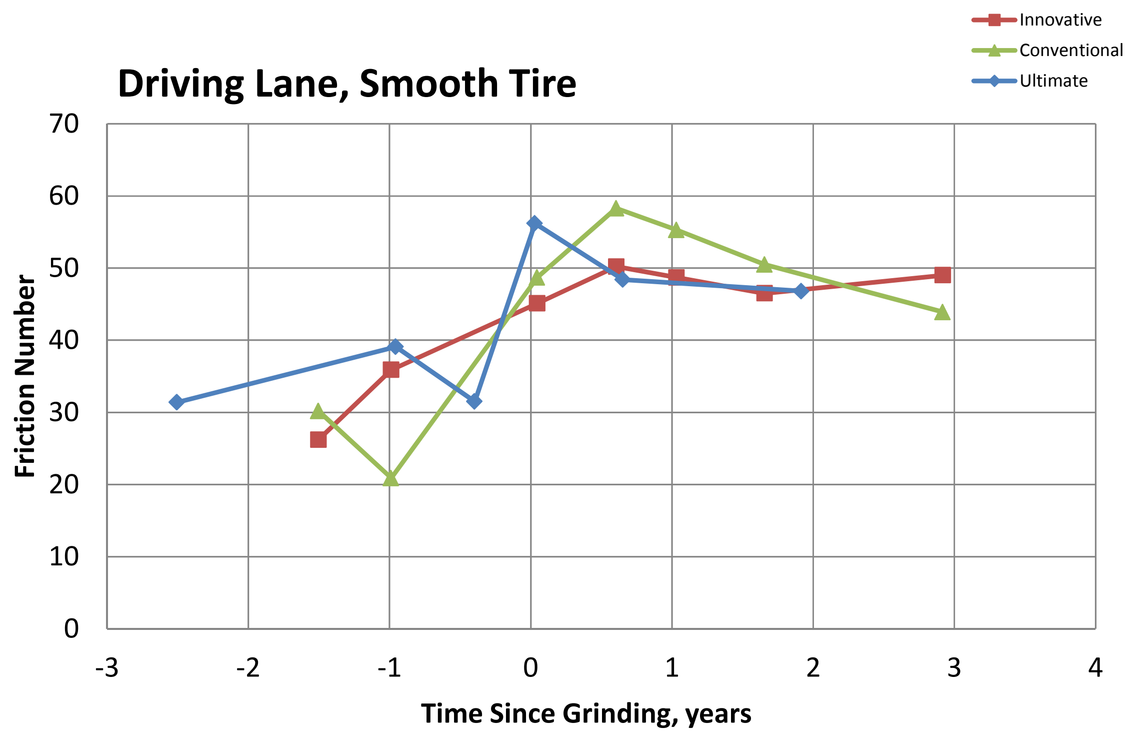

Figure 16. Friction Test – Driving Lane, Smooth Tire by Time Since Grinding.

Figure 17. Friction Test – Passing Lane, Smooth Tire by Time Since Grinding.

The results of these tests are not entirely conclusive, but a few points of interest can be noted. The first is that the friction characteristics for the NGCS surfaces were less than that of the conventional surface using the ribbed tire, and for some of the tests using the smooth tire. The intent of the ultimate grind surface is to increase the friction characteristics of the innovative grind surface. As of the most recent testing, the ultimate grind achieved a friction number that is almost FN 5.0 higher than the innovative surface using the ribbed tire in the passing lane, at the same age. In the driving lane, however, at the same age since grinding, the ultimate and innovative grind friction numbers are almost identical. Throughout the study period, the traffic volume has been intermittent on the MnROAD Mainline due to construction of new cells/maintenance etc. For this reason, future analysis will be done to compare friction characteristics with accumulated traffic on each surface.

Texture

The average texture depth was testing using the ASTM E 965 method. After the initial grinding of cells 7 and 8 the test shows that the average texture depth was much greater for the conventionally ground pavement. However, because the conventional grind has narrower fins, they are more easily broken and worn down. This causes the average texture depth from cell 8 to deteriorate much faster than for cell 7, although both seem to arrive at about the same texture measurement within about 2.5 years. The results of the texture testing are shown in Figure 18 through Figure 20.

Immediately after the cell 7 and 8 grinding in October 2007, the difference in the mean texture depth between the two cells was 0.57 mm on the driving lane. The difference in texture depth between the two cells from the most recent test (June 2010) was found to be only 0.02 mm.

As mentioned previously, the Ultimate grind was performed on cell 9 one year after the grinding of cells 7 and 8. As can be seen in Figure 18, the ultimate grind begins with a higher average texture depth than both the innovative and conventional grinds, and decreases more slowly than the conventional grind, to this point.

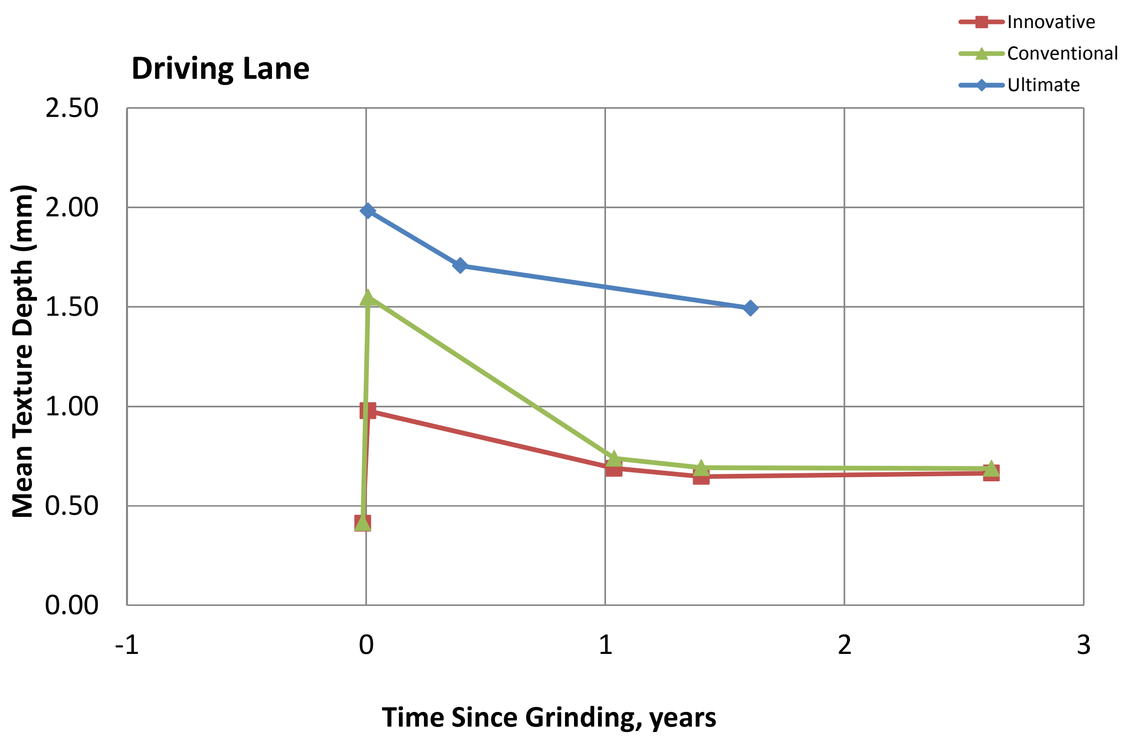

Figure 18. Average Texture Depth – Driving Lane.

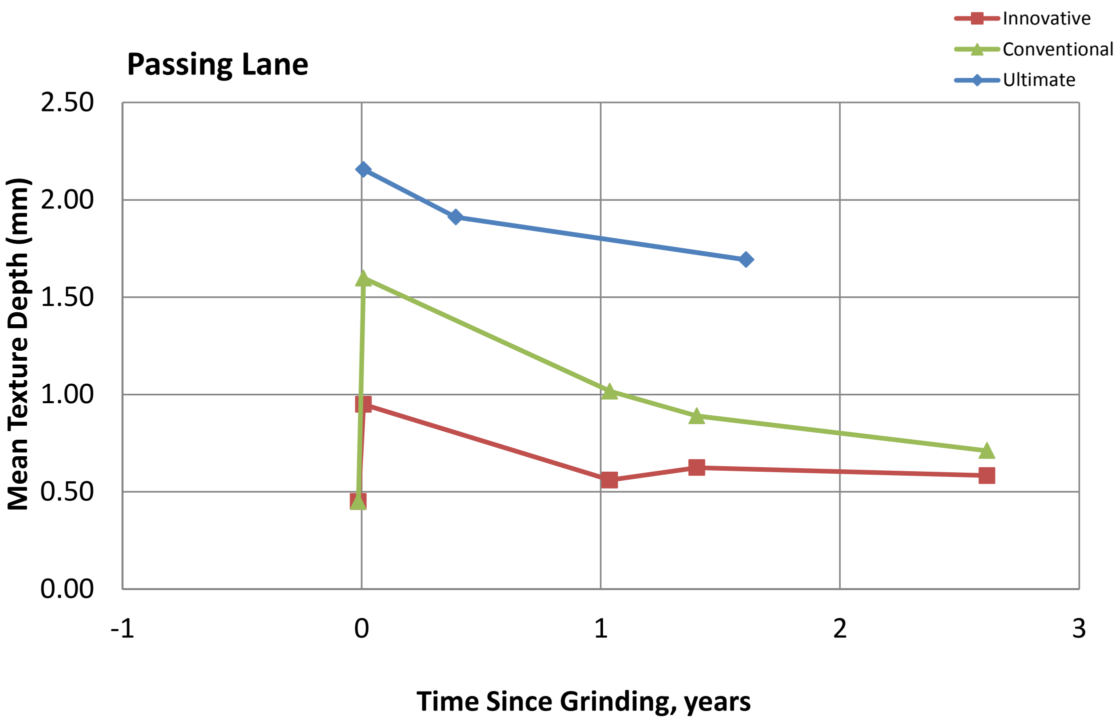

Figure 19. Average Texture Depth – Passing Lane.

In Figure 20 the trends for both the driving and passing lanes are plotted together. The solid line indicates the data from the driving lane and the dashed line indicates the data from the passing lane. The innovative and conventional grinds show the increase in texture depth due to the grinding (both were at about 0.45 mm). In the passing lane of the ultimate grind, where fewer vehicles have traveled, the MTD is greater by almost the same amount at each measurement, even though the overall measurements have decreased over time. With the other types of grind, the difference between the passing and driving lanes is more variable – in some cases they are at about the same measurement.

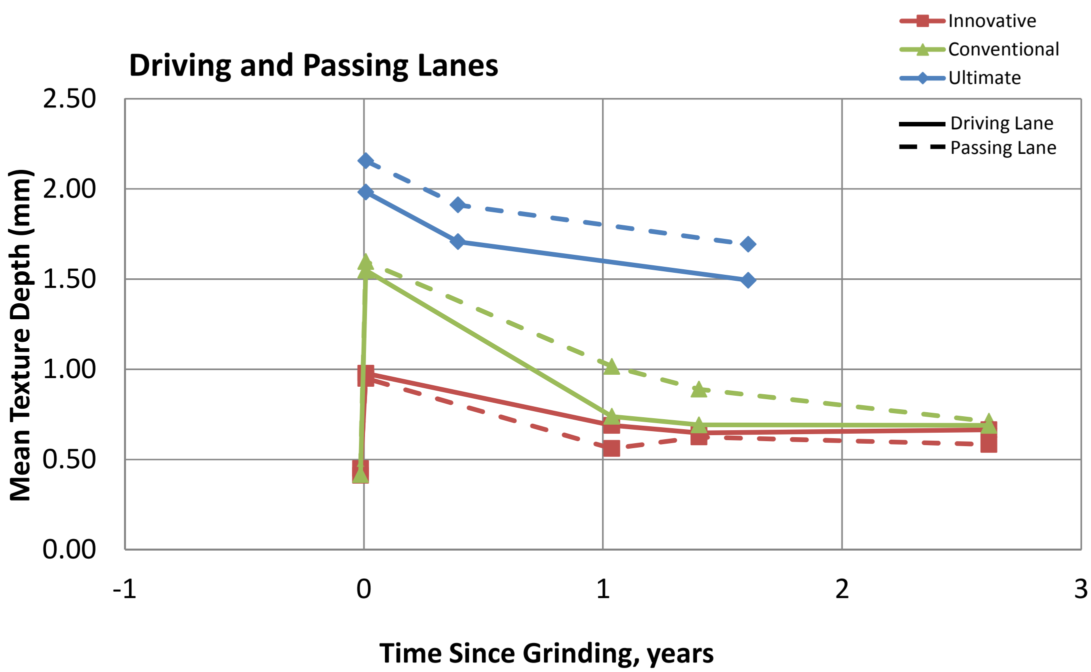

Figure 20. Average Texture Depth – Driving and Passing Lanes.

Ride Quality

Ride quality is measured using the AMES LISA Light weight profiling device. The International Roughness Index (IRI) was computed using the ProVAL software developed by the Federal Highway Administration. Although ride quality data is collected frequently at the MN Road Facility, additional data has not been obtained at this time. More ride data will be included in the next annual report.

As with the other surface characteristics, the ride quality data is presented in two ways – by date and by time since grinding. In general, the ride improved due to the grinding, on the innovative and conventional grind cells. They each decreased by almost 40 in/mi. While this is not necessarily due to the grinding, much of it might be attributed since the time between the measurements was only about six weeks, and it is unlikely that other factors contributed to a decrease in roughness.

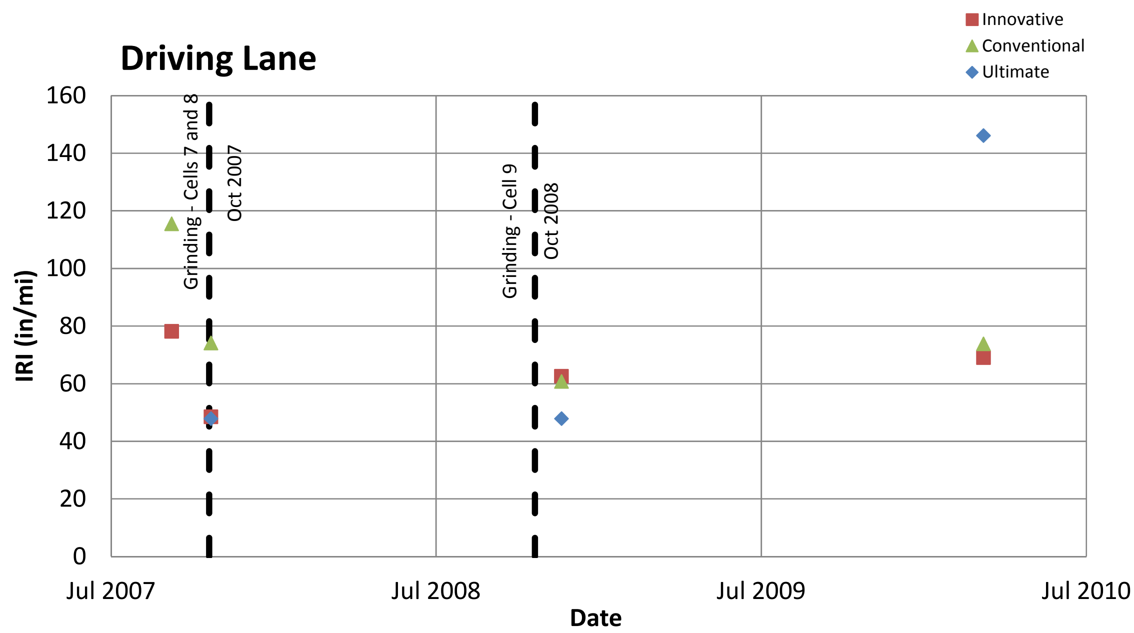

Figure 21. Ride Quality - Driving Lane by Test Date.

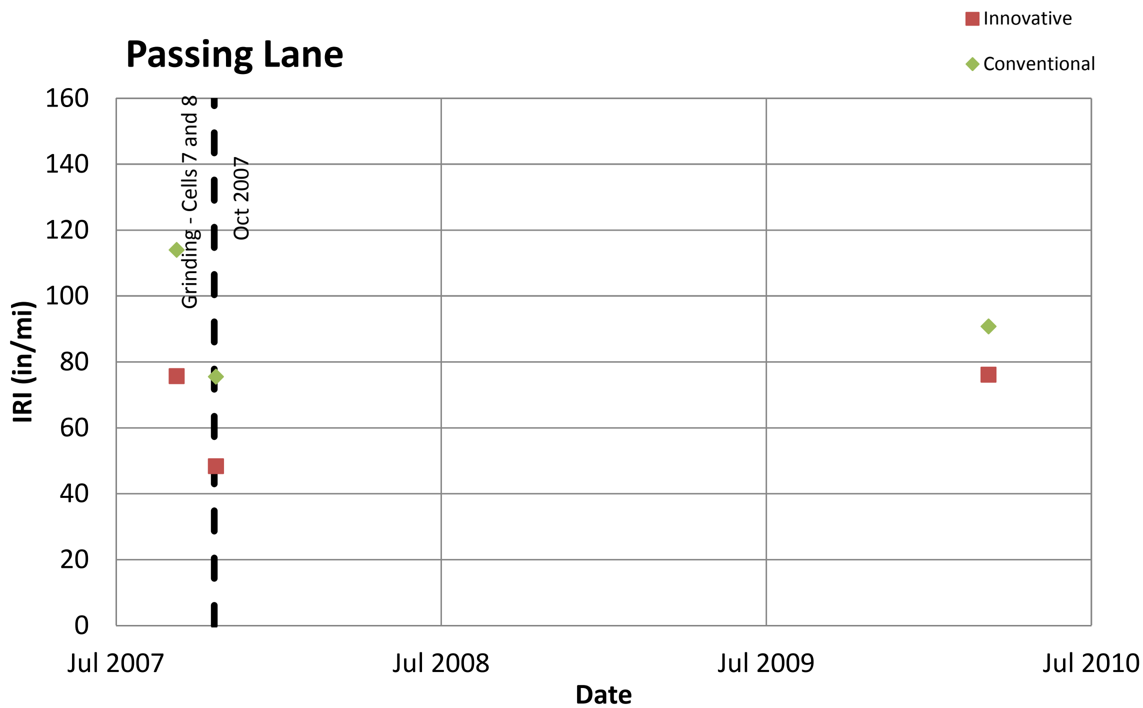

Figure 22. Ride Quality – Passing Lane by Test Date.

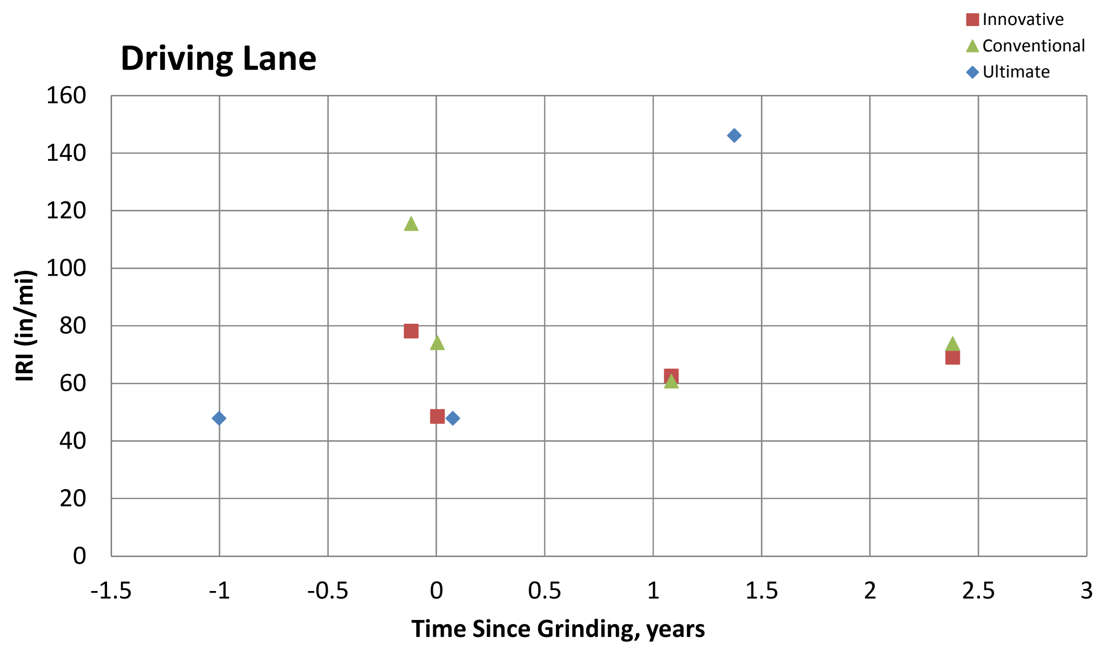

Figure 23. Ride Quality – Driving Lane by Time Since Grinding.

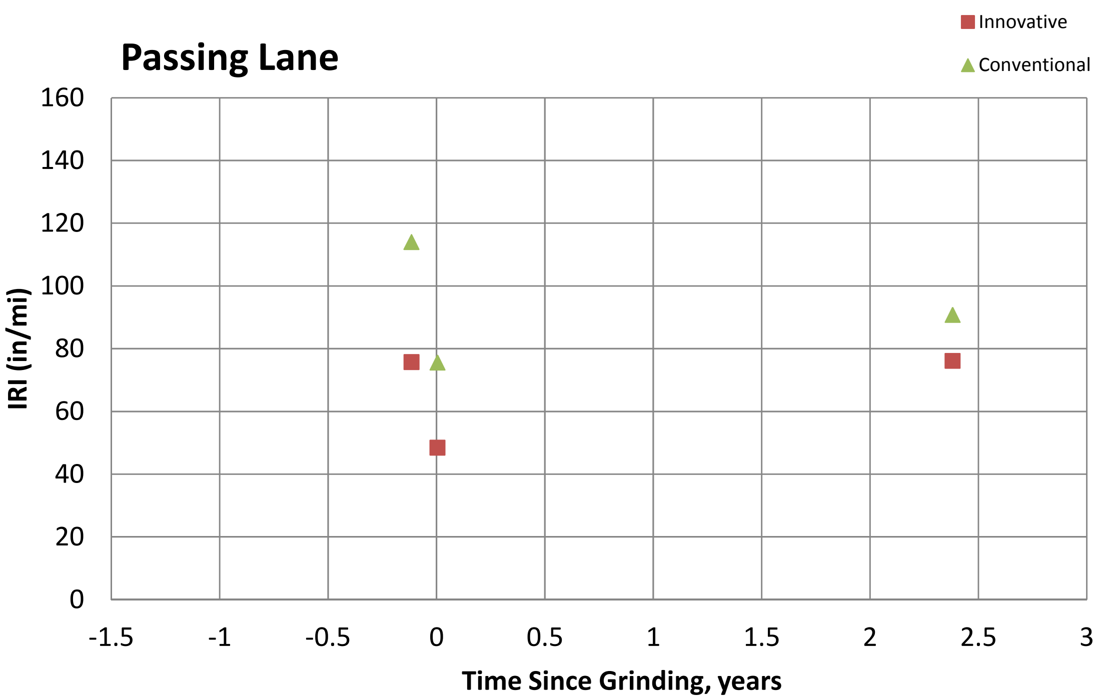

Figure 24. Ride Quality – Passing Lane by Time Since Grinding.

CONCLUSIONS

After such a short time since the grinding took place on each of the three MnROAD cells, it is difficult to draw specific conclusions regarding the effectiveness of the various grinding methodologies. As additional test results are conducted, and the data can be incorporated into the analyses above, and as additional analyses can be conducted, more detailed conclusions will be able to be drawn. One item that cause the testing interval to be interrupted during this time was an equipment malfunction and subsequent repairs that required a long period of time to complete.

In general, the following observations can be made, up to this point in the data collection effort, based on a three-year performance period for the conventional and innovative grinds, and two years for the ultimate grind.

- **Noise**
  The innovative grind has provided a quieter surface in almost all of the tests conducted since grinding. When compared by time since grinding, the innovative grind still exhibits quieter characteristics.

- **Friction**
  Over time, the conventional grind seems to retain its friction characteristics better than the innovative and ultimate grinds.

- Texture
  The ultimate grind resulted in a higher mean texture depth, which seems to be decreasing at a slower rate than the conventional grind and at about the same rate as that of the innovative grind.

- Ride
  Not enough data is available to draw conclusions or to make observations about the impact on ride quality.

APPENDIX A – TEST DATA SUMMARY

Inventory of Testing

Table 4. Inventory of Testing.

Inventory of Tests												
	Cell 7 (Innovative)				Cell 8 (Conventional)				Cell 9 (Ultimate)			
Date	OBSI	Friction	Ride	Texture	OBSI	Friction	Ride	Texture	OBSI	Friction	Ride	Texture
4/19/06		x				x				x		
10/24/06		x				x						
8/17/07	x				x							
9/8/07			x				x					
9/10/07									x			
10/15/07				x				x				
10/22/07	x		x		x		x		x		D	
10/23/07				x				x				
11/6/07		x				x				x		
4/2/08	x				x							
5/28/08		x				x				x		
10/25/08												x
10/31/08		x				x				x		
11/2/08				x				x				
11/19/08			D				D				D	
11/20/08	P				P				P			
12/5/08	D				D				D			
3/15/09				x				x				x
3/16/09	x				x				x			
6/16/09		x				x				x		
7/21/09	x				x				x			
9/15/09	x				x				x			
11/17/09	x				x				x			
3/8/10	x		x		x		x		x		x	
6/1/10				x				x				x
7/28/10	x				x				x			
9/17/10	x				x				x			
9/20/10		x				x				x		
11/17/10	x				x				x			

x = Test Completed D = Driving Lane Only P = Passing Lane Only

OBSI Testing

Table 5. OBSI Testing – Cell 7 (Innovative).

Innovative				
Cell 7				
Cell 7 Driving Lane				
Date/time	***temp (°F)***	***L. Edge***	***T. Edge***	***Average***
8/17/07 12:00 PM	71.4	-	-	101.9
10/22/07 1:18 PM	53.5	98.5	99.2	98.8
4/2/08 2:10 PM	40.4	99.9	100.6	100.3
12/5/08 11:18 AM	17.5	102.4	103.0	102.7
3/16/09 1:00 PM	58.6	100.9	101.4	101.1
7/21/09 12:16 PM	73.4	99.6	100.2	99.9
9/15/09 5:18 PM	80.7	98.0	98.9	98.5
11/17/09 1:29 PM	49.2	100.6	100.5	100.6
3/8/10 12:31 PM	36.2	101.3	101.1	101.2
7/28/10 2:12 PM	78.4	98.9	99.0	99.0
9/17/10 2:05 PM	64.1	100.0	100.0	100.0
11/17/10 10:59 AM	34.0	102.1	102.5	102.3
Cell 7 Passing Lane				
		no correction		
Date/time	***temp (°F)***	***L. Edge***	***T. Edge***	***Average***
8/17/07 12:00 PM	71.4	-	-	102.6
10/22/07 1:29 PM	53.7	98.4	99.3	98.9
4/2/08 2:47 PM	40.0	99.7	100.3	100.0
11/20/08 10:40 AM	21.3	102.1	102.5	102.3
3/16/09 12:29 PM	57.5	100.6	101.0	100.9
7/21/09 12:43 PM	74.1	98.5	99.3	98.9
9/15/09 4:39 PM	81.4	97.6	98.6	98.1
11/17/09 1:55 PM	49.6	99.6	99.4	99.5
3/8/10 10:57 AM	35.5	100.4	100.1	100.3
7/28/10 1:32 PM	77.7	98.8	99.2	99.0
9/17/10 2:15 PM	64.1	100.2	100.5	100.3
11/17/10 11:08 AM	34.0	101.9	102.4	102.2

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Table 6. OBSI Testing – Cell 8 (Conventional).

Conventional				
Cell 8				
Cell 8 Driving Lane				
Date/time	***temp (°F)***	***L. Edge***	***T. Edge***	***Average***
8/17/07 12:00 PM	71.4	-	-	100.8
10/22/07 1:18 PM	53.5	103.8	102.8	103.3
4/2/08 2:10 PM	40.4	102.0	101.8	101.9
12/5/08 11:18 AM	17.5	103.9	103.9	103.9
3/16/09 1:00 PM	58.6	102.3	102.1	102.2
7/21/09 12:16 PM	73.4	101.1	101.0	101.1
9/15/09 5:18 PM	80.7	100.5	100.2	100.3
11/17/09 1:29 PM	49.2	102.3	102.0	102.2
3/8/10 12:31 PM	36.2	102.8	102.4	102.6
7/28/10 2:12 PM	78.4	101.1	101.1	101.1
9/17/10 2:05 PM	64.1	103.2	102.8	103.0
11/17/10 10:59 AM	34.0	104.3	104.5	104.4
Cell 8 Passing Lane				
		no correction		
Date/time	***temp (°F)***	***L. Edge***	***T. Edge***	***Average***
8/17/07 12:00 PM	71.4	-	-	101.7
10/22/07 1:29 PM	53.7	103.7	102.8	103.3
4/2/08 2:47 PM	40.0	102.6	102.4	102.5
11/20/08 10:40 AM	21.3	104.5	104.8	104.6
3/16/09 12:29 PM	57.5	102.9	102.9	102.9
7/21/09 12:43 PM	74.1	101.8	101.2	101.5
9/15/09 4:39 PM	81.4	101.4	101.1	101.3
11/17/09 1:55 PM	49.6	102.9	102.5	102.7
3/8/10 10:57 AM	35.5	103.4	103.3	103.4
7/28/10 1:32 PM	77.7	101.4	101.2	101.3
9/17/10 2:15 PM	64.1	103.8	103.4	103.6
11/17/10 11:08 AM	34.0	104.5	104.8	104.7

Table 7. OBSI Testing – Cell 9 (Ultimate).

Ultimate				
Cell 9				
Cell 9 Driving Lane				
Date/time	***temp (°F)***	***L. Edge***	***T. Edge***	***Average***
9/10/07	52.9	103.3	102.7	103.0
12/5/08	17.5	101.3	102.1	101.7
3/16/09	58.6	101.0	101.4	101.2
7/21/09	73.4	100.0	100.3	100.2
9/15/09	80.7	98.8	99.1	99.0
11/17/09	49.2	101.2	101.3	101.2
3/8/10	36.2	102.4	102.3	102.4
7/28/10	78.4	99.9	100.0	100.0
9/17/10	64.1	101.8	101.9	101.8
11/17/10	34.0	103.3	103.6	103.4

Cell 9 Passing Lane				
		no correction		
Date/time	***temp (°F)***	***L. Edge***	***T. Edge***	***Average***
9/10/07	52.9	103.3	102.7	103.0
11/20/08	21.3	102.3	102.8	102.6
3/16/09	57.5	101.4	101.9	101.7
7/21/09	74.1	99.9	100.4	100.2
9/15/09	81.4	99.0	99.1	99.1
11/17/09	49.6	101.0	100.9	101.0
3/8/10	35.5	102.0	101.9	101.9
7/28/10	77.7	99.9	99.8	99.9
9/17/10	64.1	102.3	102.2	102.2
11/17/10	34.0	103.4	103.9	103.6

Friction

Table 8. Friction Testing – Driving Lane Ribbed Tire.

	Driving Lane Ribbed Tire												
	Cell	**Lane**	**Date**	**Time**	**FN**	**Peak**	**Speed (mph)**	**Air Temp (F)**	**Pvmt Temp (F)**	**Tire Type**	**Min FN**	**Max FN**	**Slip**
Cell 7	Innovative	Driving	4/19/2006	11:08 AM	55.7	82.81	40.4	59		Ribbed	51	60	16
		Driving	10/24/2006	12:00 AM	59.5	78.6	40	42	62.8	Ribbed	0	0	0
		Driving	11/6/2007	10:10 AM	46.1	65.67	40.8	37	45.7	Ribbed	44	48	8
		Driving	5/28/2008	11:15 AM	44.7	66.87	40.4	66	99.3	Ribbed	42	47	16
		Driving	10/31/2008	10:47 AM	45.1	68.54	41.4	68	70.3	Ribbed	43	47	13
		Driving	6/16/2009	11:23 AM	44.6	60.17	40.2	68	93.5	Ribbed	42	48	15
		Driving	9/20/2010	11:24 AM	41.9	67.95	40.1	55	64.4	Ribbed	38	44	12
Cell 8	Conventional	Driving	4/19/2006	11:08 AM	60.7	81.89	40.5	59		Ribbed	55	66	17
		Driving	10/24/2006	12:00 AM	48	64.14	40.3	42	61.7	Ribbed	0	0	0
		Driving	11/6/2007	10:10 AM	55.4	81.24	40.4	36	45.4	Ribbed	52	58	14
		Driving	5/28/2008	11:14 AM	57.75	86.7	40.05	65.5	98.75	Ribbed	54	61	10.5
		Driving	10/31/2008	10:46 AM	54	82.2	41.3	68	69.8	Ribbed	52	56	9
		Driving	6/16/2009	11:23 AM	48.9	75.99	40.3	68	93.2	Ribbed	45	52	18
		Driving	9/20/2010	11:23 AM	48.8	67.2	39.8	55	63.9	Ribbed	44	54	13
Cell 9	Ultimate	Driving	4/19/2006	11:08 AM	66	92.83	40.3	60		Ribbed	62	71	12
		Driving	11/6/2007	10:10 AM	49.9	79.21	40.9	37	46.9	Ribbed	46	53	15
		Driving	5/28/2008	11:14 AM	56.25	84.785	39.55	65.5	101.7	Ribbed	51	60	14.5
		Driving	10/31/2008	10:46 AM	48.2	76.29	40.4	68	69.1	Ribbed	43	54	12
		Driving	6/16/2009	11:23 AM	45.3	65.76	40.9	68	92.2	Ribbed	43	48	12
		Driving	9/20/2010	11:23 AM	45.2	64.39	40.4	55	63.2	Ribbed	43	47	14

Table 9. Friction Testing – Driving Lane Smooth Tire.

	Driving Lane - Smooth Tire												
	Cell	**Lane**	**Date**	**Time**	**FN**	**Peak**	**Speed (mph)**	**Air Temp (F)**	**Pvmt Temp (F)**	**Tire Type**	**Min FN**	**Max FN**	**Slip**
Cell 7	Innovative	Driving	4/19/2006	11:32 AM	26.2	45.26	40.5	60		Smooth	23	30	13
		Driving	10/24/2006	12:00 AM	35.9	51.97	40.2	43	63	Smooth	0	0	0
		Driving	11/6/2007	10:27 AM	45.1	63.08	40.7	37	46.9	Smooth	41	48	21
		Driving	5/28/2008	11:21 AM	50.2	72.7	42.2	65	96.5	Smooth	45	54	11
		Driving	10/31/2008	11:10 AM	48.7	79.46	39.8	68	67.8	Smooth	42	53	13
		Driving	6/16/2009	11:40 AM	46.5	69.86	40.5	68	88	Smooth	42	54	11
		Driving	9/20/2010	11:40 AM	49	79.27	39.9	55	64.4	Smooth	45	53	10
Cell 8	Conventional	Driving	4/19/2006	11:32 AM	30.2	37.58	40.5	61		Smooth	23	42	6
		Driving	10/24/2006	12:00 AM	20.9	28.87	40.6	43	61	Smooth	0	0	0
		Driving	11/6/2007	10:27 AM	48.7	75.74	40.3	37	45.9	Smooth	44	53	9
		Driving	5/28/2008	11:20 AM	58.3	99.28	41.7	65	92.4	Smooth	52	64	8
		Driving	10/31/2008	11:09 AM	55.3	94.17	40.2	68	68.6	Smooth	50	60	9
		Driving	6/16/2009	11:40 AM	50.5	81.54	40.6	68	88.8	Smooth	44	55	14
		Driving	9/20/2010	11:39 AM	43.9	73	40	55	63.4	Smooth	37	47	10
Cell 9	Ultimate	Driving	4/19/2006	11:32 AM	31.4	54.87	40.5	61		Smooth	26	37	27
		Driving	11/6/2007	10:27 AM	39.1	46.77	40.8	36	47.4	Smooth	34	45	4
		Driving	5/28/2008	11:20 AM	31.5	45.645	41.7	65	96.75	Smooth	21.5	43	15
		Driving	10/31/2008	11:09 AM	56.2	86.88	40.3	68	68.3	Smooth	51	60	9
		Driving	6/16/2009	11:40 AM	48.4	69.55	40.2	68	86.8	Smooth	45	51	7
		Driving	9/20/2010	11:39 AM	46.8	68.06	40	55	63.2	Smooth	44	49	8

Table 10. Friction Testing – Passing Lane Ribbed Tire.

	Passing Lane - Ribbed Tire												
	Cell	***Lane***	***Date***	***Time***	***FN***	***Peak***	***Speed (mph)***	***Air Temp (F)***	***Pvmt Temp (F)***	***Tire Type***	***Min FN***	***Max FN***	***Slip***
Cell7	Innovative	Passing	4/19/2006	11:49 AM	57.5	81.56	40.4	60		Ribbed	53	60	15
		Passing	10/24/2006	12:00 AM	59.4	75.81	40	45	64	Ribbed	0	0	0
		Passing	11/6/2007	10:48 AM	46.2	70.7	40.6	37	48.7	Ribbed	41	49	9
		Passing	5/28/2008	11:37 AM	43.8	66.05	40.7	65	100.9	Ribbed	41	46	13
		Passing	6/16/2009	10:12 AM	41.5	63.1	40.4	68	89.1	Ribbed	37	44	11
		Passing	9/20/2010	12:00 PM	46.7	72.28	40.6	55	66.1	Ribbed	42	50	14
Cell 8	Conventional	Passing	4/19/2006	11:48 AM	52.6	80.73	40	61		Ribbed	47	60	14
		Passing	10/24/2006	12:00 AM	47	68.09	40.1	44	63.3	Ribbed	0	0	0
		Passing	11/6/2007	10:48 AM	55.7	82.84	40.3	37	48.2	Ribbed	50	61	9
		Passing	5/28/2008	11:37 AM	56.6	83.925	40.25	66	98.6	Ribbed	52.5	60.5	14.5
		Passing	6/16/2009	10:12 AM	49.7	75.27	39.7	68	88.8	Ribbed	46	53	13
		Passing	9/20/2010	12:00 PM	54	73.77	40.3	55	65.9	Ribbed	50	57	12
Cell 9	Ultimate	Passing	4/19/2006	11:48 AM	54.2	78.43	40.5	62		Ribbed	48	60	24
		Passing	11/6/2007	10:48 AM	52.9	75.1	41.2	37	48.6	Ribbed	48	57	18
		Passing	5/28/2008	11:37 AM	53.7	82.545	39.9	67	104.6	Ribbed	50	58	13
		Passing	6/16/2009	10:12 AM	36.3	49.73	40.9	68	87.8	Ribbed	34	40	9
		Passing	9/20/2010	12:00 PM	46.2	62.85	40.5	55	65.4	Ribbed	42	49	19

Table 11. Friction Testing – Passing Lane Smooth Tire.

	Passing Lane - Smooth Tire												
	Cell	***Lane***	***Date***	***Time***	***FN***	***Peak***	***Speed (mph)***	***Air Temp (F)***	***Pvmt Temp (F)***	***Tire Type***	***Min FN***	***Max FN***	***Slip***
Cell 7	Innovative	Passing	4/19/2006	12:10 PM	40.4	78.95	40.2	62		Smooth	30	55	21
		Passing	5/28/2008	11:43 AM	47	71.28	40.7	65	97.7	Smooth	43	52	9
		Passing	6/16/2009	10:29 AM	48.4	72.24	40.3	68	90.8	Smooth	43	52	9
		Passing	9/20/2010	12:15 PM	51.1	74.76	40.3	55	64.4	Smooth	45	54	13
Cell 8	Conventio	Passing	4/19/2006	12:09 PM	28	81.77	39.9	62		Smooth	17	49	10
		Passing	5/28/2008	11:43 AM	58.1	106.195	40.2	66	98.0	Smooth	52	65	10
		Passing	6/16/2009	10:28 AM	55	90.97	39.7	68	89.3	Smooth	50	62	9
		Passing	9/20/2010	12:15 PM	55.1	79.41	39.7	55	64.6	Smooth	50	62	12
Cell 9	Ultimate	Passing	4/19/2006	12:09 PM	44.5	81.27	40.4	62		Smooth	36	57	7
		Passing	5/28/2008	11:43 AM	38.5	59.065	40.3	66	102.3	Smooth	28	52	24
		Passing	6/16/2009	10:28 AM	41.1	56.19	40.4	68	91.3	Smooth	36	46	12
		Passing	9/20/2010	12:15 PM	45.1	63.55	40.4	55	64.2	Smooth	43	48	12

Texture Depth

Table 12. Average Texture Depth.

		Date	MTD Passing Lane (mm)	MTD Driving Lane (mm)
Cell 7	Innovative	10/15/2007	0.45	0.41
		10/23/2007	0.95	0.98
		11/2/2008	0.56	0.69
		3/15/2009	0.62	0.65
		6/1/2010	0.58	0.67
Cell 8	Conventional	10/15/2007	0.45	0.41
		10/23/2007	1.60	1.55
		11/2/2008	1.02	0.74
		3/15/2009	0.89	0.69
		6/1/2010	0.71	0.69
Cell 9	Ultimate	10/25/2008	2.16	1.98
		3/15/2009	1.91	1.71
		6/1/2010	1.69	1.49