Performance Grade Asphalt Cement
Waterford, Vermont

February 2006

Reporting on Work Plan 1994-R-4

State of Vermont
Agency of Transportation
Materials and Research Section

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16. Abstract

This update report summarizes the implementation and evaluation of a performance graded (PG) asphalt cement binder. The purpose of this investigation was to compare a commonly used asphalt cement (AC-20) to a performance graded binder (PG 52-40) with regards to thermal and fatigue cracking, rutting, and the international roughness index (IRI).

Over the 11 year investigation period, the PG 58-40 binder well outperformed the AC 20 binder with regards to thermal and fatigue cracking. Conclusions concerning reflective cracking, rutting, and IRI values could not be made due to the large variation within these data sets.

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INTRODUCTION:

This update report summarizes the implementation and evaluation of a performance graded (PG) asphalt cement binder. The PG binder was incorporated into the composition of a pavement mixture that was applied on VT Route 18 in the Town of Waterford during the summer of 1994. The investigation was initiated by a nationwide effort to use an asphalt cement binder that adheres to specific performance requirements developed by SHRP (Strategic Highway Research Program). The purpose of this investigation was to compare a commonly used asphalt cement (AC-20) to a performance graded binder (PG 52-40) with regards to thermal and load cracking, rutting, and the international roughness index (IRI).

The specified experimental binder in the work plan (WP 94-R-4) for the investigation was a PG 52-40. This classification indicates that the binder should perform satisfactorily at an average 7 day high temperature of 52^{o}C, or 126^{o}F, at 20 mm below the pavement surface and an average one day low temperature of -40^{o}C, or -40^{o}F, at the pavement surface. The binder was designed to perform satisfactorily within these limits. In regards to this project, it is important to note that the binder, produced by Bitumar of Montréal, Canada, was certified as PG 58-40 which exceeded the specified maximum temperature of the design requirement. Therefore the binder will be designated as such for the remainder of the document. The control binder specified in the work plan was AC-20, which has been found to perform similarly to a PG 64-22

PROJECT DESCRIPTION:

The Waterford pavement project, CM-RS 0225(3) was constructed in 1994 and began on VT Route 18 at mile marker (MM) 0.034 and continued north to MM 2.868 for a total length of 2.834 miles. The project included drainage improvements, full depth reclamation and resurfacing. The project plans specified a reclaimed stabilized base depth of 4.5" with an overlay of 1.75" of a type II binder course, which contains a nominal maximum size aggregate of 0.75", and 1.25" thickness of a type III wearing course, which contains a nominal maximum size of aggregate of 0.50". No chemical stabilization was used in the reclaimed base, but optimum compaction was assured through moisture-density evaluations. An preliminary investigation report entitled "Initial Report 95-4" outlines the implementation and associated testing of the pavement treatment, along with the preconstruction observations concerning the pavement condition prior to and immediately following installation which encompassed the collection of cracking, rutting, IRI, and Falling Weight Deflectometer (FWD) values.

In accordance with the work plan, the control and experimental sections were placed as indicated below:

Waterford CMRS 0225(3) Rehabilitation Project						
	North Bound Lane			South Bound Lane		
Section Type:	Mile Marker:	To	Mile Marker:	Mile Marker:	To	Mile Marker:
Standard/Control	0.000	-	0.580	0.000	-	0.540
Experimental	0.580	-	2.180	0.540	-	2.177
Standard/Control	2.180	-	2.868	2.177	-	2.868

Table 1

A total of thirteen test sites were established. Of the thirteen test sites, seven sites were located within the control sections, and six sites were identified within the experimental sections. However, one of the control sections, TS 0.40, was established in a transition zone between the experimental and control sections. Due to the variance of the treatment within this area, this test site has been eliminated from the study and is no longer under evaluation. Each test site consists of a length of 100’ in the direction of travel and are approximately 22’ wide encompassing both the north and southbound lanes. Generally, each test site was examined annually for cracking, rutting, and IRI. The figures as provided below depict a typical test site immediately following construction and ten years after construction.

Figure 1: Test Site 0.65, 1994

Figure 2: Test Site 0.65, 2004

PERFORMANCE:

Cracking, rutting, and IRI values are often utilized to assess the performance and service life of pavement treatments or in this case differing pavement mix designs. It has been shown that the surface condition of a pavement is directly correlated to its structural condition and is a non-linear system that can be characterized by different rates of deterioration. The following is an examination of the surface condition of both the experimental and control pavements.

As stated previously, the binder utilized for the control sections was AC-20 and the binder used for the experimental sections was PG 58-40. It was anticipated that the control binder, AC-20, may perform better than the PG 58-40 at higher temperatures given the inherent temperature specifications. Conversely, the PG 58-40 was expected to perform better than AC-20 at lower temperatures resulting in less transverse or thermal cracking. With regards to longitudinal or load cracking, both of the pavement mixes were designed for the same loading requirements and, as such, it was predicted that there would not be a significant difference between sections.

CRACKING

There are several causations for cracking in flexible pavements, including inadequate structural support such as the loss of base, subbase or subgrade support, an increase in loading, inadequate design, poor construction, or poor choice of materials including binder. For this analysis, longitudinal, transverse and reflective cracking were examined. Longitudinal cracks run parallel to the laydown direction and are usually a type of fatigue or load associated failure. Transverse cracks run perpendicular to the pavement's centerline and are usually a type of thermal fatigue that may be induced by multiple freeze-thaw cycles. Reflection cracks occur from previous cracking that may exist within the subbase or subgrade material and continue through the wearing course. In all cases, the cracks allow for moisture infiltration and can result in structural failure over time.

Pavement condition surveys of each test section were conducted throughout the study duration period, with the exception of 2002 and 2003, in accordance with the "Distress Identification Manual for the Long-Term Pavement Performance Program" published in May of 1993 by the SHRP. Crack data is collected by locating the beginning of each test section, often keyed into mile markers or other identifiable land marks. The test section is then marked at intervals of ten feet from the beginning of the test section for a length of 100'. Pavement surveys start at the beginning of a test section and the locations and length of each crack are hand drawn onto a data collection sheet. Once in the office, the information is processed and the total length of transverse, longitudinal, centerline and miscellaneous cracking is determined and recorded into the associated field on the survey form. For this analysis, failure criterion is met when the amount of post construction cracking is equal to or greater than the amount of preconstruction cracking. Please note that all recorded crack data is provided in Attachment A.

I. Fatigue Cracking

The following assessment began with examining longitudinal or fatigue cracking. As indicated by the "Distress Identification Manual", fatigue cracking occurs in areas subjected to repeated traffic loading, or wheel paths, and may be a series of interconnected cracks in early stages of development that progresses into a series of chicken wire/alligator cracks in later stages. For this investigation, the wheel paths were determined to be three feet in width with a center of 3.5' from the right wheel path and 8.5' from the shoulder for the left wheel path on either side of roadway. An important parameter considered during the pavement design process is a wheel load characterized as an ESAL, or equivalent single axle load. An ESAL is defined by Clemson University as “the effect on pavement performance of any combination of axle loads of varying magnitude equated to the number of 80-kN (18,000-lb.) single-axle loads that are required to produce an equivalent effect.” Basically, pavements are designed to structurally support traffic loads which are often calculated by AADT or ESALs with regards to roadway use. ESAL information was not available for this investigation. Therefore a comparison between average cumulative fatigue cracking of the experimental and control sections vs. AADT is provided in Figure 3 below. Averages were calculated by adding up all of the recorded linear feet of cracking of each test section within one of the two mix types and dividing by the total number of test sections.

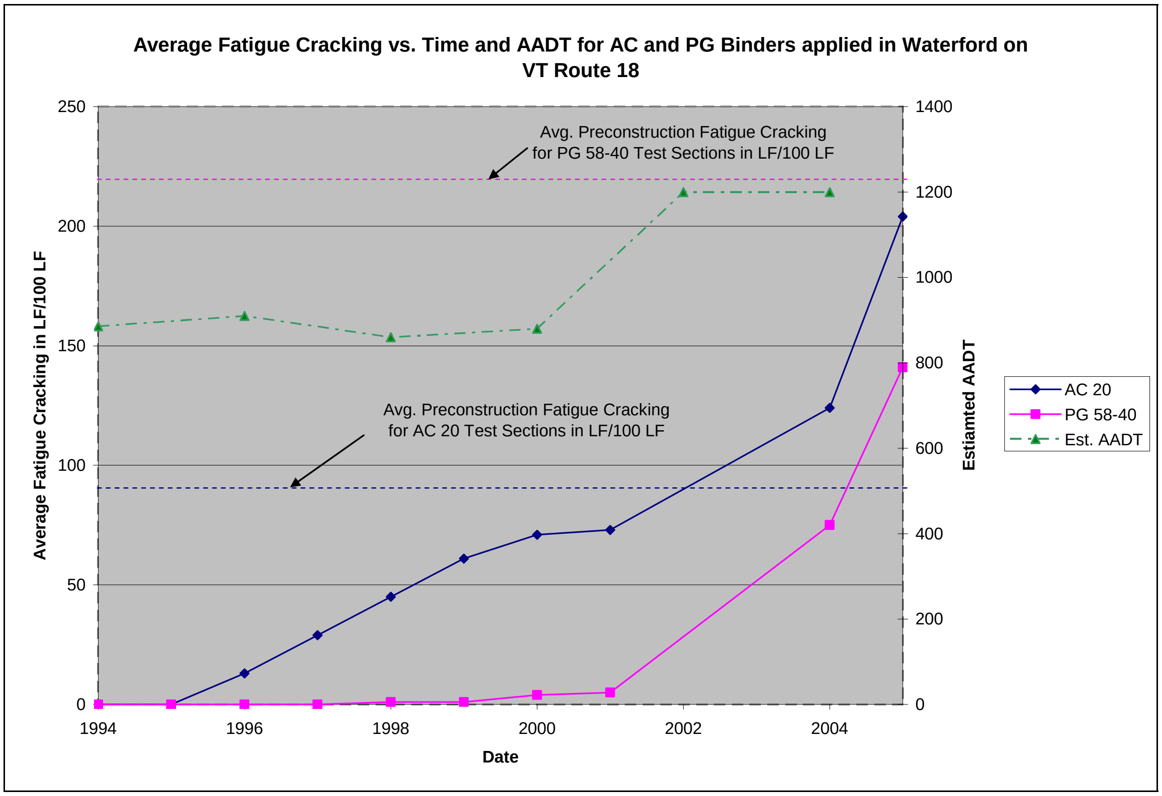

Figure 3

In this case, AADT is a constant variable across all test sections within the investigation. With that in mind, it appears that while the test sections containing the PG binder had a larger amount of preconstruction cracking, 230 LF on average, as compared with the AC binder test sections, 95 LF on average, it is clear the there is a much greater accumulation of fatigue cracking within the AC test sections. Additionally, according to the failure criterion, which is met when the amount of post construction cracking is equal or greater than the amount of preconstruction cracking, the AC graded sections were interpolated to fail for fatigue cracking in 2002. There also appears to be a large increase in fatigue cracking following data collection in 2001 which may be partially attributed to the increase in AADT from 880 in 2000 to 1200 in 2002, as well as, the occurrence of accelerated deterioration over time. A nonlinear relationship between cumulative fatigue cracking and time has also been identified as the slope of the accumulation increases between field visits.

II. Transverse Cracking

The formation of transverse cracking is largely due to climatic conditions and is often induced by freeze-thaw cycles or maximum low temperature shrinkage cracking. One of the main goals of this research was to implement a binder with performance based specifications with regards to temperature. The PG binder was expected to outperform the AC binder at low temperatures as it was designed. In addition to comparison of the cumulative transverse cracking between the experimental and control sections, monthly average minimum temperatures were attained from a weather station that resides in Burlington, VT, and are provided in Figure 4 below:

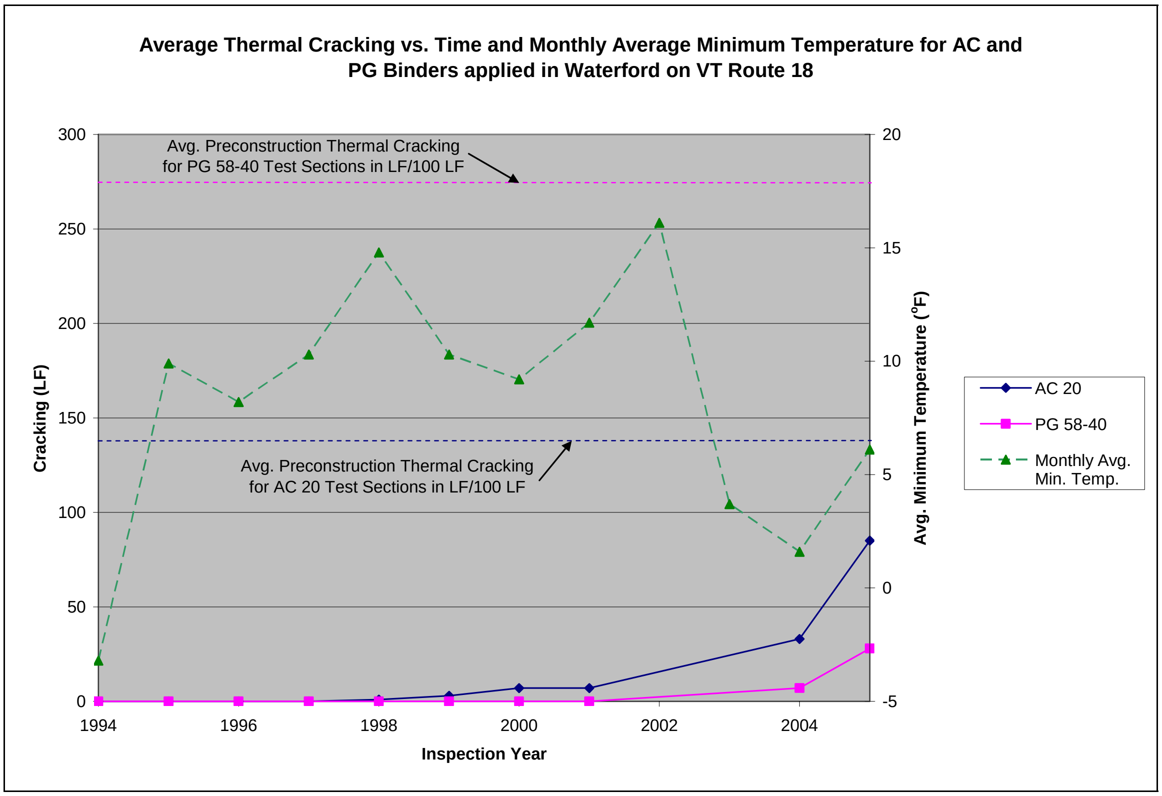

Figure 4

As with AADT, temperature remains a constant variable across all test sections. Although the average length of preconstruction cracking, 257 LF, within the experimental sections is much higher than the average length of preconstruction cracking, 137 LF, within the control sections, the PG graded binder clearly outperformed the AC binder. Although it is not depicted within the graph, as is often the case when calculating averages, two out of six test sections containing the AC binder failed between site visits conducted in 2004 and 2005. Conversely, no test sections have failed with the experimental pavement. While data was not gathered in 2002 and 2003, there is an increase in the accumulation rate of thermal cracking which may be the result of the average minimum temperature of 3.7°F in 2003. The rate of accumulation also increases between 2004 and 2005 which is most likely due to an average minimum temperature of 1.6°F. In any case, a non-linear relationship between rates of accumulation vs. time has been identified. It is important to note that the onset of thermal cracking does not occur with the experimental section until 2002 within the experimental section, while thermal cracking was apparent with control sections during the 1998 field visit. Additionally, there is a larger rate of accumulation within control sections as delineated by slope of the data points.

III. Reflective Cracking

According to Dr. Beatriz Martin-Perez of the National Research Council of Canada, reflective cracking is defined as "the propagation of cracks from the existing pavement into the layer of pavement added (overlay) during rehabilitation." As stated within the "Project Description" section above, the design included reclaimed stabilized base to a depth of 4.5". This process involves the removal of the preexisting pavement. It is less likely to observe reflective cracking with a reclaimed stabilized base as compared to a standard overlay.

An attempt was made to decipher the reflective cracking within all test sections. This is typically performed by overlaying the preconstruction data on top of the post construction data and counting the length of cracks that appear to be similar in location and overall length. However, there is a great deal of variability within the pavement surveys due to the nature of the data collection process, typically involving a large variation in field personnel, who may have differing personal interpretations. Therefore, reflective cracking could not be thoroughly examined.

RUTTING

Rutting is generally caused by permanent deformation within any of the pavements layers or subgrade and is usually caused by consolidation or lateral movement of the materials due to traffic loading. Throughout the duration of the investigation a rut gauge was utilized to quantify the overall depth of rut within each test section. This was done by collecting rut measurements at 50' foot intervals from the beginning to the end of each test section. The measurement was collected by extending a string across the width of the road and measuring the vertical length between the string and the deepest depression within all wheel paths identified along the length of the string. All measurements were recorded onto a standard field form in 1/8" intervals. It is important to note that this procedure is highly subjective due to the nature of the data collection procedure. The following table displays the rut data that was collected throughout the duration of the investigation. All rut data is provided in Appendix B.

Average Rutting in Inches for VT 18 between MM 0.0 and MM 2.9								
	SB Right WP		SB Left WP		NB Left WP		NB Right WP	
Year	AC 20	PG 58-40	AC 20	PG 58-40	AC 20	PG 58-40	AC 20	PG 58-40
1994 (Preconstruction)	0.25	0.38	0.33	0.36	0.25	0.24	0.21	0.29
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	0.10	0.07	0.03	0.06	0.00	0.01	0.00	0.06
1997	0.13	0.06	0.10	0.04	0.01	0.04	0.03	0.06
1998	0.23	0.10	0.14	0.12	0.10	0.08	0.10	0.10
1999	0.27	0.21	0.17	0.21	0.13	0.17	0.16	0.18
2000	0.32	0.23	0.19	0.22	0.17	0.20	0.19	0.20
2001	0.28	0.23	0.22	0.20	0.18	0.18	0.17	0.20
2004	0.31	0.19	0.11	0.17	0.10	0.13	0.12	0.19
2005	0.41	0.35	0.21	0.26	0.19	0.22	0.23	0.26
Percent of Preconstruction:	**164**	**92**	**63**	**72**	**76**	**91**	**110**	**89**

Table 2

In general, the overall depth of rutting increases throughout all test sections on an annual basis. However, the data from 2004 appears to be erroneous as the depth of rut decreases significantly in all cases with the exception of the AC 20 test sections within the southbound right wheel path. According to the project history extracted from the "Pavement Management Database", there was no record of a "rut fill" at any point during the investigation period. Therefore, this data was excluded from the subset. Additionally, there was a greater increase of rutting over time within the right (outside) wheel paths in the southbound and northbound lane for both the AC-20 and PG 58-40 sections which is most likely due to the underlying subgrade and reduced lateral support. It is not conclusive as to which binder performed better with regards to rutting over time.

IRI

IRI, or International Roughness Index, is utilized to characterize the longitudinal profile within wheel paths and constitutes a standardized measurement of smoothness. According to Better Roads Magazine, "the pavement's IRI in inches per mile measures the cumulative movement of the suspension of the quarter-car system divided by the traveled distance. This simulates ride smoothness at 50 miles per hour." IRI values were collected on an annual basis with the exception of 1999 through the Pavement Management Section of VTrans utilizing road profilers. Please note that the data was collected by different vendors through the investigation which resulted in poor correlation between collection events. The following figure provides a summary of the IRI data:

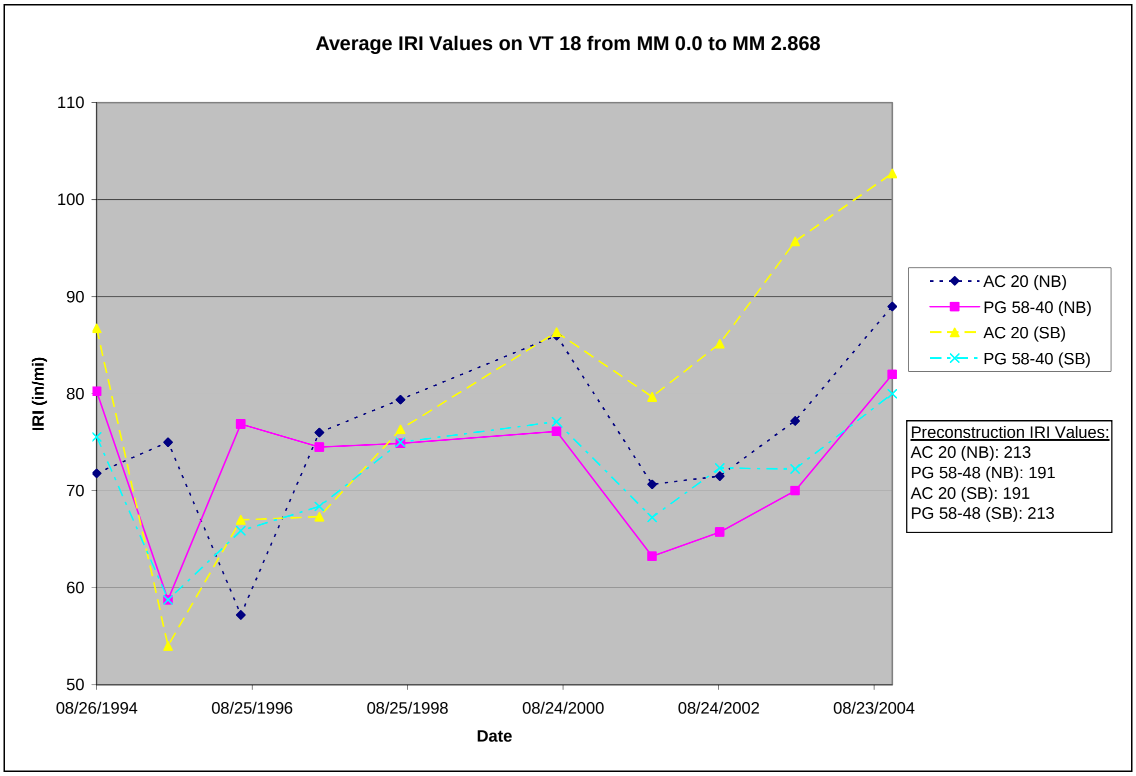

Figure 5

There are some discontinuities within the data set. Usually IRI values are at a minimum immediately following construction as the pavement condition is optimum and will then degrade over time. Therefore, it was anticipated the there would be an upward trend throughout data collection. However the initial IRI values are greater than those from following years which is most likely caused by the variation in testing equipment. The data from 2001 through 2004 does appear to have a consistent upward trend. In 2004, the IRI value was 88 in/mile, well below preconstruction conditions. This inference may not be accurate due to the variability of sampling equipment. It was documented that three different road profilers were utilized for the collection of the IRI values throughout the investing period. Each of the road profilers vary from one another which causes discontinuities between annual data sets. In addition, while the AC-20 sections may appear to increasing at a greater rate than the PG 58-40 sections from 2001 through 2004, it is difficult to make a conclusion with regards to which binder outperformed the other. It is also important to keep in mind that IRI is directly related to all pavement distresses. Due to the fact that the rutting data is inconclusive and the data displays large variations, it is reasonable to presume that a comparison between binder types cannot be made at this time. It is recommended that all future IRI values are collected by the same profiling device for research projects evaluating various pavement treatments in order to provide consistency and accuracy.

SUMMARY:

In conclusion, the PG 58-40 binder well outperformed the AC 20 binder with regards to thermal and load cracking. Conclusions concerning reflective cracking, rutting, and IRI values could not be made due to the large variation within these data sets. The use of performance graded binders is recommended on future paving projects with the caveat that climatic and load information as well as other important parameters is taken into consideration when selecting a binder for a particular paving project.

FOLLOW-UP:

It is recommended that this project is no longer examined.

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Dr. Beatriz Martin-Perez. "IRC Tackles Reflective Cracking Problem in Pavements." Construction Innovation 5.1 (2000) 15 Nov. 2005 <http://irc.nrc-cnrc.gc.ca/pubs/ci/v5no1/v5no1_16_e.html>.

Ruth W. Stidger. "Diagnosing Problem Pavements." Better Roads. June 2002. 15 Nov 2004 <http://www.betterroads.com/articles/jun02b.htm>.

APPENDIX A:
CRACK DATA

					Overall Project Location			Test Section Locations		
PROJECT	PROJECT NUMBER	ROAD	Treatment Type	Details	MM	MM	Total Miles	Test Section ID	Begin MM	End MM
All AC Test Secitons										
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS1	0.15	0.17
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS2	0.31	0.33
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS10	2.20	2.22
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS11	2.40	2.42
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS12	2.60	2.62
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS13	2.80	2.82
All PG Test Sections										
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS4	0.65	0.67
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS5	0.90	0.92
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS6	1.11	1.13
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS7	1.60	1.62
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS8	1.73	1.75
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS9	2.05	2.07

					Overall Project Location			Test Section Locations		
PROJECT	PROJECT NUMBER	ROAD	Treatment Type	Details	MM	MM	Total Miles	Test Section ID	Begin MM	End MM
All AC Test Secitons										
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS1	0.15	0.17
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS2	0.31	0.33
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS10	2.20	2.22
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS11	2.40	2.42
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS12	2.60	2.62
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS13	2.80	2.82
All PG Test Sections										
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS4	0.65	0.67
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS5	0.90	0.92
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS6	1.11	1.13
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Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS8	1.73	1.75
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5", 1.75" Type IIS+1.25" Type IIIS, PG52-40	0.03	2.87	2.83	TS9	2.05	2.07

Pre-Treatment (1994)							1995						
Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking	Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking
All AC Test Secitons													
24	175	98	0	0	90	199	0	0	0	0	0	0	0
0	176	214	34	0	76	176	0	0	0	0	0	0	0
0	130	512	80	0	93	130	0	0	0	0	0	0	0
0	136	724	43	0	78	136	0	0	0	0	0	0	0
0	74	230	5	18	65	74	0	0	0	0	0	0	0
0	104	298	10	0	165	104	0	0	0	0	0	0	0
All PG Test Sections													
0	247	320	35	0	157	247	0	0	0	0	0	0	0
0	261	236	0	0	130	261	0	0	0	0	0	0	0
24	286	214	61	0	162	310	0	0	0	0	0	0	0
0	323	505	0	0	366	323	0	0	0	0	0	0	0
48	241	597	11	0	262	289	0	0	0	0	0	0	0
24	198	635	7	0	305	222	0	0	0	0	0	0	0
2000							2001						
Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking	Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking
All AC Test Secitons													
0	0	0	0	27	0	0	0	0	19	0	27	3	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	21	343	54	0	312	21	0	21	359	76	0	312	21
0	3	136	0	0	79	3	0	3	141	0	0	79	3
0	2	10	3	0	10	2	0	2	27	3	0	17	2
0	18	45	6	0	26	18	0	18	45	15	0	29	18
All PG Test Sections													
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	9	0	0	9	0	0	0	12	0	0	12	0
0	0	2	0	0	2	0	0	0	6	0	0	6	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	28	0	0	14	0	0	0	28	0	0	14	0

1996							1997						
Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking	Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking
All AC Test Secitons													
0	0	0	0	0	0	0	0	0	0	0	19	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	69	14	0	67	1	0	1	162	31	0	160	1
0	0	9	0	0	9	0	0	0	16	0	0	16	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
All PG Test Sections													
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
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0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0

2002							2003						
Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking	Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking
All AC Test Secitons													
All PG Test Sections													

1998							1999						
Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking	Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking
All AC Test Secitons													
0	0	0	0	19	0	0	0	0	0	0	27	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	4	238	41	0	223	4	0	9	329	45	0	304	9
0	0	57	0	0	36	0	0	0	100	0	0	49	0
0	0	0	0	0	0	0	0	2	6	3	0	6	2
0	0	25	6	0	9	0	0	6	25	6	0	9	6
All PG Test Sections													
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	10	0	0	4	0	0	0	10	0	0	4	0

2004							2005						
Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking	Transverse from shoulder to shoulder	All other Transverse cracks	All Longitudinal Cracks	Misc.	CL crack	Fatigue Cracking	All Transverse Cracking
All AC Test Secitons													
0	11	19	0	27	3	11	0	54	120	17	37	97	54
0	0	4	0	0	0	0	0	59	120	22	0	61	59
0	28	400	86	0	341	28	0	43	565	139	0	469	43
0	44	273	32	0	225	44	0	106	395	40	0	311	106
0	38	139	8	0	127	38	0	86	218	22	0	191	86
22	52	66	24	0	48	74	22	142	114	29	0	92	164
All PG Test Sections													
0	0	81	0	0	81	0	0	0	110	10	0	110	0
0	8	76	0	0	67	8	0	51	205	16	0	205	51
0	24	135	11	0	128	24	0	80	203	42	0	165	80
0	10	78	5	0	76	10	0	26	137	28	0	133	26
0	0	22	3	0	14	0	0	6	86	14	0	56	6
0	0	95	0	0	81	0	3	0	205	5	0	176	3

APPENDIX B:
RUT DATA

					Overall Project Location			Test Section Locations				Pre-Treatment (1994)	
PROJECT	PROJECT NUMBER	ROAD	Treatment Type	Details	MM	MM	Total Miles	Test Section ID	Begin MM	End MM	Location	SB Rigth Wheel Path	SB Left Wheel Path
All AC Test Sections													
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS1	0.15	0.17	0+00	0.25	0.25
											0+50	0.00	0.25
											0+100	0.25	1.00
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS2	0.31	0.33	0+00	0.13	0.13
											0+50	0.13	0.13
											0+100	0.25	0.25
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS10	2.20	2.22	0+00	0.38	0.25
											0+50	0.13	0.13
											0+100	0.38	0.38
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS11	2.40	2.42	0+00	0.25	0.38
											0+50	0.25	0.63
											0+100	0.13	0.25
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS12	2.60	2.62	0+00	0.38	0.13
											0+50	0.25	0.25
											0+100	0.25	0.38
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS13	2.80	2.82	0+00	0.00	0.00
											0+50	0.13	0.00
											0+100		0.00
All PG Test Sections													
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS4	0.65	0.67	0+00	0.25	0.13
											0+50	0.25	0.25
											0+100	0.25	0.13
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS5	0.90	0.92	0+00	0.25	0.25
											0+50	0.25	0.25
											0+100	0.13	0.38
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS6	1.11	1.13	0+00	0.25	0.38
											0+50	0.38	0.63
											0+100	0.63	0.63
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS7	1.60	1.62	0+00	0.63	0.50
											0+50	0.63	0.50
											0+100	0.50	0.50
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS8	1.73	1.75	0+00	0.63	0.38
											0+50	0.38	0.38
											0+100	0.88	0.38
Waterford	CMRS 0225 (3)	VT 18	RSB	4.5" RSB, 1.75" Type II, 1.25" Type III	0.03	2.87	2.83	TS9	2.05	2.07	0+00	0.25	0.38
											0+50	0.13	0.25
											0+100	0.25	0.25

Pre-Treatment (1994)		1995				1996				1997			
NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path
All AC Test Sections													
0.13	0.38					0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00
0.25	0.38					0.25	0.00	0.00	0.00	0.25	0.13	0.00	0.00
0.75	0.38					0.13	0.00	0.00	0.13	0.13	0.00	0.00	0.13
0.13	0.13					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.13	0.25					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.13					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.25					0.25	0.00	0.00	0.00	0.25	0.38	0.13	0.13
0.25	0.38					0.25	0.13	0.00	0.00	0.38	0.25	0.00	0.00
0.00	0.25					0.25	0.00	0.00	0.00	0.13	0.25	0.13	0.00
0.13	0.25					0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00
0.13	0.13					0.13	0.13	0.00	0.00	0.13	0.13	0.00	0.00
0.25	0.25					0.13	0.13	0.00	0.00	0.13	0.00	0.00	0.00
0.13	0.25					0.13	0.13	0.00	0.00	0.25	0.13	0.00	0.00
0.25	0.25					0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00
0.13	0.13					0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00
0.13	0.13					0.13	0.00	0.00	0.00	0.13	0.13	0.00	0.13
0.13	0.13					0.13	0.00	0.00	0.13	0.13	0.13	0.00	0.13
0.25	0.13					0.13	0.00	0.00	0.13	0.13	0.00	0.00	0.00
All PG Test Sections													
0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.25	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.00	0.13	0.13	0.13	0.00
0.25	0.13	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.13	0.00
0.13	0.25	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.13	0.13	0.13	0.00
0.25	0.25	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00
0.25	0.25	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.13	0.13	0.00	0.00
0.38	0.38	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13	0.13	0.13	0.00	0.13
0.13	0.50	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13	0.00	0.00	0.00	0.00
0.38	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.13
0.38	0.38	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.13	0.13	0.00	0.00	0.13
0.25	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.13
0.38	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.38
0.38	0.38	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.13	0.00	0.13	0.13
0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.13	0.00	0.13	0.00
0.00	0.25	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.13	0.13	0.13	0.13
0.25	0.13	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.13	0.13	0.00	0.00

1998				1999				2000				2001	
SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path
All AC Test Sections													
0.25	0.13	0.00	0.13	0.13	0.13	0.13	0.00	0.25	0.13	0.13	0.25	0.13	0.13
0.25	0.13	0.00	0.13	0.38	0.13	0.13	0.13	0.38	0.13	0.13	0.13	0.13	0.25
0.13	0.00	0.13	0.25	0.25	0.00	0.13	0.38	0.38	0.13	0.13	0.38	0.13	0.25
0.00	0.13	0.25	0.00	0.00	0.13	0.13	0.00	0.13	0.13	0.25	0.13	0.13	0.13
0.00	0.13	0.25	0.00	0.00	0.00	0.13	0.00	0.13	0.13	0.25	0.13	0.13	0.25
0.25	0.00	0.25	0.00	0.13	0.00	0.13	0.13	0.13	0.13	0.25	0.13	0.13	0.13
0.63	0.25	0.13	0.25	0.50	0.25	0.13	0.25	0.88	0.25	0.25	0.38	1.00	0.38
0.38	0.13	0.13	0.13	0.50	0.25	0.13	0.25	0.50	0.25	0.13	0.25	0.63	0.38
0.38	0.25	0.00	0.00	0.38	0.25	0.13	0.13	0.63	0.25	0.25	0.13	0.50	0.25
0.13	0.13	0.13	0.13	0.25	0.25	0.13	0.13	0.25	0.25	0.25	0.25	0.25	0.25
0.25	0.25	0.13	0.13	0.38	0.25	0.25	0.00	0.38	0.25	0.25	0.13	0.38	0.25
0.13	0.25	0.13	0.13	0.38	0.25	0.25	0.25	0.25	0.25	0.13	0.13	0.25	0.13
0.25	0.13	0.00	0.00	0.38	0.25	0.13	0.25	0.38	0.25	0.13	0.13	0.25	0.13
0.13	0.13	0.13	0.13	0.25	0.25	0.13	0.13	0.25	0.25	0.13	0.13	0.25	0.13
0.13	0.13	0.00	0.13	0.13	0.25	0.00	0.13	0.13	0.13	0.13	0.13	0.25	0.25
0.38	0.13	0.00	0.13	0.25	0.13	0.13	0.25	0.25	0.13	0.13	0.13	0.13	0.13
0.25	0.13	0.00	0.13	0.38	0.25	0.13	0.25	0.25	0.25	0.13	0.25	0.25	0.25
0.25	0.13	0.13	0.00	0.25	0.13	0.13	0.25	0.25	0.13	0.13	0.25	0.13	0.25
All PG Test Sections													
0.00	0.00	0.13	0.00	0.25	0.13	0.13	0.13	0.13	0.13	0.13	0.00	0.13	0.13
0.00	0.13	0.13	0.00	0.00	0.13	0.25	0.13	0.00	0.13	0.25	0.13	0.13	0.13
0.00	0.13	0.13	0.00	0.00	0.13	0.13	0.00	0.13	0.13	0.13	0.13	0.13	0.13
0.13	0.13	0.13	0.13	0.25	0.25	0.25	0.13	0.38	0.38	0.25	0.25	0.38	0.25
0.00	0.13	0.13	0.00	0.25	0.38	0.25	0.25	0.25	0.25	0.25	0.13	0.25	0.13
0.13	0.13	0.13	0.00	0.25	0.25	0.13	0.25	0.25	0.25	0.13	0.25	0.25	0.25
0.13	0.13	0.00	0.13	0.25	0.25	0.25	0.13	0.25	0.13	0.25	0.13		
0.13	0.13	0.00	0.13	0.25	0.25	0.13	0.13	0.25	0.25	0.13	0.13		
0.13	0.13	0.00	0.25	0.13	0.38	0.38	0.25	0.25	0.25	0.25	0.38		
0.13	0.13	0.13	0.13	0.25	0.38	0.25	0.13	0.25	0.25	0.25	0.25	0.25	0.25
0.13	0.13	0.00	0.13	0.25	0.13	0.13	0.25	0.25	0.25	0.25	0.25	0.25	0.25
0.13	0.13	0.00	0.13	0.38	0.25	0.13	0.13	0.25	0.25	0.25	0.25	0.25	0.25
0.13	0.13	0.13	0.25	0.13	0.13	0.25	0.25	0.25	0.13	0.25	0.25	0.25	0.25
0.00	0.13	0.13	0.25	0.00	0.13	0.13	0.25	0.13	0.13	0.13	0.25	0.13	0.13
0.13	0.13	0.13	0.13	0.25	0.13	0.13	0.25	0.25	0.25	0.25	0.25	0.25	0.13
0.25	0.13	0.13	0.13	0.38	0.25	0.13	0.13	0.38	0.25	0.25	0.25	0.25	0.25
0.25	0.13	0.00	0.13	0.25	0.13	0.00	0.25	0.25	0.25	0.13	0.25	0.25	0.25
0.13	0.13	0.00	0.00	0.25	0.13	0.13	0.25	0.25	0.25	0.13	0.13	0.25	0.25

2001		2002				2003				2004			
NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path	SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path
All AC Test Sections													
0.13	0.13									0.00	0.13	0.13	0.25
0.13	0.13									0.00	0.00	0.00	0.00
0.00	0.25									0.00	0.13	0.00	0.25
0.25	0.13									0.00	0.00	0.00	0.00
0.25	0.13									0.00	0.00	0.00	0.00
0.13	0.25									0.00	0.00	0.00	0.00
0.25	0.25									1.38	0.25	0.13	0.25
0.13	0.25									0.75	0.13	0.13	0.13
0.25	0.25									1.25	0.13	0.38	0.13
0.25	0.13									0.25	0.25	0.13	0.13
0.25	0.25									0.88	0.13	0.13	0.13
0.25	0.13									0.63	0.25	0.13	0.13
0.13	0.13									0.38	0.13	0.13	0.13
0.13	0.25									0.13	0.13	0.13	0.13
0.13	0.13									0.13	0.13	0.13	0.13
0.13	0.13									0.25	0.13	0.00	0.13
0.25	0.13									0.25	0.38	0.13	0.38
0.25	0.13									0.25	0.13	0.25	0.25
All PG Test Sections													
0.13	0.13									0.00	0.13	0.25	0.13
0.13	0.13									0.13	0.13	0.13	0.13
0.13	0.13									0.13	0.13	0.13	0.13
0.25	0.25									0.00	0.25	0.13	0.00
0.25	0.25									0.00	0.00	0.13	0.00
0.13	0.25									0.13	0.00	0.00	0.00
										0.13	0.13	0.13	0.25
										0.38	0.13	0.13	0.13
										0.25	0.25	0.13	0.38
0.25	0.25									0.25	0.25	0.13	0.25
0.13	0.25									0.25	0.25	0.13	0.25
0.25	0.13									0.25	0.25	0.13	0.25
0.13	0.25									0.25	0.13	0.13	0.38
0.25	0.13									0.13	0.13	0.13	0.38
0.13	0.25									0.25	0.13	0.13	0.25
0.25	0.25									0.25	0.13	0.13	0.13
0.13	0.25									0.50	0.38	0.13	0.38
0.13	0.13									0.13	0.25	0.13	0.13

2005			
SB Rigth Wheel Path	SB Left Wheel Path	NB Left Wheel Path	NB Right Wheel Path
All AC Test Sections			
0.25	0.13	0.13	0.25
0.63	0.13	0.13	0.13
0.50	0.25	0.25	0.50
0.13	0.25	0.25	0.13
0.13	0.13	0.25	0.13
0.25	0.13	0.13	0.13
0.28	0.38	0.25	0.50
0.88	0.25	0.25	0.25
1.50	0.38	0.38	0.25
0.38	0.38	0.25	0.25
0.75	0.25	0.25	0.38
0.88	0.38	0.25	0.25
0.63	0.25	0.13	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.38	0.25	0.13	0.13
0.38	0.25	0.25	0.38
0.25	0.13	0.25	0.38
All PG Test Sections			
0.13	0.13	0.25	0.13
0.13	0.25	0.25	0.13
0.13	0.25	0.25	0.13
0.50	0.38	0.38	0.25
0.25	0.25	0.25	0.25
0.50	0.25	0.25	0.13
0.63	0.25	0.25	0.25
0.50	0.38	0.13	0.25
0.25	0.25	0.25	0.38
0.38	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.50	0.25	0.25	0.25
0.38	0.13	0.25	0.38
0.25	0.25	0.25	0.38
0.38	0.25	0.13	0.38
0.38	0.25	0.13	0.13
0.50	0.38	0.13	0.75
0.25	0.25	0.13	0.13