PCC SURFACE CHARACTERISTICS
MNROAD STUDIES
DATA ANALYSIS

Year 3 Annual Report

Task 4: Submit Annual Reports

Dr. W. James Wilde, P.E.
Minnesota State University, Mankato
Center for Transportation Research and Implementation

July 2012

This is the third and final annual report describing the data analysis and the performance of various methods of diamond grinding on Cells 7, 8, 9 and 71 at the MnROAD pavement testing facility near Albertville, Minnesota. The purpose of this study is to analyze the long term performance of different diamond grinding patterns ground on Portland Cement Concrete Pavement. Cells 7 and 9 are Next Generation Concrete Surface grinds (NGCS) and Cell 8 is a conventionally ground surface. Cells 7 and 8 were ground in October 2007, Cell 9 was ground in October 2008, and Cell 71 is another iteration of the ultimate grind, which was conducted in May 2010. Cell 12 is used as a control section, since it has not been ground, and has its original transverse tined surface texture. Cell 12 was originally constructed in 1992.

The data collection for this project was conducted by MnDOT, with data analysis and reporting conducted by the research staff at the Center for Transportation Research and Implementation at Minnesota State University, Mankato. For this third annual report, data is included through the spring of 2012. This report describes the data that has been collected and the dates and times of its collection, since the beginning of the project.

In addition, a summary of the trend analysis of the data using the Mann-Kendall Trend Test is introduced to determine the probability of a trend existing over time. This is described in detail in the next section. The information in Table 1 summarizes the test data available to the research project, conducted by MnDOT since the grinding on the test cells.

Trend Analysis

The Kendall family of trend tests were developed to identify correlations between ranked data. In Kendall's 1962 introduction to this type of analysis (1), an example is used comparing the mathematical and musical ability in children. If the children are arranged by mathematical ability, is there a similar trend in the musical ability? While this is similar to correlation analysis, it can also be applied to time-series data where the primary rank is based on time or age of a sample, and comparisons can be made within the ranking of the specific variable in question (noise, friction, etc.). The Mann-Kendall test is a non-parametric test used to identify trends in time-series data. This method has been used to identify trends in concentration levels of trichloroethylene in wells over time by the Corps of Engineers (2) and for other environmental measurements by the US Geological Survey (3). The remainder of this section presents a summary of the Mann-Kendall test for identifying trends in the surface characteristics in the diamond grinding cells at MnROAD. The results of the analyses are presented in the individual characteristics sections.

The initial assumption is that there is no trend in the data, such that the Mann-Kendall statistic (S) is equal to 0. The data are ordered in a time series, as the data was collected over the past several years. For each value in the series, if a value from a later time period is greater than itself, S is incremented by 1. If a value from a later time period is less than the value in question, the test statistic is decremented by 1. The result of all the increments and decrements is the final value of S.

Table 1. Dates and Types of Testing Conducted.

Testing Date	Characteristics Measured			
	Noise	**Friction**	**Texture**	**Ride**
17 Aug 2007	X			
8-10 Sep 2007	X			X
15 Oct 2007			X	
22-23 Oct 2007	X		X	X
21 Nov 2007		X		X
28 Mar 2008				X
2 Apr 2008	X			
28 May 2008		X		
25 Oct 2008			X	
31 Oct 2008		X		
2 Nov 2008			X	
19-20 Nov 2008	X			X
5 Dec 2008	X			
15-16 Mar 2009	X		X	
27 April 2009				X
16 Jun 2009		X		
21 Jul 2009	X			
15 Sep 2009	X			
28 Oct 2009				X
17 Nov 2009	X			
8 Mar 2010	X			X
8 Apr 2010				X
1 Jun 2010			X	
28 Jul 2010	X			
17 Sep 2010	X			
17-20 Sep 2010	X	X		
12 Oct 2010				X
20 Oct 2010			X	
17 Nov 2010	X			
15-16 Mar 2011	X			X
14 Apr 2011		X		
24-28 Jun 2011	X		X	X
20-29 Sep 2011	X	X		X
27 Oct - 1 Nov 2011			X	
19 Mar 2012				X
24-25 Apr 2012	X	X		
8 Jun 2012		X		

This process of adding or subtracting 1 from the test statistic proceeds beginning with comparing the first value to all subsequent values, and then moving on to the second value and comparing it with all subsequent values. This process is conducted for all values that have been collected until the second to last value, which is only compared to the final value. The mathematical representation for the computation of S is shown below.

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{(x_i - x_j)}{|(x_i - x_j)|} \quad \text{only where } x_i \neq x_j$$

where:

x = value in the time series, and
n = number of values in the time series.

As described above, if $x_i - x_j > 0$ then S is incremented by 1, and if $x_i - x_j < 0$ then S is decremented by 1. In the case where $x_i - x_j = 0$, S is unchanged, but an adjustment must be made to the significance test for the presence of the tied data, described below.

The test for significance involves the standard normal distribution and the variance of the data based on the number of samples and adjusted for the number and magnitude of tied values in the data set. The variance (σ^2) of the data is computed as follows.

$$\sigma^2 = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{t=1}^{g} t_t (t_t - 1)(2t_t + 5) \right]$$

where:

g = the number of tied groups in the data set, and
t_t = the number of tied data points in group g.

The normalized test statistic (z) is computed as 0 when S = 0, and

$$z = \frac{S-1}{\sigma} \quad \text{for S > 0 and}$$

$$z = \frac{S+1}{\sigma} \quad \text{for S < 0.}$$

The level of significance is chosen to indicate the likelihood of a trend existing in the data. Often this is chosen at 95%. In the following sections, however, the test for significance is not conducted (comparing the probability of the test statistic to the associated level of significance). Instead, the probability of the existence of a trend is left in the tables to indicate the probability of a trend existing (either upward or downward, as will be shown in the example below).

There are several assumptions inherent in this type of analysis. The first assumption is that there are at least 10 data points in the set of values. Kendall indicates that this is necessary in order to use the standard normal distribution for comparison of the test statistic, but also provides a table of values to use in cases where $n < 10$. Another assumption is that the data in a time series are taken at equal intervals. While this is not precisely the case in the MnROAD surface characteristics data, there are many data points in a short period of time, and these can be approximated to a relatively common data collection interval.

An example of this method is shown in the tables and discussion below, for the friction data on Cell 7, Passing Lane, with the Smooth Tire. For the first reading, 47, each subsequent data point is higher than itself, and thus each cell below the 47 receives a ‘1’ value. Comparing the third reading, 51, to each subsequent reading shows that one is greater (56, thus increment by 1), one is lower (50, thus decrement by 1) and the final reading is a tie (thus the 0 entry, and the adjustment for ties required in the variance equation).

Date	Friction, FN
5/28/2008	47
6/16/2009	48
9/20/2010	51
4/14/2011	56
9/29/2011	50
4/24/2012	51

Friction, FN	47	48	51	56	50	51
47						
48	1					
51	1	1				
56	1	1	1			
50	1	1	-1	-1		
51	1	1	0	-1	1	

The S statistic is 8 (the sum of all -1, 0, and 1 values in the table). Since there is one set of duplicate values (two 51 values) this must be considered in the variance calculation.

The variance, σ^2, is 27.3, as shown below, with n = 6, g = 1, and t_t = 2.

$$\sigma^2 = \frac{1}{18}\left[6(6-1)(2(6)+5)-2(2-1)(2(2)+5)\right] = 27.3$$

$$z = \frac{S-1}{\sigma} = \frac{8-1}{\sqrt{27.3}} = 1.34$$

The standard normal distribution statistic for this variance is 1.34, representing a probability of 94%, or only a 6% chance that this data **does not** represent a trend.

With this analysis, data that do not represent a trend have a probability statistic near 50%. Data trending upward have a probability above 90% or 95% (depending on the level of significance selected), and data trending downward have a probability below 10% or 5%, again depending on the significance level selected. A summary of the trend analysis for all data categories is presented in the next section.

Once a set of data is identified as representing a trend, a decision must be made about the type of trend, and if the data can be simulated with a regression model. Further, if a regression model is possible, the type of relationship over time or traffic must be selected. Regression models for the data representing upward or downward trends are discussed in the final report.

Summary of Trend Analyses

This section is a summary of the analyses using the Mann-Kendall statistic for identifying trends in data. While a short summary is provided here, more detailed information is included in each subsequent section. The final column (on the right side of each table below) provides the trend indicator (whether the data are trending upward, downward, or if no trend can be concluded). The trend indication is based on the 10% criteria (anything above 90% confidence indicates an upward trend, and anything below 10% indicates a downward trend).

The noise trend analysis is shown in Table 2. It can be seen that the noise measured in Cells 7, 8, and 9 show strong upward trends, in both the driving and the passing lanes, since they were ground, and that Cells 12 and 71 do not show enough evidence to indicate a trend in noise changes. The differences between the control cell (Cell 12) and the others, shown in Table 3. As would be indicated from the previous figure, the deviations from the measurements at Cell 12 indicate strong trends in almost all data sets except Cell 71 and the driving lane of Cell 7.

Table 2. Analysis of Trends in OBSI.

Analysis	Number of Observations (after grinding)	Probability of Trend	Probability (Corrected for small N)	Trend (Upward or Downward)
Cell 7 DL	15	97.6%		Up
Cell 7 PL	15	99.5%		Up
Cell 8 DL	15	99.4%		Up
Cell 8 PL	15	93.3%		Up
Cell 9 DL	13	99.6%		Up
Cell 9 PL	13	98.4%		Up
Cell 12 DL	9	89.5%	89.0%	None
Cell 12 PL	10	35.8%		None
Cell 71 DL	7	72.8%	71.9%	None
Cell 71 PL	7	61.9%	61.4%	None

Table 3. Analysis of Trends in OBSI – Deviation from Control Cell.

Analysis	Number of Observations (after grinding)	Probability of Trend	Probability (Corrected for small N)	Trend (Upward or Downward)
Cell 12 – Cell 7 DL	8	19.1%	19.9%	None
Cell 12 – Cell 7 PL	9	3.0%	3.0%	Down
Cell 12 – Cell 8 DL	8	3.1%	3.1%	Down
Cell 12 – Cell 8 PL	9	3.0%	3.0%	Down
Cell 12 – Cell 9 DL	8	1.3%	1.3%	Down
Cell 12 – Cell 9 PL	9	0.6%	0.6%	Down
Cell 12 – Cell 71 DL	6	12.6%	13.6%	None
Cell 12 – Cell 71 PL	6	34.8%	36.0%	None

Since the time the cells were ground, with regard to friction, there is less consistency in the trend analysis. For example, there are four sets of data for Cell 7 (driving and passing lanes, ribbed and smooth tires) and three different outcomes. The driving lane with the ribbed tire indicates a downward trend, but the passing lane with the ribbed tire indicates no trend. Also, the driving lane with the smooth tire indicates no trend, while the passing lane with smooth tire indicates an upward trend (opposite of the driving lane with ribbed tire). Cell 8 seems the most consistent, with three downward trends, and the fourth close to the 10% cutoff to indicate a downward trend. Cell 9 is the most consistent without any sets indicating a trend. It might be expected that after so many years of traffic, Cell 12 would not display a trend in either direction, and for the most part, it does not, but seems to lean toward the downward (decreasing friction) trend. If anything, this would be the expected direction.

Table 4. Analysis of Trends in Friction.

Analysis	**Number of Observations (after grinding)**	**Probability of Trend**	**Probability (Corrected for small N)**	**Trend (Upward or Downward)**
Cell 7 DL, Ribbed Tire	9	2.1%	1.9%	Down
Cell 7 DL, Smooth Tire	9	45.8%	46.0%	None
Cell 7 PL, Ribbed Tire	7	61.9%	61.5%	None
Cell 7 PL, Smooth Tire	6	93.7%	93.5%	Up
Cell 8 DL, Ribbed Tire	9	0.2%	0.1%	Down
Cell 8 DL, Smooth Tire	9	2.1%	1.9%	Down
Cell 8 PL, Ribbed Tire	7	6.7%	6.8%	Down
Cell 8 PL, Smooth Tire	6	12.6%	13.2%	None
Cell 9 DL, Ribbed Tire	7	18.1%	18.8%	None
Cell 9 DL, Smooth Tire	7	18.1%	18.8%	None
Cell 9 PL, Ribbed Tire	5	59.7%	59.2%	None
Cell 9 PL, Smooth Tire	5	76.9%	76.8%	None
Cell 12 DL, Ribbed Tire	6	4.3%	4.6%	Down
Cell 12 DL, Smooth Tire	6	13.0%	13.6%	None
Cell 12 PL, Ribbed Tire	4	36.7%	37.5%	None
Cell 12 PL, Smooth Tire	4	15.4%	16.7%	None
Cell 71 DL, Ribbed Tire	5	10.3%	11.0%	None
Cell 71 DL, Smooth Tire	5	1.4%	0.8%	Down
Cell 71 PL, Ribbed Tire	4	36.7%	37.5%	None
Cell 71 PL, Smooth Tire	4	15.4%	16.7%	None

Texture, based on the figures presented later in this report, seems to be flat at a certain value for each method of grinding. Based on the information in Table 5, both lanes in Cell 9 and the passing lane of Cell 8 indicate a downward trend in texture, since the time of grinding. The other five data sets do not show these indications.

Table 5. Analysis of Trends in Texture.

Analysis	**Number of Observations (after grinding)**	**Probability of Trend**	**Probability (Corrected for small N)**	**Trend (Upward or Downward)**
Cell 7 DL	4	13.9%	15.2%	None
Cell 7 PL	4	32.7%	33.5%	None
Cell 8 DL	5	20.3%	21.4%	None
Cell 8 PL	5	1.4%	0.8%	Down
Cell 9 DL	4	3.5%	3.2%	Down
Cell 9 PL	4	4.5%	4.2%	Down
Cell 71 DL	4	64.1%	63.3%	None
Cell 71 PL	4	13.9%	15.2%	None

The ride data seems less variable overall, with the exception of Cell 9. This data seem suspect, however, and the cause for dramatically increasing ride data on Cell 9 may be related to the nature of the grinding.

However, Cell 71 was ground in the same way, and does not show the same trends. The passing lanes of Cell 8 and of Cell 71 both indicate a slight downward trend.

Table 6. Analysis of Trends in Ride.

Analysis	**Number of Observations (after grinding)**	**Probability of Trend**	**Probability (Corrected for small N)**	**Trend (Upward or Downward)**
Cell 7 DL	13	42.7%		None
Cell 7 PL	13	19.6%		None
Cell 8 DL	13	17.9%		None
Cell 8 PL	12	5.7%		Down
Cell 9 DL	7	96.4%	96.5%	Up
Cell 9 PL	8	98.3%	98.5%	Up
Cell 12 DL	13	66.6%		None
Cell 12 PL	10	26.3%		None
Cell 71 DL	4	50.0%	62.5%	None
Cell 71 PL	5	8.8%	9.5%	Down

Noise

The method of noise testing was described in the previous two annual reports. This section is devoted to an update of the noise data and the trend analysis described above. As the previous annual report indicated, the temperature correction for the noise measurements was implemented, and all of the results shown in this report are the corrected values.

Cell 9 was ground in October of 2008, approximately 1 year after Cells 7 and 8. Cell 71 was ground about 1½ years after Cell 9 (May 2010). Figures 1 and 2 show the OBSI noise level measurements for the driving lane and passing lane of all four of the grinding cells as well as the control cell (Cell 12).

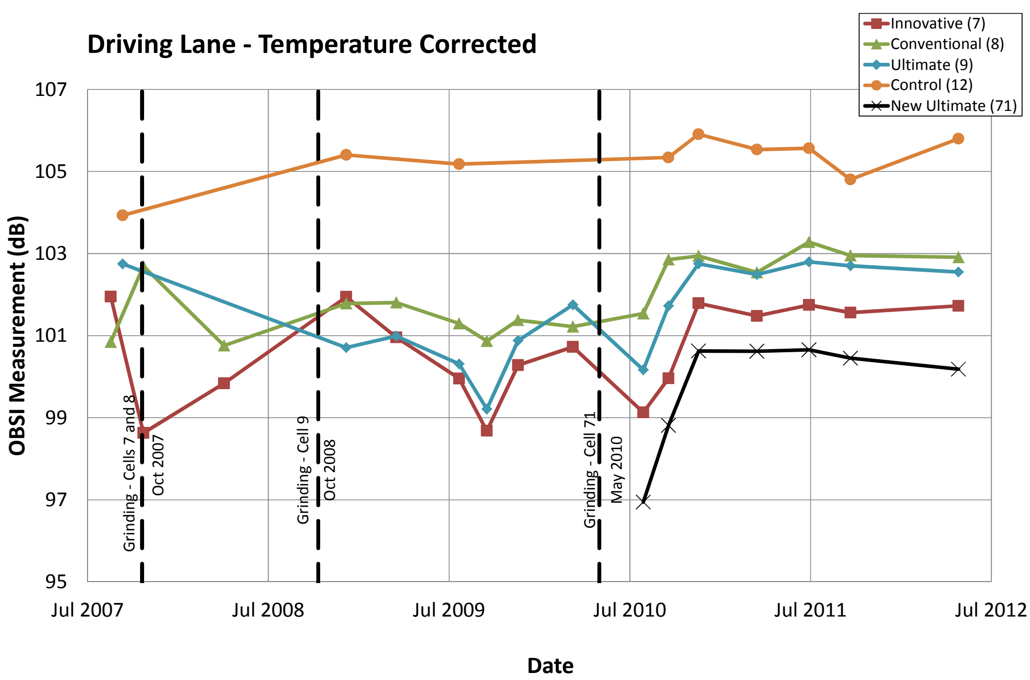

Figure 1. OBSI Measurements – Driving Lane – Preliminary Temperature Correction.

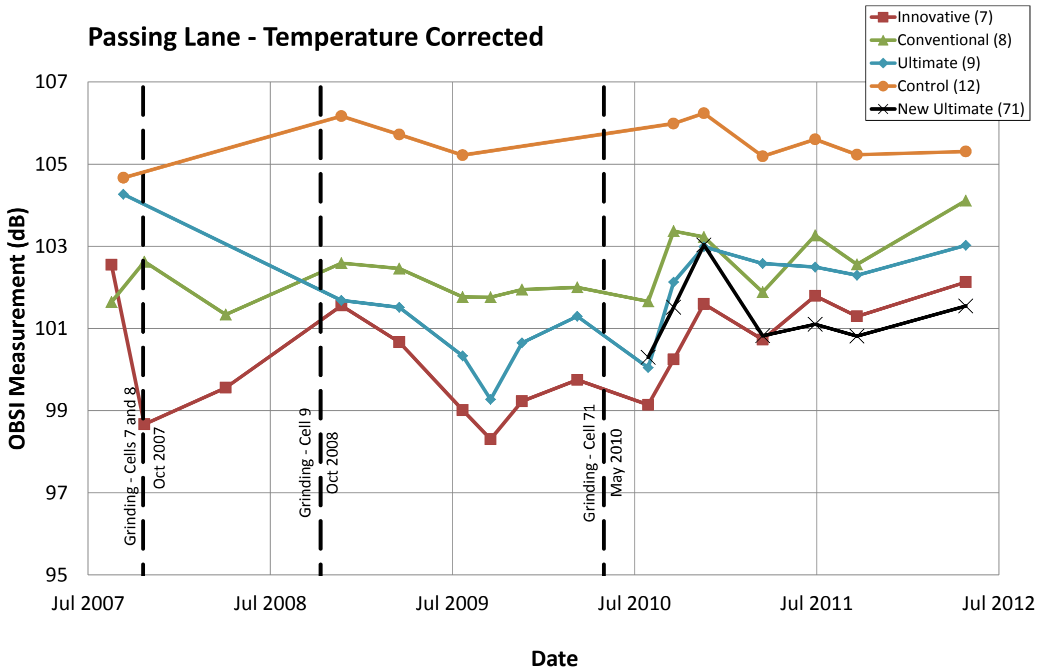

Figure 2. OBSI Measurements – Passing Lane – Preliminary Temperature Correction

No OBSI testing was conducted immediately prior to the grinding of Cell 9, so the immediate effects on noise levels are not known.

The figures below show a comparison of noise data between the grinding cells and the control cell (Cell 12). Cell 12 is a useful comparison since it has not shown much change in OBSI measurements over the four years of data collection during this project, as seen in Figures 1 and 2 and in the trend analysis in Table 2. The comparisons in Figure 3 reflect the variations in the measured data from the previous figures. It can be seen in Figure 3 that after the initial year or two after grinding the difference in noise levels between each of them and the control cell has been decreasing, with the exception of the most recent data point. In fact, the increase seen between July 2011 and July 2012 is due to an increase in the noise measurement in the driving lane of Cell 12 in September 2011 more than a decrease in noise in the other cells.

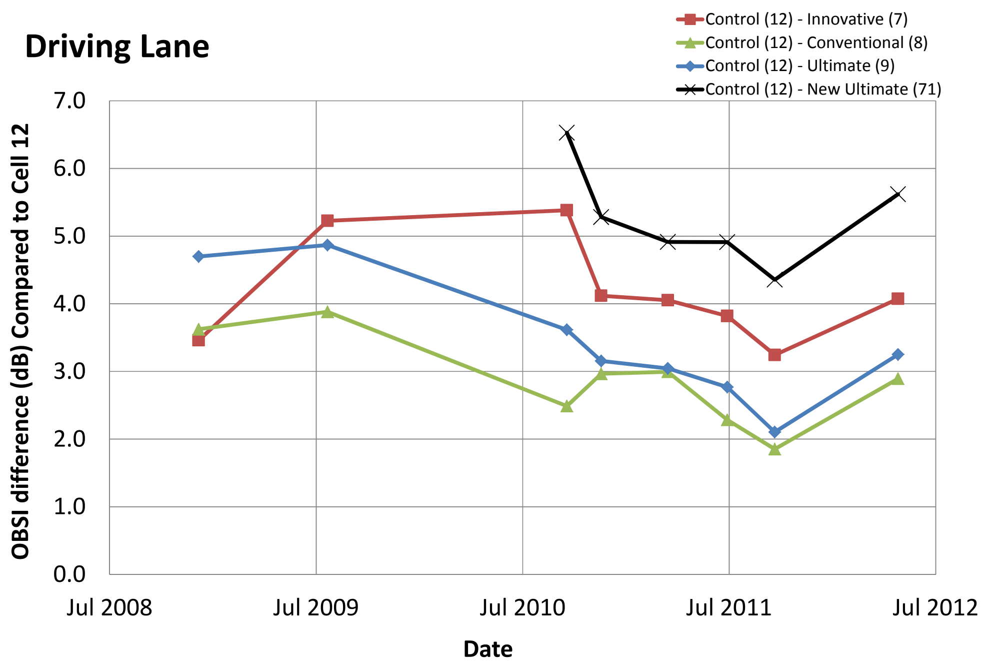

Figure 3. Difference in OBSI Measurements – Driving Lane, Grinding Cells Compared to Control.

The passing lane does not show the same decrease in September 2011, as seen in Figure 4. In fact, the decrease in the comparison in this figure are all related to increases in noise on cells 7, 8, 9, and 71, with a relatively flat (0.1 dB increase) in noise in Cell 12.

One other important method of comparison is to observe the differences in noise by the time since the grinding was conducted on each cell. As described in the previous annual report, 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 within a few days of the same age on Cells 7 and 8. The comparison of noise measurements based on time since grinding in the driving and passing lanes are shown in Figures 5 and 6, respectively.

An observation that is readily noticed in the driving lane figure is that the innovative and ultimate grinds started at about 5 dB quieter than the control cell, whereas the conventional grind started at just over 1 dB quieter. This may be an effect of the variation in the noise measurement, however, since at about one year after grinding all four cells were about 3.5 to 5.0 dB quieter than the control section. After about two years post-grind, however, the conventional and ultimate grinds seem to remain about 2.5 to 3.0 dB quieter than the control. Similarly, the innovative grind seems to have remained at about 4.0 dB quieter than the control since about three years post-grind. There is still not adequate data to make specific determinations about these trends, however.

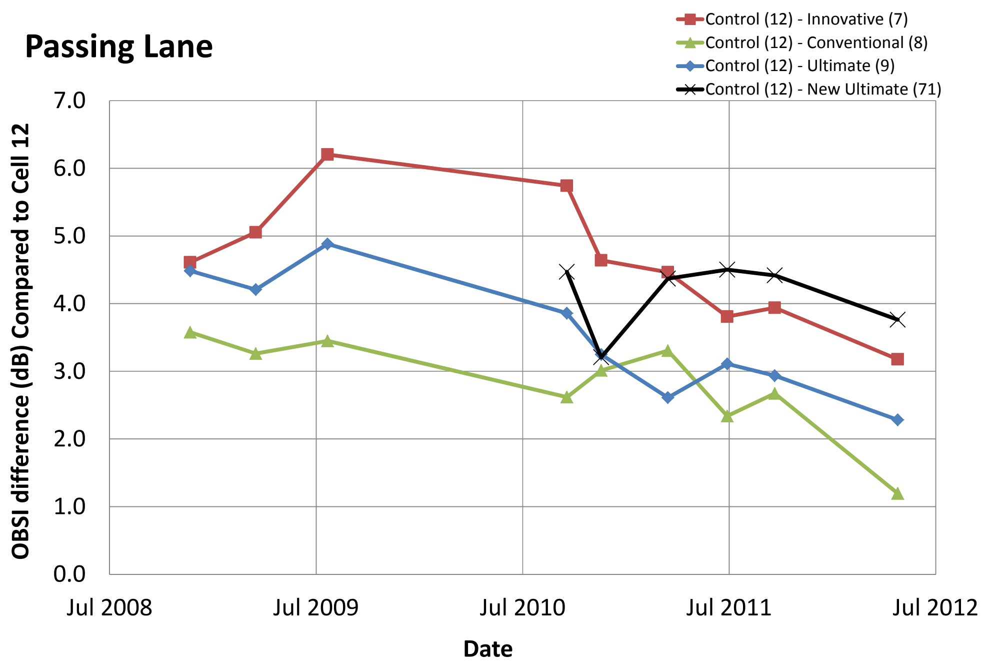

Figure 4. Difference in OBSI Measurements – Passing Lane, Grinding Cells Compared to Control.

Another difficulty in comparing the graphs of noise trends is that even with the temperature corrections discussed in the 2nd annual report, there are some obvious seasonal variations that are not corrected. These can be seen in all of the previous figures in this section. The next two figures show the same noise graphs but shifted to place them at equivalent times since the grinding operation. The comparisons should be more clear in this manner, but this does not seem to be the case. It is clear, however, that plotting the noise measurements by time since grinding seems to be more appropriate for the passing lane than for the grinding lane.

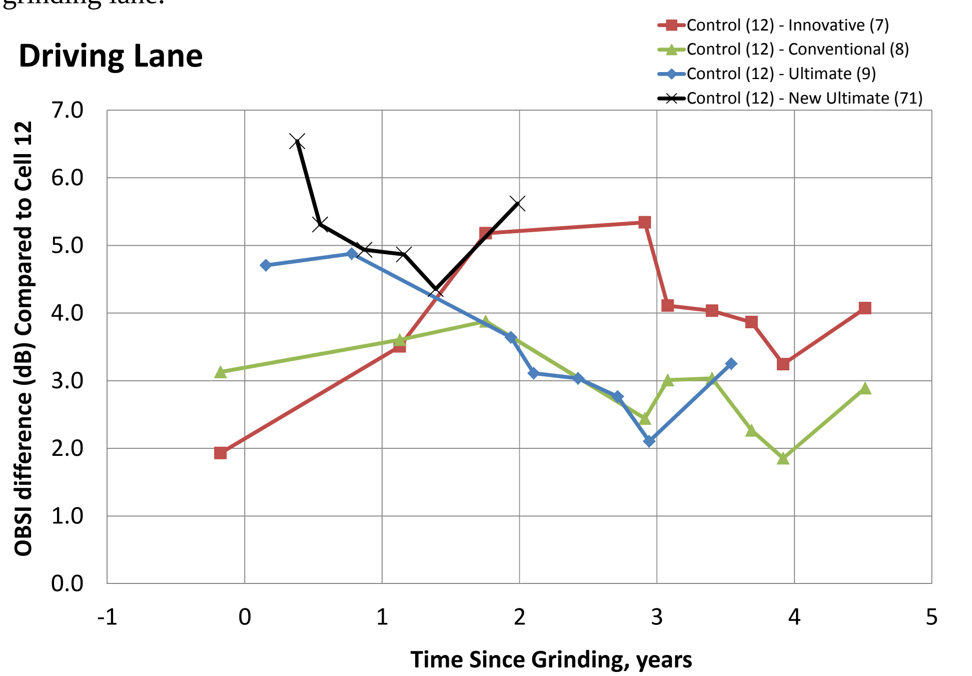

Figure 5. Difference in OBSI Measurements by Time Since Grinding – Driving Lane.

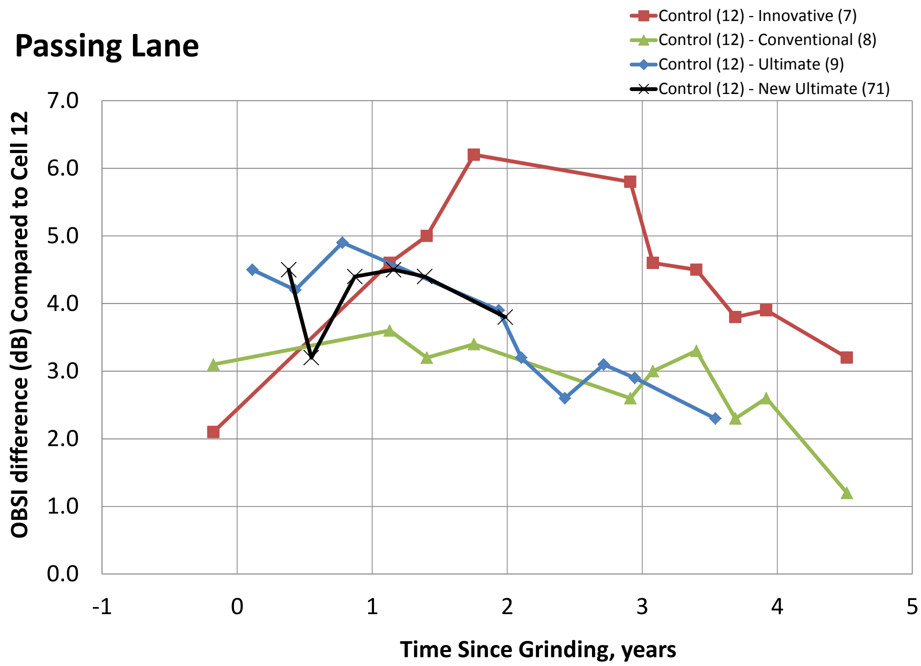

Figure 6. Difference in OBSI Measurements by Time Since Grinding – Passing Lane.

Friction

The purpose of friction testing is to compare how the performance of the 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 Figures 7 through 10. The same results for the smooth tire testing are shown in Figures 11 through 14. Only one additional set of friction testing was conducted since the last annual report, thus the many of the conclusions will remain the same.

After Cells 7 and 8 were ground, it appears that the friction on Cell 8 (conventional) increased while the friction of Cell 7 (conventional) decreased between the first and second test dates. 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. 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 friction on the conventional grind decreased at approximately a constant rate for about a year, and then has remained mostly constant at a friction number of 50 since July 2009. The innovative grind has had a relatively constant friction number of about 45 since it was ground. The ultimate grind surface has similarly remained at about 45 to 50 since grinding.

For the driving lane and ribbed tire, the friction of the control cell is very similar to the other cells – with friction numbers around 45 to 50. In the passing lane, the control and conventional grind are slightly higher in friction number, but only by about 5 or 6 points. The innovative and conventional grinds are almost identical, at about FN of 49.

With the smooth tire, the control cell shows a significantly lower FN than all of the grinding cells (in the driving lane) and only slightly less in the passing lane. This seems reasonable, since the driving lane will have had much more traffic than the passing lane over time.

The friction performance can be compared perhaps more appropriately by comparing the surfaces with respect to the elapsed time since they were ground, instead of by date. Figures 9 and 10 are made up of the same friction data as Figures 7 and 8, but are shown in terms of the age, or time since grinding. Essentially, the ultimate grind data are offset so that it can be directly compared to the others which were ground one year earlier.

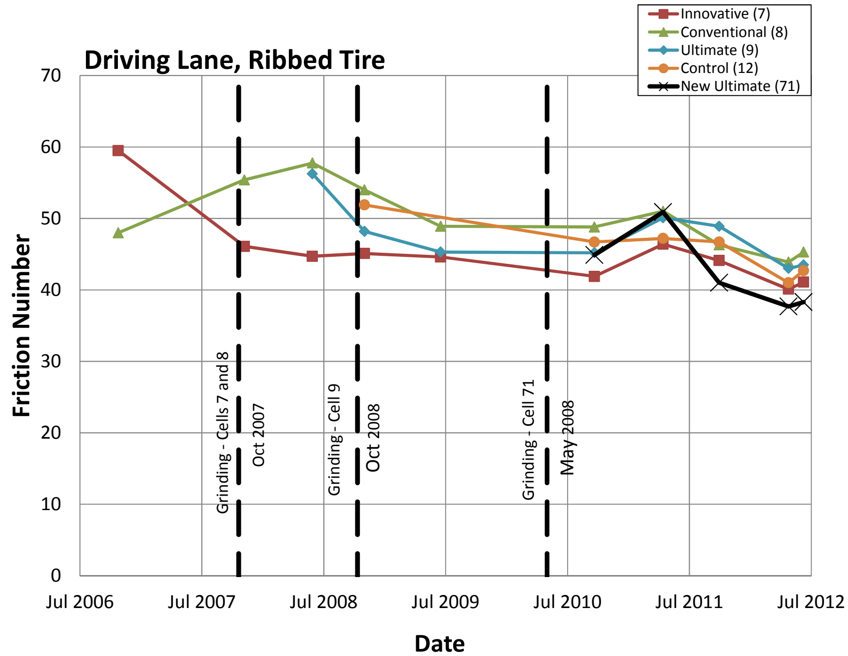

Figure 7. Friction Test – Driving Lane, Ribbed Tire by Test Date.

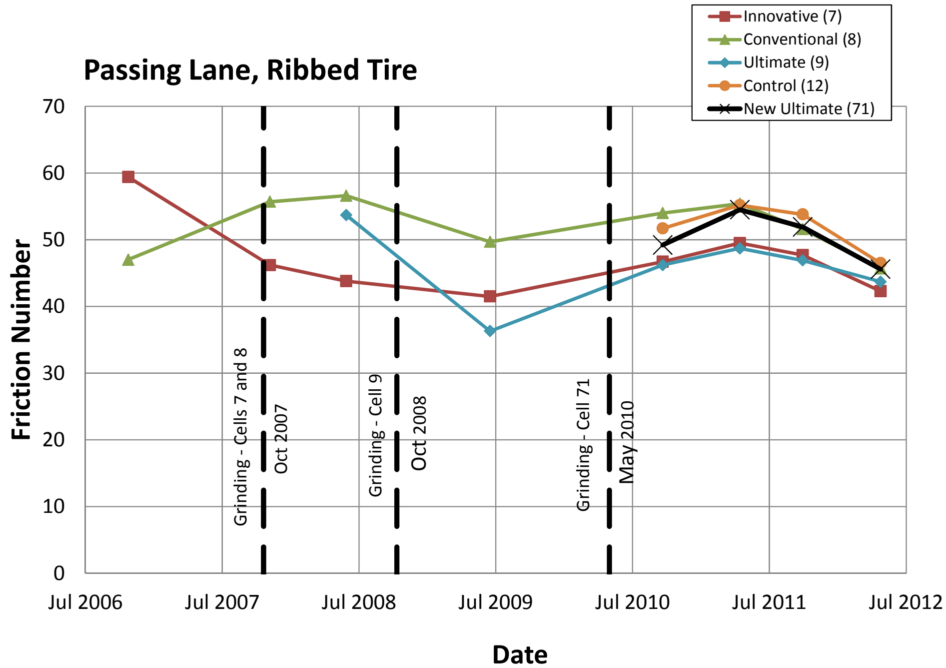

Figure 8. Friction Test – Passing Lane, Ribbed Tire by Test Date.

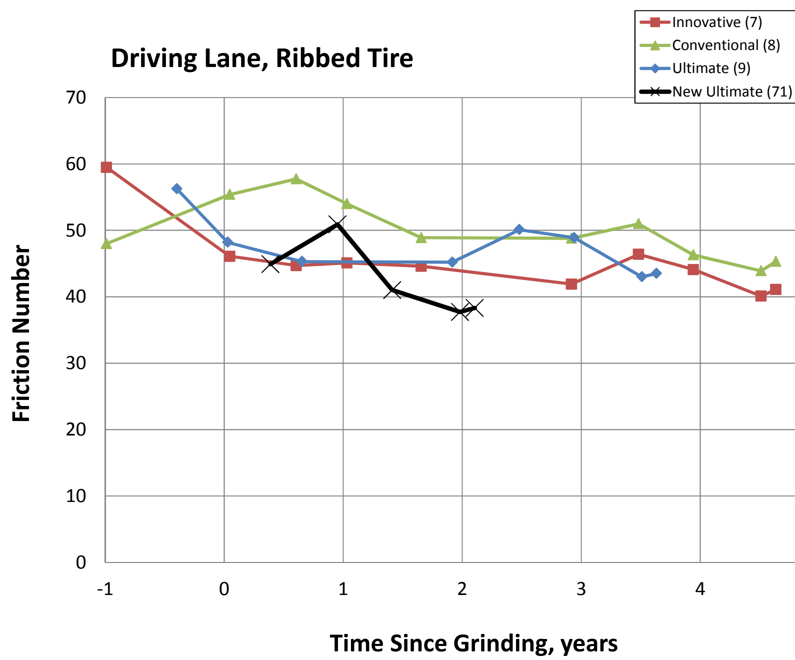

Figure 9. Friction – Driving Lane, Ribbed Tire by Time Since Grinding.

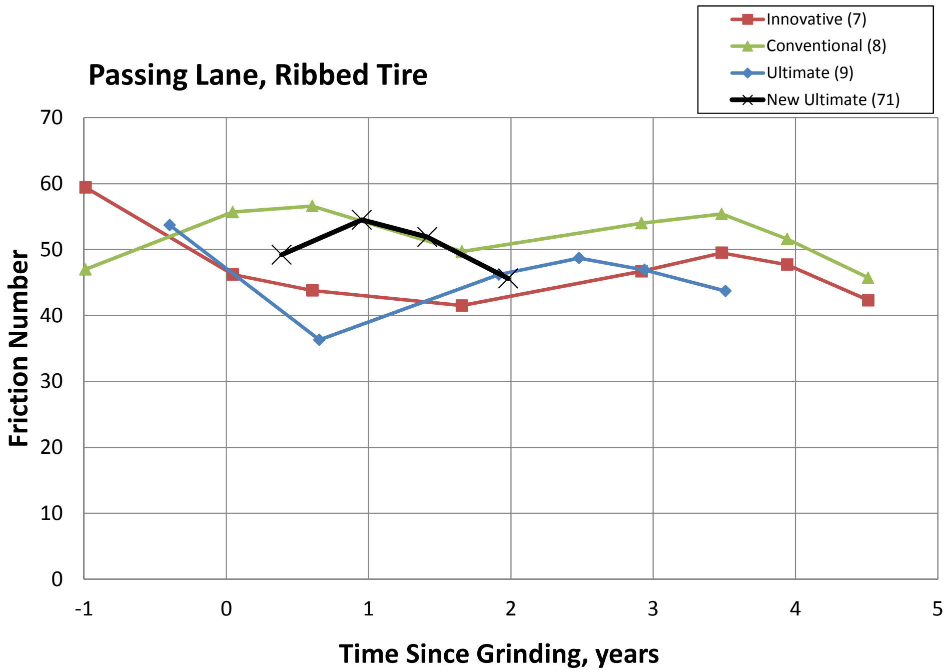

Figure 10. Friction – Passing Lane, Ribbed Tire by Time Since Grinding.

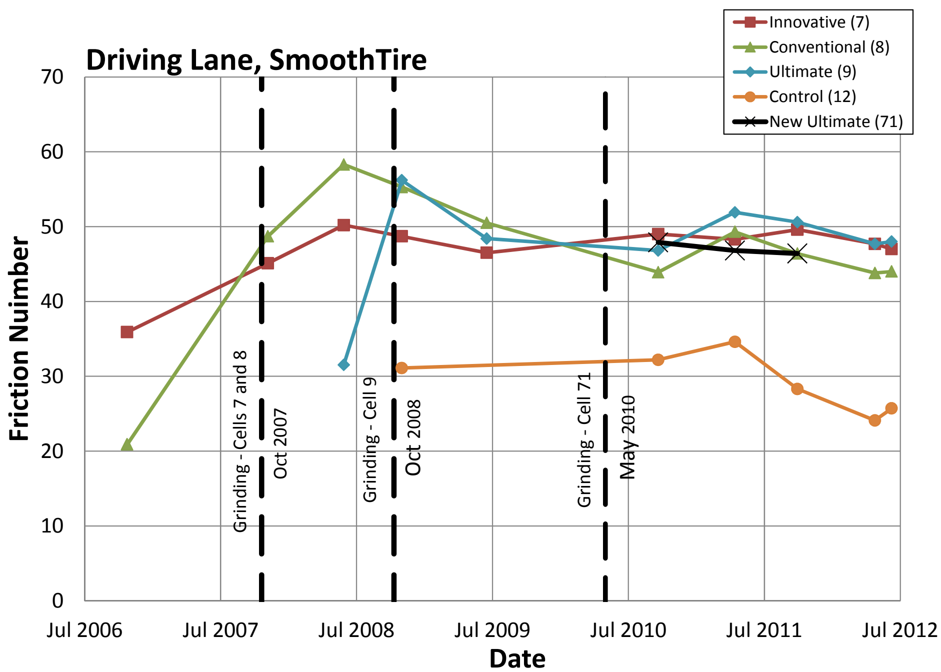

Figure 11. Friction Test – Driving Lane, Smooth Tire by Test Date.

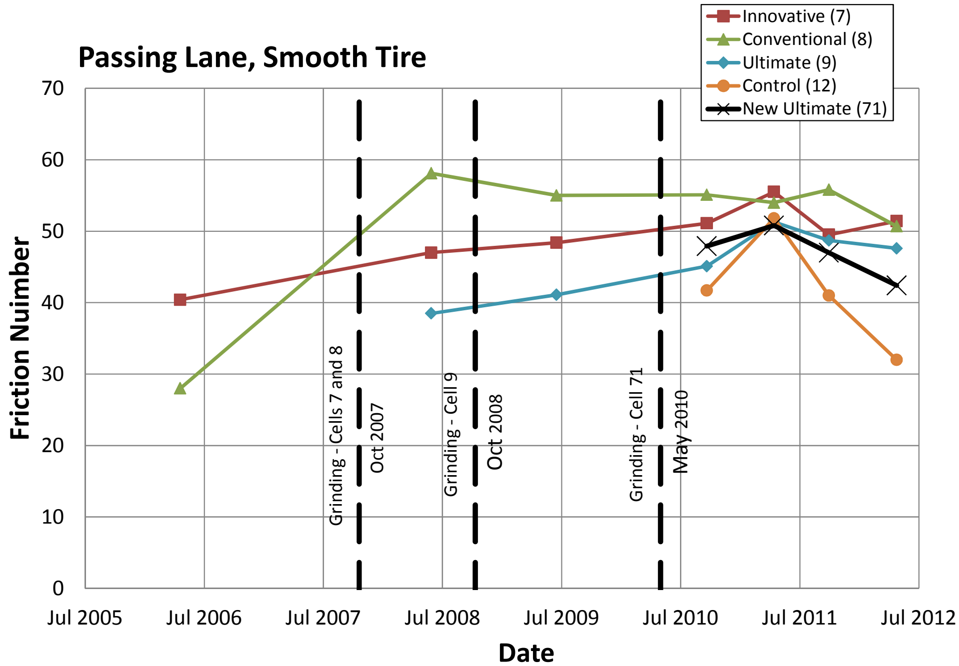

Figure 12. Friction Test – Passing Lane, Smooth Tire by Test Date.

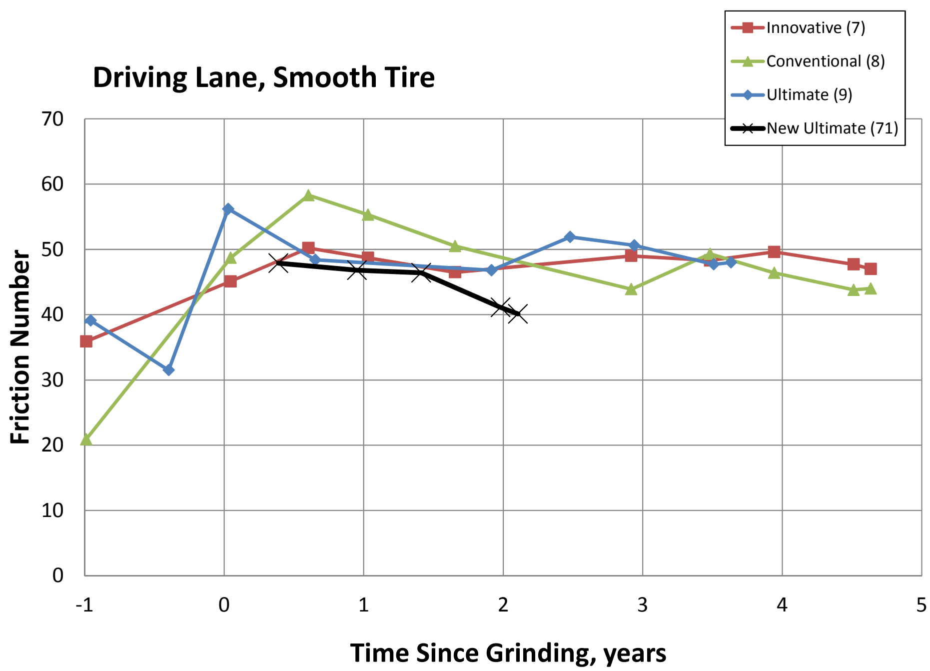

Figure 13. Friction Test – Driving Lane, Smooth Tire by Time Since Grinding.

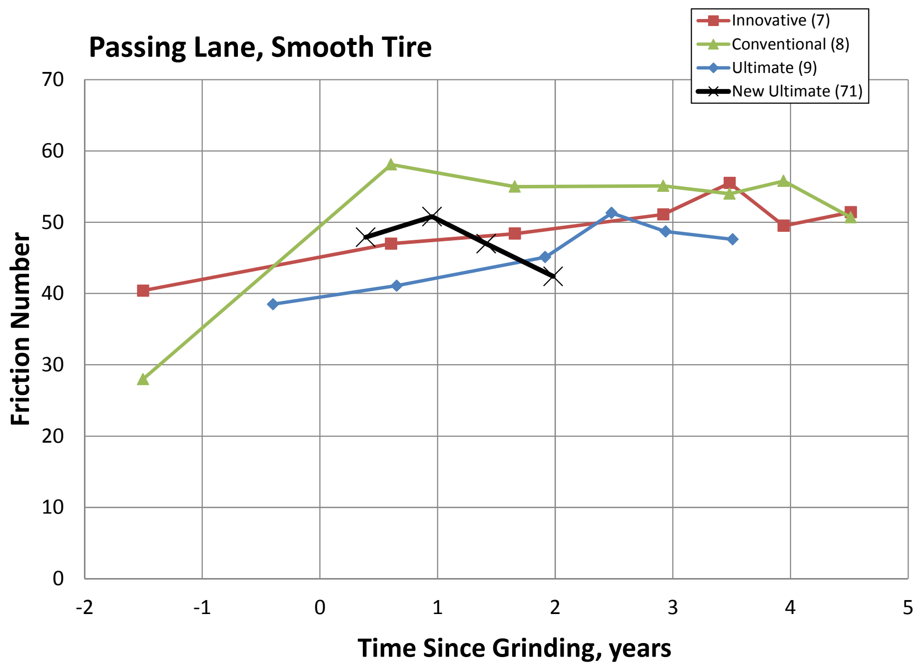

Figure 14. Friction Test – Passing Lane, Smooth Tire by Time Since Grinding.

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 innovative and ultimate grind 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. The conventional grind has consistently demonstrated a friction number almost FN 5.0 higher than the innovative surface when considering the ribbed tire in both lanes, at the same age.

Texture

New data for mean texture depth is not available since the last annual report, except for the additional data for Cell 71. Thus, new information is not included in this section. For continuity, however, the previous discussion is maintained in this annual report, with minor corrections and clarifications.

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 more quickly 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 Figures 15 and 16.

Immediately after Cells 7 and 8 were ground 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, and the new ultimate grind on Cell 71 was conducted 18 months after that. As can be seen in Figure 15, 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. The new iteration of the ultimate grind does not display texture depth any different than the other two types of grind.

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.

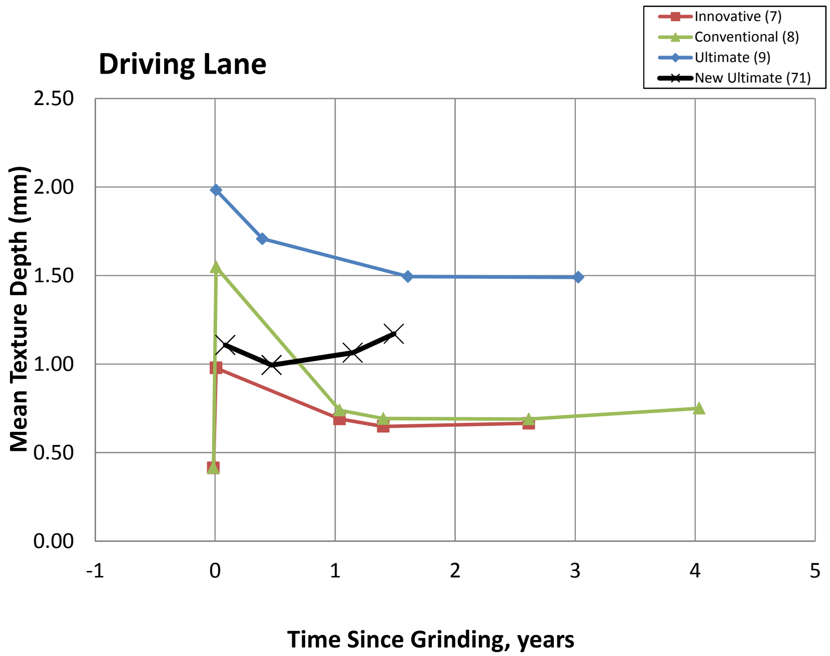

Figure 15. Average Texture Depth – Driving Lane.

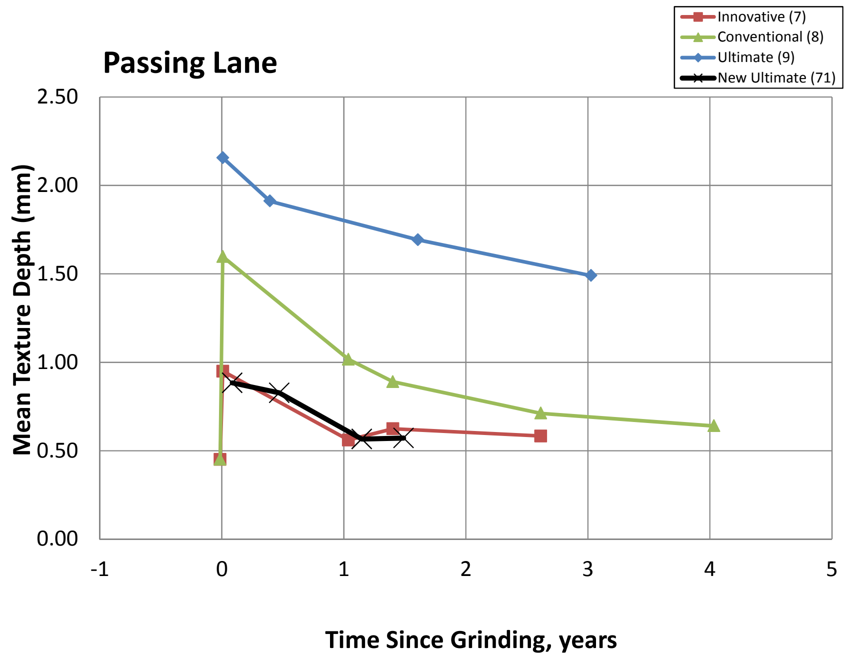

Figure 16. Average Texture Depth – Passing Lane.

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 beyond October 2010 has not been obtained at this time. 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 about 30 – 40 in/mi. While all of this improvement 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.

As can be seen in Figures 17 through 20, the IRI for the two grinding cells completed in 2007 improved dramatically at the next measurement immediately following the grinding. The data for the ultimate grind (Cell 9) seemed reasonable *prior* to grinding, but the first measurement after grinding reported an IRI of over 200 in/mi, where only six months earlier it had been about 85 in/mi. In fact, the measurement at the time of the grinding of Cells 7 and 8 (one year prior to its own grinding) Cell 9 was profiled and reported only 48 in/mi. Such a dramatic increase, spanning the time of the grinding, seems unreasonable, and thus the data for this cell were removed from the analysis.

Another seeming anomaly is the spike in IRI on the control cell (Cell 12) in March 2010. Disregarding that data point, the remainder of the IRI data for Cells 7, 8 and 12 seem reasonable, and commensurate with the data on the passing lane.

There are other reasons for not including much more information on ride at this point, primarily that additional information needs to be collected about the analyses conducted on the data at different times since grinding. For example, the data filters applied to the pavement profiles need to be the same for a real comparison to be of any value.

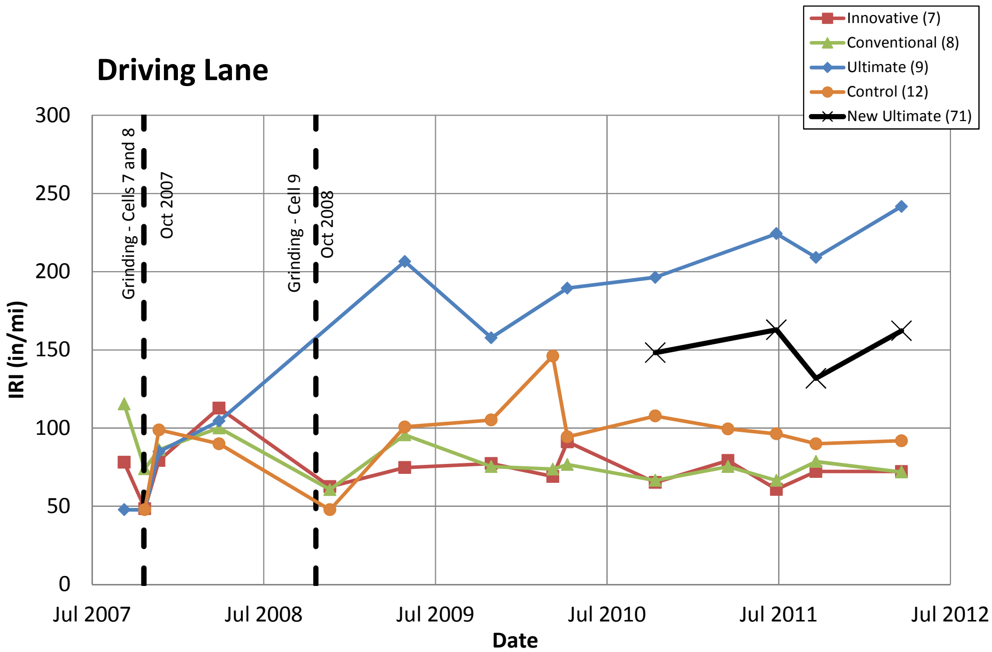

Figure 17. Ride Quality - Driving Lane by Test Date.

When comparing the IRI data plotted by time since grinding, it is apparent that Cells 7 and 8 (the innovative and conventional grind cells, respectively) have IRI values between about 80 in/mi, and that the measurements remain somewhat consistent over several years.

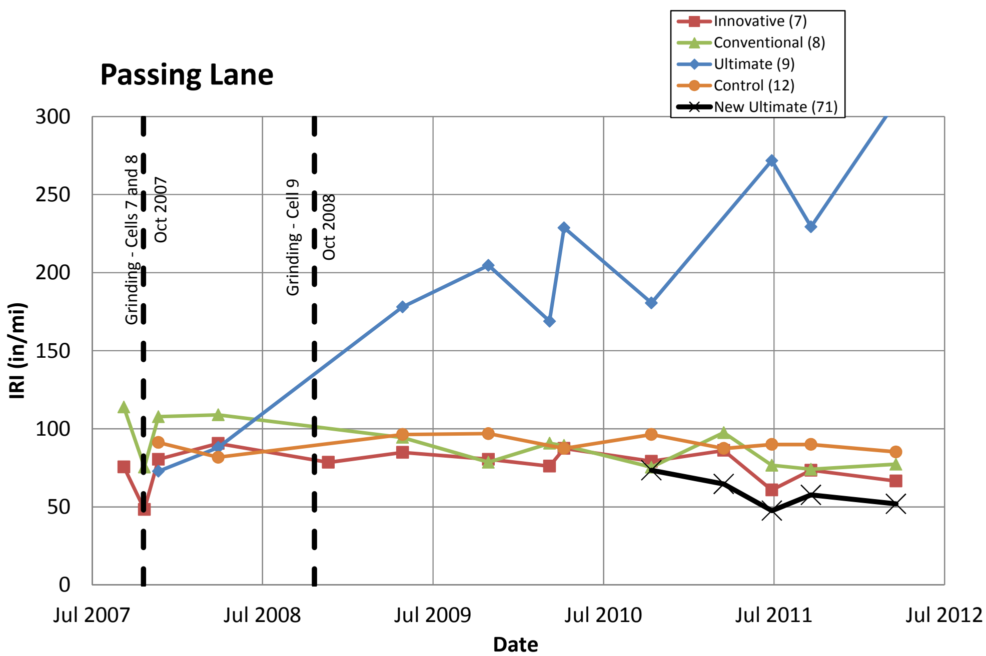

Figure 18. Ride Quality – Passing Lane by Test Date.

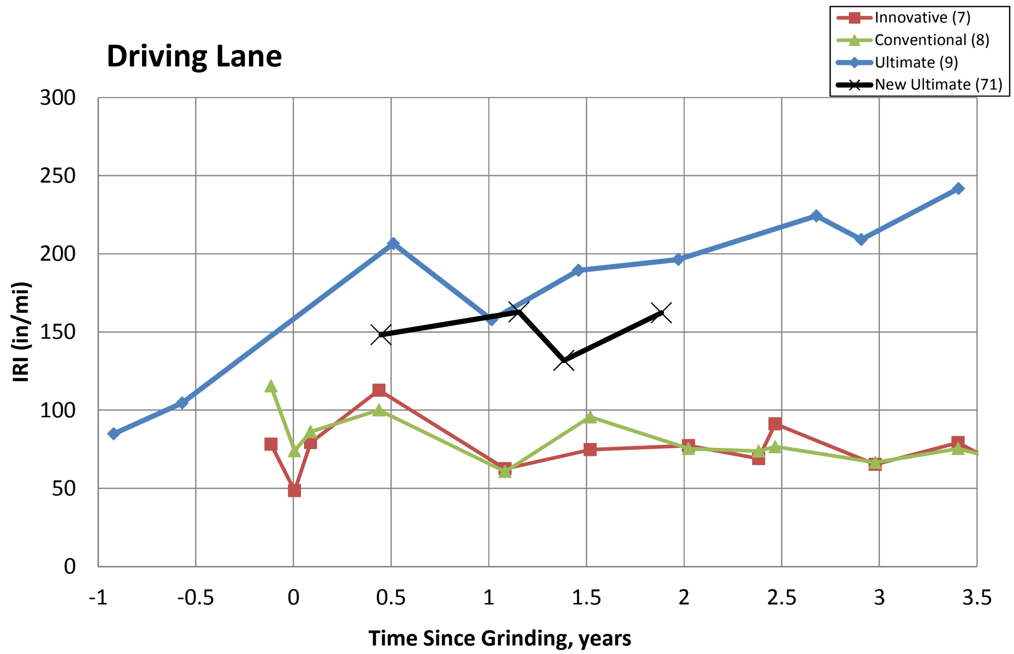

Figure 19. Ride Quality – Driving Lane by Time Since Grinding.

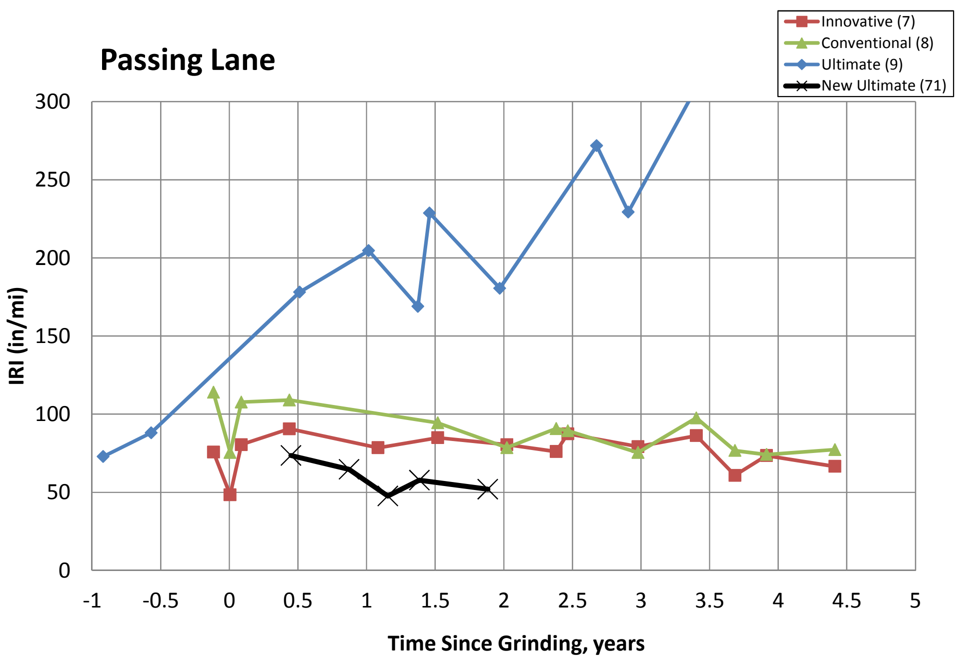

Figure 20. Ride Quality – Passing Lane by Time Since Grinding.

References

1. Kendall, M.G., *Rank and Correlation Methods*, 4th Edition, Charles Griffin, London, 1962.

2. HydroGeoLogic, Inc., *Final 2004 Annual Groundwater Monitoring Report*, HydroGeoLogic Inc., Sacramento, CA, 2005.

3. Helsel, D.R., D.K. Mueller and J.R. Slack, *Computer Program for the Kendall Family of Trend Tests*, Scientific Investigations Report 2005-5275, US Geological Survey, Reston, VA, 2006

APPENDIX A – TEST DATA SUMMARY

OBSI Testing

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

Innovative (7)							
Cell 7 Driving Lane							
		Measured			**Corrected**		
Date/time	**Air Temp (°F)**	**L. Edge**	**T. Edge**	**Ave.**	**L. Edge**	**T. Edge**	**Ave.**
8/17/07 12:00 PM	71.4	-	-	101.9			102.0
10/22/07 1:18 PM	53.5	98.5	99.2	98.8	98.3	99.0	98.6
4/2/08 2:10 PM	40.4	99.9	100.7	100.3	99.4	100.3	99.8
12/5/08 11:18 AM	17.5	102.4	103.0	102.7	101.6	102.2	101.9
3/16/09 1:00 PM	58.6	100.9	101.3	101.1	100.8	101.2	101.0
7/21/09 12:16 PM	73.4	99.6	100.2	99.9	99.7	100.3	100.0
9/15/09 5:18 PM	80.7	98.0	98.9	98.5	98.2	99.1	98.7
11/17/09 1:29 PM	49.2	100.6	100.4	100.6	100.3	100.1	100.3
3/8/10 12:31 PM	36.2	101.3	101.1	101.2	100.8	100.6	100.7
7/28/10 2:12 PM	78.4	98.9	99.0	99.0	99.1	99.2	99.1
9/17/10 2:05 PM	64.1	100.0	100.0	100.0	100.0	100.0	100.0
11/17/10 10:59 AM	34.0	102.0	102.5	102.3	101.5	102.0	101.8
3/15/11 9:42 AM	33.1	102.2	101.8	102.0	101.7	101.3	101.5
6/28/11 10:08 AM	67.6	101.9	101.6	101.8	101.9	101.6	101.7
9/20/11 10:30 AM	68.3	101.3	101.8	101.6	101.3	101.8	101.6
4/25/12 11:32 AM	69.9	101.5	102.0	101.7	101.5	102.0	101.7
Cell 7 Passing Lane							
		Measured			**Corrected**		
Date/time	**Air Temp (°F)**	**L. Edge**	**T. Edge**	**Ave.**	**L. Edge**	**T. Edge**	**Ave.**
8/17/07 12:00 PM	71.4	-	-	102.5			102.6
10/22/07 1:29 PM	53.7	98.4	99.3	98.9	98.2	99.1	98.7
4/2/08 2:47 PM	40.0	99.7	100.3	100.0	99.2	99.8	99.6
11/20/08 10:40 AM	21.3	102.0	102.5	102.3	101.3	101.8	101.6
3/16/09 12:29 PM	57.5	100.6	101.0	100.8	100.4	100.9	100.7
7/21/09 12:43 PM	74.1	98.5	99.3	98.9	98.6	99.4	99.0
9/15/09 4:39 PM	81.4	97.6	98.6	98.1	97.8	98.8	98.3
11/17/09 1:55 PM	49.6	99.6	99.4	99.5	99.3	99.2	99.2
3/8/10 10:57 AM	35.5	100.4	100.1	100.2	99.9	99.6	99.8
7/28/10 1:32 PM	77.7	98.8	99.2	99.0	98.9	99.3	99.1
9/17/10 2:15 PM	64.1	100.2	100.4	100.3	100.1	100.3	100.2
11/17/10 11:08 AM	34.0	101.9	102.4	102.1	101.3	101.8	101.6
3/15/11 9:42 AM	33.1	101.3	101.2	101.3	100.8	100.7	100.7
6/28/11 10:08 AM	67.6	101.7	101.9	101.8	101.7	101.9	101.8
9/20/11 10:15 AM	67.9	100.3	102.1	101.3	100.3	102.1	101.3
4/25/12 11:32 AM	69.9	101.4	102.8	102.1	101.4	102.8	102.1

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

Conventional (8)							
Cell 8							
Cell 8 Driving Lane							
		Measured			***Corrected***		
Date/time	***Air Temp (°F)***	***L. Edge***	***T. Edge***	***Ave.***	***L. Edge***	***T. Edge***	***Ave.***
8/17/07 12:00 PM	71.4	-	-	100.7			100.8
10/22/07 1:18 PM	53.5	103.8	102.8	103.3	103.2	102.2	102.7
4/2/08 2:10 PM	40.4	102.0	101.9	101.9	100.8	100.7	100.8
12/5/08 11:18 AM	17.5	103.9	103.9	103.9	101.8	101.7	101.8
3/16/09 1:00 PM	58.6	102.3	102.1	102.2	101.9	101.7	101.8
7/21/09 12:16 PM	73.4	101.1	101.0	101.1	101.4	101.2	101.3
9/15/09 5:18 PM	80.7	100.5	100.2	100.3	101.0	100.7	100.9
11/17/09 1:29 PM	49.2	102.3	102.0	102.2	101.5	101.2	101.4
3/8/10 12:31 PM	36.2	102.8	102.3	102.6	101.4	101.0	101.2
7/28/10 2:12 PM	78.4	101.1	101.1	101.1	101.6	101.5	101.5
9/17/10 2:05 PM	64.1	103.1	102.8	103.0	102.9	102.7	102.9
11/17/10 10:59 AM	34.0	104.3	104.4	104.4	102.8	103.0	102.9
3/15/11 9:42 AM	33.1	104.2	103.8	104.0	102.7	102.3	102.5
6/28/11 10:08 AM	67.6	103.6	102.9	103.3	103.6	102.9	103.3
9/20/11 10:33 AM	68.0	103.0	102.9	103.0	103.0	102.9	103.0
4/25/12 11:43 AM	70.6	102.7	102.9	102.8	102.8	103.0	102.9
Cell 8 Passing Lane							
		Measured			***Corrected***		
Date/time	***Air Temp (°F)***	***L. Edge***	***T. Edge***	***Ave.***	***L. Edge***	***T. Edge***	***Ave.***
8/17/07 12:00 PM	71.4	-	-	101.5			101.6
10/22/07 1:29 PM	53.7	103.6	102.8	103.2	103.0	102.2	102.6
4/2/08 2:47 PM	40.0	102.6	102.4	102.5	101.4	101.2	101.3
11/20/08 10:40 AM	21.3	104.4	104.7	104.6	102.4	102.7	102.6
3/16/09 12:29 PM	57.5	102.9	102.9	102.9	102.5	102.5	102.5
7/21/09 12:43 PM	74.1	101.8	101.2	101.5	102.1	101.5	101.8
9/15/09 4:39 PM	81.4	101.4	101.0	101.2	101.9	101.6	101.8
11/17/09 1:55 PM	49.6	102.9	102.5	102.7	102.1	101.7	101.9
3/8/10 10:57 AM	35.5	103.4	103.3	103.4	102.1	101.9	102.0
7/28/10 1:32 PM	77.7	101.4	101.1	101.3	101.8	101.5	101.7
9/17/10 2:15 PM	64.1	103.7	103.4	103.5	103.5	103.2	103.4
11/17/10 11:08 AM	34.0	104.5	104.8	104.7	103.1	103.4	103.2
3/15/11 9:42 AM	33.1	103.4	103.3	103.4	101.9	101.8	101.9
6/28/11 10:08 AM	67.6	103.4	103.2	103.3	103.4	103.1	103.3
9/20/11 10:33 AM	68.0	101.8	103.2	102.6	101.8	103.2	102.6
4/25/12 11:43 AM	70.6	103.9	104.1	104.0	104.0	104.2	104.1

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

Ultimate (9)							
Cell 9 Driving Lane							
		Measured			**Corrected**		
Date/time	**Air Temp (°F)**	**L. Edge**	**T. Edge**	**Ave.**	**L. Edge**	**T. Edge**	**Ave.**
9/10/07 1:06 PM	52.9	103.3	102.7	103.0	103.0	102.4	102.7
12/5/08 11:18 AM	17.5	101.3	102.0	101.7	100.3	101.0	100.7
3/16/09 1:00 PM	58.6	100.9	101.4	101.2	100.7	101.2	101.0
7/21/09 12:16 PM	73.4	100.0	100.3	100.2	100.1	100.4	100.3
9/15/09 5:18 PM	80.7	98.8	99.1	99.0	99.0	99.4	99.2
11/17/09 1:29 PM	49.2	101.2	101.3	101.2	100.9	100.9	100.9
3/8/10 12:31 PM	36.2	102.4	102.3	102.4	101.8	101.7	101.8
7/28/10 2:12 PM	78.4	99.9	100.0	100.0	100.1	100.2	100.2
9/17/10 2:05 PM	64.1	101.8	101.8	101.8	101.7	101.7	101.7
11/17/10 10:59 AM	34.0	103.2	103.6	103.4	102.6	103.0	102.8
3/15/11 9:42 AM	33.1	103.2	103.1	103.2	102.5	102.4	102.5
6/28/11 10:08 AM	67.6	103.0	102.6	102.8	103.0	102.6	102.8
9/20/11 10:33 AM	68.0	102.6	102.8	102.7	102.6	102.8	102.7
4/25/12 11:43 AM	70.6	102.3	102.7	102.5	102.3	102.7	102.5
Cell 9 Passing Lane							
		Measured			**Corrected**		
Date/time	**Air Temp (°F)**	**L. Edge**	**T. Edge**	**Ave.**	**L. Edge**	**T. Edge**	**Ave.**
9/10/07 10:52 AM	52.9	104.7	104.4	104.6	104.4	104.1	104.3
11/20/08 10:40 AM	21.3	102.3	102.8	102.6	101.4	101.9	101.7
3/16/09 12:29 PM	57.5	101.5	101.9	101.7	101.3	101.7	101.5
7/21/09 12:43 PM	74.1	100.0	100.4	100.2	100.1	100.5	100.3
9/15/09 4:39 PM	81.4	98.9	99.1	99.0	99.2	99.4	99.3
11/17/09 1:55 PM	49.6	101.0	100.9	101.0	100.7	100.6	100.6
3/8/10 10:57 AM	35.5	101.9	101.9	101.9	101.3	101.3	101.3
7/28/10 1:32 PM	77.7	99.9	99.8	99.9	100.1	100.0	100.0
9/17/10 2:15 PM	64.1	102.3	102.1	102.2	102.2	102.0	102.1
11/17/10 11:08 AM	34.0	103.4	103.9	103.6	102.7	103.3	103.0
3/15/11 9:42 AM	33.1	103.1	103.4	103.2	102.4	102.7	102.6
6/28/11 10:08 AM	67.6	102.6	102.4	102.5	102.6	102.4	102.5
9/20/11 10:33 AM	68.0	101.3	103.1	102.3	101.3	103.1	102.3
4/25/12 11:43 AM	70.6	102.5	103.4	103.0	102.5	103.4	103.0

Table 10. OBSI Testing – Cell 12 (Control).

Control (12)							
Cell 12							
Cell 12 Driving Lane							
		Measured			Corrected		
Date/time	Air Temp (°F)	L. Edge	T. Edge	Ave.	L. Edge	T. Edge	Ave.
9/10/07 1:23 PM	52.9	104.6	103.8	104.2	104.3	103.5	103.9
12/5/08 11:06 AM	17.4	106.8	105.9	106.4	105.8	105.0	105.4
7/21/09 12:03 PM	73.1	105.5	104.6	105.1	105.6	104.7	105.2
9/17/10 1:23 PM	63.4	105.9	104.9	105.4	105.8	104.8	105.3
11/17/10 10:45 AM	33.5	106.9	106.2	106.6	106.2	105.5	105.9
3/15/11 9:40 AM	33.1	106.5	105.9	106.2	105.8	105.2	105.5
6/28/11 10:08 AM	67.6	106.0	105.1	105.6	106.0	105.1	105.6
9/20/11 10:33 AM	68.0	105.0	104.6	104.8	105.0	104.6	104.8
4/25/12 11:42 AM	70.5	105.9	105.6	105.8	105.9	105.6	105.8
Cell 12 Passing Lane							
		Measured			Corrected		
Date/time	Air Temp (°F)	L. Edge	T. Edge	Ave.	L. Edge	T. Edge	Ave.
9/10/07 1:23 PM	52.9	105.1	104.8	105.0	104.8	104.5	104.7
11/20/08 10:32 AM	21.2	107.5	106.6	107.1	106.6	105.7	106.2
3/16/09 12:29 PM	57.5	106.3	105.5	105.9	106.1	105.3	105.7
7/21/09 12:03 PM	73.1	105.5	104.7	105.1	105.6	104.8	105.2
9/17/10 1:23 PM	63.4	106.5	105.6	106.1	106.4	105.5	106.0
11/17/10 10:45 AM	33.5	107.1	106.7	106.9	106.4	106.0	106.2
3/15/11 9:40 AM	33.1	106.0	105.7	105.9	105.3	105.0	105.2
6/28/11 10:08 AM	67.6	105.9	105.3	105.6	105.9	105.3	105.6
9/20/11 10:33 AM	68.0	104.7	105.7	105.2	104.7	105.7	105.2
4/25/12 11:42 AM	70.5	105.0	105.5	105.3	105.0	105.5	105.3

Table 11. OBSI Testing – Cell 71 (New Ultimate).

New Ultimate (71)							
Cell 71							
Cell 17 Driving Lane							
		Measured			Corrected		
Date/time	Air Temp (°F)	L. Edge	T. Edge	Ave.	L. Edge	T. Edge	Ave.
7/28/10 1:51 PM	77.9	96.8	96.9	96.9	96.9	97.0	96.9
9/17/10 2:28 PM	64.1	98.9	98.8	98.9	98.9	98.8	98.8
11/17/10 11:34 AM	34.1	100.9	101.0	101.0	100.6	100.7	100.6
3/15/11 10:17 AM	33.1	101.1	100.8	101.0	100.8	100.5	100.6
6/28/11 10:08 AM	67.6	100.9	100.4	100.7	100.9	100.4	100.7
9/20/11 9:55 AM	67.6	100.3	100.6	100.5	100.3	100.6	100.4
4/25/12 11:43 AM	70.6	99.9	100.4	100.2	99.9	100.4	100.2
Cell 71 Passing Lane							
		Measured			Corrected		
Date/time	Air Temp (°F)	L. Edge	T. Edge	Ave.	L. Edge	T. Edge	Ave.
7/28/10 1:51 PM	77.9	100.3	100.1	100.2	100.4	100.2	100.3
9/17/10 2:28 PM	64.1	101.7	101.4	101.6	101.7	101.4	101.5
11/17/10 11:34 AM	34.1	103.2	103.5	103.4	102.9	103.2	103.0
3/15/11 10:17 AM	33.1	101.2	101.1	101.2	100.9	100.8	100.8
6/28/11 10:23 AM	68.0	101.1	101.1	101.1	101.1	101.1	101.1
9/20/11 9:55 AM	67.6	100.0	101.5	100.8	100.0	101.5	100.8
4/25/12 11:43 AM	70.6	101.1	101.9	101.5	101.1	101.9	101.5

Friction

Table 12. Friction Testing – Driving Lane Ribbed Tire.

Driving Lane Ribbed Tire											
Cell	***Age***	***Date***	***Time***	***FN***	***Peak***	***Speed (mph)***	***Air Temp (F)***	***Pvmt Temp (F)***	***Min FN***	***Max FN***	***Slip***
Innovative (7)	-1.5	4/19/2006	11:08 AM	55.7	82.81	40.4	59		51	60	16
	-1.0	10/24/2006	12:00 AM	59.5	78.6	40	42	62.8	0	0	0
	0.0	11/6/2007	10:10 AM	46.1	65.67	40.8	37	45.7	44	48	8
	0.6	5/28/2008	11:15 AM	44.7	66.87	40.4	66	99.3	42	47	16
	1.0	10/31/2008	10:47 AM	45.1	68.54	41.4	68	70.3	43	47	13
	1.7	6/16/2009	11:23 AM	44.6	60.17	40.2	68	93.5	42	48	15
	2.9	9/20/2010	11:24 AM	41.9	67.95	40.1	55	64.4	38	44	12
	3.5	4/14/2011	10:26 AM	46.4	63.85	40.2	37	57.6	44	49	10
	3.9	9/29/2011	10:55 AM	44.1	66.7	39.8	32	74.7	40	63	17
	4.5	4/24/2012	12:39 PM	40.1	60.84	40.4	63		34	47	13
	4.6	6/8/2012	10:46 AM	41.1	59.1	40.2	70	97.4	37	48	13
Conventional (8)	-1.5	4/19/2006	11:08 AM	60.7	81.89	40.5	59		55	66	17
	-1.0	10/24/2006	12:00 AM	48	64.14	40.3	42	61.7	0	0	0
	0.0	11/6/2007	10:10 AM	55.4	81.24	40.4	36	45.4	52	58	14
	0.6	5/28/2008	11:14 AM	57.75	86.7	40.05	65.5	98.75	54	61	10.5
	1.0	10/31/2008	10:46 AM	54	82.2	41.3	68	69.8	52	56	9
	1.7	6/16/2009	11:23 AM	48.9	75.99	40.3	68	93.2	45	52	18
	2.9	9/20/2010	11:23 AM	48.8	67.2	39.8	55	63.9	44	54	13
	3.5	4/14/2011	10:26 AM	51	72.21	40.1	37	58.1	46	54	12
	3.9	9/29/2011	10:55 AM	46.3	70.75	39.3	32	74.7	43	50	11
	4.5	4/24/2012	12:39 PM	43.9	64.68	40.1	62		41	48	15
	4.6	6/8/2012	10:46 AM	45.3	63.2	39.9	70	97.9	43	49	12
Ultimate (9)	-2.5	4/19/2006	11:08 AM	66	92.83	40.3	60		62	71	12
	-1.0	11/6/2007	10:10 AM	49.9	79.21	40.9	37	46.9	46	53	15
	-0.4	5/28/2008	11:14 AM	56.25	84.785	39.55	65.5	101.7	51	60	14.5
	0.0	10/31/2008	10:46 AM	48.2	76.29	40.4	68	69.1	43	54	12
	0.7	6/16/2009	11:23 AM	45.3	65.76	40.9	68	92.2	43	48	12
	1.9	9/20/2010	11:23 AM	45.2	64.39	40.4	55	63.2	43	47	14
	2.5	4/14/2011	10:26 AM	50.1	70.53	40.5	38	55.9	48	52	9
	2.9	9/29/2011	10:55 AM	48.9	70.61	40.7	11	74.5	46	51	11
	3.5	4/24/2012	12:39 PM	43	61.75	40.6	63		41	45	19
	3.6	6/8/2012	10:45 AM	43.5	61.2	39.6	70	98.1	39	45	13
Control (12)		10/31/2008	10:46 AM	51.9	76.08	40.2	68	69.8	48	56	9
		9/20/2010	11:23 AM	46.7	69.34	40	55	64.9	41	51	9
		4/14/2011	10:26 AM	47.2	67.94	40.3	38	59.3	39	52	9
		9/29/2011	10:54 AM	46.7	75.52	39.6	15	74.6	39	51	9
		4/24/2012	12:38 PM	41	66.76	40.3	64		35	44	26
		6/8/2012	10:44 AM	42.7	64.9	40.4	70	97.9	34	46	7
New Ultimate (71)	0.4	9/20/2010	11:23 AM	44.9	61.71	40.2	55	64.6	42	48	11
	1.0	4/14/2011	10:25 AM	50.9	63.08	40.1	38	58.1	48	55	13
	1.4	9/29/2011	10:54 AM	41	63.58	40.3	12	75	36	45	11
	2.0	4/24/2012	12:39 PM	37.7	55.26	40.2	63		35	43	19
	2.1	6/8/2012	10:45 AM	38.3	55.4	40.7	70	97.8	35	44	9

Table 13. Friction Testing – Driving Lane Smooth Tire.

Driving Lane - Smooth Tire											
Cell	**Age**	**Date**	**Time**	**FN**	**Peak**	**Speed (mph)**	**Air Temp (F)**	**Pvmt Temp (F)**	**Min FN**	**Max FN**	**Slip**
Innovative (7)	-1.5	4/19/2006	11:32 AM	26.2	45.26	40.5	60		23	30	13
	-1.0	10/24/2006	12:00 AM	35.9	51.97	40.2	43	63	0	0	0
	0.0	11/6/2007	10:27 AM	45.1	63.08	40.7	37	46.9	41	48	21
	0.6	5/28/2008	11:21 AM	50.2	72.7	42.2	65	96.5	45	54	11
	1.0	10/31/2008	11:10 AM	48.7	79.46	39.8	68	67.8	42	53	13
	1.7	6/16/2009	11:40 AM	46.5	69.86	40.5	68	88	42	54	11
	2.9	9/20/2010	11:40 AM	49	79.27	39.9	55	64.4	45	53	10
	3.5	4/14/2011	10:37 AM	48.3	79.72	40	37	55.5	45	51	10
	3.9	9/29/2011	11:06 AM	49.6	83.26	39.3	32	69.9	46	66	9
	4.5	4/24/2012	12:52 PM	47.7	72.36	40.1	64		44	50	27
	4.6	6/8/2012	10:56 AM	47	72.7	40.9	70	95.5	42	50	13
Conventional (8)	-1.5	4/19/2006	11:32 AM	30.2	37.58	40.5	61		23	42	6
	-1.0	10/24/2006	12:00 AM	20.9	28.87	40.6	43	61	0	0	0
	0.0	11/6/2007	10:27 AM	48.7	75.74	40.3	37	45.9	44	53	9
	0.6	5/28/2008	11:20 AM	58.3	99.28	41.7	65	92.4	52	64	8
	1.0	10/31/2008	11:09 AM	55.3	94.17	40.2	68	68.6	50	60	9
	1.7	6/16/2009	11:40 AM	50.5	81.54	40.6	68	88.8	44	55	14
	2.9	9/20/2010	11:39 AM	43.9	73	40	55	63.4	37	47	10
	3.5	4/14/2011	10:37 AM	49.3	77.91	40	37	55.4	41	55	10
	3.9	9/29/2011	11:06 AM	46.4	84.71	39.2	32	69.4	43	50	7
	4.5	4/24/2012	12:51 PM	43.8	76.34	39.6	64		40	47	14
	4.6	6/8/2012	10:56 AM	44	74.2	39.8	70	97.2	41	48	11
Ultimate (9)	-2.5	4/19/2006	11:32 AM	31.4	54.87	40.5	61		26	37	27
	-1.0	11/6/2007	10:27 AM	39.1	46.77	40.8	36	47.4	34	45	4
	-0.4	5/28/2008	11:20 AM	31.5	45.645	41.7	65	96.75	21.5	43	15
	0.0	10/31/2008	11:09 AM	56.2	86.88	40.3	68	68.3	51	60	9
	0.7	6/16/2009	11:40 AM	48.4	69.55	40.2	68	86.8	45	51	7
	1.9	9/20/2010	11:39 AM	46.8	68.06	40	55	63.2	44	49	8
	2.5	4/14/2011	10:37 AM	51.9	71.61	39.8	37	54.3	50	55	13
	2.9	9/29/2011	11:06 AM	50.6	68.81	40.5	32	70.1	48	54	10
	3.5	4/24/2012	12:51 PM	47.7	70.35	39.7	64		46	50	8
	3.6	6/8/2012	10:56 AM	48	68.7	39.6	70	92.3	46	51	10
Control (12)		10/31/2008	10:46 AM	31.1	52.4	40.1	68	68.6	21	38	26
		9/20/2010	11:23 AM	32.2	50.37	40.1	55	64.4	25	41	30
		4/14/2011	10:26 AM	34.6	50.64	40.3	38	59.4	25	41	10
		9/29/2011	11:05 AM	28.3	46.27	39.8	32	68.6	18	41	10
		4/24/2012	12:50 PM	24.1	40.81	40.2	64		16	36	48
		6/8/2012	10:55 AM	25.7	31.6	40.1	70	90.3	17	36	22
New Ultimate (71)	0.4	9/20/2010	11:39 AM	47.9	66.38	40.2	55	64.2	44	52	7
	1.0	4/14/2011	10:37 AM	46.8	64.83	40.2	38	55.9	42	51	12
	1.4	9/29/2011	11:06 AM	46.4	66.37	39.9	32	71.3	43	49	14
	2.0	4/24/2012	12:51 PM	41.1	61.17	39.9	61		39	43	13
	2.1	6/8/2012	10:55 AM	40.1	60.9	40.7	70	92.7	38	43	9

Table 14. Friction Testing – Passing Lane Ribbed Tire.

Passing Lane - Ribbed Tire											
Cell	**Age**	**Date**	**Time**	**FN**	**Peak**	**Speed (mph)**	**Air Temp (F)**	**Pvmt Temp (F)**	**Min FN**	**Max FN**	**Slip**
Innovative (7)	-1.5	4/19/2006	11:49 AM	57.5	81.56	40.4	60		53	60	15
	-1.0	10/24/2006	12:00 AM	59.4	75.81	40	45	64	0	0	0
	0.0	11/6/2007	10:48 AM	46.2	70.7	40.6	37	48.7	41	49	9
	0.6	5/28/2008	11:37 AM	43.8	66.05	40.7	65	100.9	41	46	13
	1.7	6/16/2009	10:12 AM	41.5	63.1	40.4	68	89.1	37	44	11
	2.9	9/20/2010	12:00 PM	46.7	72.28	40.6	55	66.1	42	50	14
	3.5	4/14/2011	10:50 AM	49.5	67.46	40.4	38	58.1	46	52	7
	3.9	9/29/2011	10:42 AM	47.7	71.46	40.6	11	75	40	71	8
	4.5	4/24/2012	1:04 PM	42.3	63.04	40	63		39	49	13
Conventional (8)	-1.5	4/19/2006	11:48 AM	52.6	80.73	40	61		47	60	14
	-1.0	10/24/2006	12:00 AM	47	68.09	40.1	44	63.3	0	0	0
	0.0	11/6/2007	10:48 AM	55.7	82.84	40.3	37	48.2	50	61	9
	0.6	5/28/2008	11:37 AM	56.6	83.925	40.25	66	98.6	52.5	60.5	14.5
	1.7	6/16/2009	10:12 AM	49.7	75.27	39.7	68	88.8	46	53	13
	2.9	9/20/2010	12:00 PM	54	73.77	40.3	55	65.9	50	57	12
	3.5	4/14/2011	10:50 AM	55.4	73.23	39.1	38	57.9	52	60	14
	3.9	9/29/2011	10:42 AM	51.6	74.76	40.1	17	74.6	47	55	17
	4.5	4/24/2012	1:04 PM	45.7	67.47	40	64		42	50	9
Ultimate (9)	-2.5	4/19/2006	11:48 AM	54.2	78.43	40.5	62		48	60	24
	-1.0	11/6/2007	10:48 AM	52.9	75.1	41.2	37	48.6	48	57	18
	-0.4	5/28/2008	11:37 AM	53.7	82.545	39.9	67	104.6	50	58	13
	0.7	6/16/2009	10:12 AM	36.3	49.73	40.9	68	87.8	34	40	9
	1.9	9/20/2010	12:00 PM	46.2	62.85	40.5	55	65.4	42	49	19
	2.5	4/14/2011	10:50 AM	48.7	63.69	40.8	38	58.1	45	52	9
	2.9	9/29/2011	10:42 AM	46.9	65.79	39.7	14	74.2	44	50	12
	3.5	4/24/2012	1:04 PM	43.7	57.77	40.2	64		39	46	15
Control (12)		9/20/2010	11:23 AM	51.7	71.8	40.4	55	65.9	46	56	20
		4/14/2011	10:26 AM	55.2	72.79	39.9	38	61.1	48	59	26
		9/29/2011	10:41 AM	53.8	79.54	39.2	20	74.2	50	57	14
		4/24/2012	1:03 PM	46.5	73.28	40.1	64		43	49	16
New Ultimate (71)	0.4	9/20/2010	11:59 AM	49.2	72.34	40.1	55	65.6	45	52	11
	1.0	4/14/2011	10:49 AM	54.5	77.02	39.6	38	58.6	51	58	10
	1.4	9/29/2011	10:41 AM	51.9	75.98	39.7	12	74.7	49	56	12
	2.0	4/24/2012	10:55 AM	45.6	62.96	40	64		42	48	9

Table 15. Friction Testing – Passing Lane Smooth Tire.

Cell	Age	Date	Time	FN	Peak	Speed (mph)	Air Temp (F)	Pvmt Temp (F)	Min FN	Max FN	Slip
Passing Lane - Smooth Tire											
Innovative (7)	-1.5	4/19/2006	12:10 PM	40.4	78.95	40.2	62		30	55	21
	0.6	5/28/2008	11:43 AM	47	71.28	40.7	65	97.7	43	52	9
	1.7	6/16/2009	10:29 AM	48.4	72.24	40.3	68	90.8	43	52	9
	2.9	9/20/2010	12:15 PM	51.1	74.76	40.3	55	64.4	45	54	13
	3.5	4/14/2011	11:01 AM	55.5	87.16	40.2	38	60.5	50	60	11
	3.9	9/29/2011	11:18 AM	49.5	81.27	40.2	32	73	47	52	15
	4.5	4/24/2012	1:19 PM	51.4	79.64	39.8	65		48	54	14
Conventional (8)	-1.5	4/19/2006	12:09 PM	28	81.77	39.9	62		17	49	10
	0.6	5/28/2008	11:43 AM	58.1	106.195	40.2	66	98.0	52	65	10
	1.7	6/16/2009	10:28 AM	55	90.97	39.7	68	89.3	50	62	9
	2.9	9/20/2010	12:15 PM	55.1	79.41	39.7	55	64.6	50	62	12
	3.5	4/14/2011	11:01 AM	54	79.39	40.5	39	56.6	40	64	18
	3.9	9/29/2011	11:17 AM	55.8	88.48	39.6	32	74.5	17	68	12
	4.5	4/24/2012	1:18 PM	50.7	79.48	39.7	64		39	55	9
Ultimate (9)	-2.5	4/19/2006	12:09 PM	44.5	81.27	40.4	62		36	57	7
	-0.4	5/28/2008	11:43 AM	38.5	59.065	40.3	66	102.3	28	52	24
	0.7	6/16/2009	10:28 AM	41.1	56.19	40.4	68	91.3	36	46	12
	1.9	9/20/2010	12:15 PM	45.1	63.55	40.4	55	64.2	43	48	12
	2.5	4/14/2011	11:01 AM	51.3	80.38	40.3	39	57.5	43	64	9
	2.9	9/29/2011	11:17 AM	48.7	69.18	39.5	32	74.2	44	53	22
	3.5	4/24/2012	1:18 PM	47.6	70.75	40	64		44	51	18
Control (12)		9/20/2010	12:14 AM	41.7	53.81	40.4	55	65.9	35	49	6
		4/14/2011	10:26 AM	51.8	83.77	40.3	39	63.9	38	68	15
		9/29/2011	11:16 AM	41	59.39	39.8	32	73.5	28	52	11
		4/24/2012	1:17 PM	32	50.74	40	64		19	40	16
New Ultimate (71)	0.4	9/20/2010	12:14 PM	47.9	81.03	40.2	55	65.4	43	51	6
	1.0	4/14/2011	11:00 AM	50.8	79.19	40.4	39	59.3	40	59	13
	1.4	9/29/2011	11:17 AM	47	89.15	39.9	32	73.8	39	53	6
	2.0	4/24/2012	1:18 PM	42.4	76.48	39.9	65		39	46	8

Texture Depth

Table 16. Average Texture Depth.

	Date	MTD Passing Lane (mm)	MTD Driving Lane (mm)
Innovative (7)	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
Conventional (8)	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
	11/1/2011	0.64	0.75
Ultimate (9)	10/25/2008	2.16	1.98
	3/15/2009	1.91	1.71
	6/1/2010	1.69	1.49
	11/1/2011	1.49	1.49
New Ultimate (71)	6/1/2010	0.88	1.11
	10/20/2010	0.83	0.99
	6/24/2011	0.57	1.06
	10/27/2011	0.57	1.17