Influence of Dynamic Modulus on M-EPDG Outputs

Marta Juhasz, P.Eng.
Surfacing Standards Specialist
Alberta Transportation
Edmonton, Alberta

Chuck McMillan, M.Sc., P.Eng.
Director, Surface Engineering and Aggregates
Alberta Transportation
Edmonton, Alberta

ABSTRACT

The dynamic modulus (E*) of an asphalt mix characterizes its stiffness response under sinusoidal loading. A key input parameter into the Mechanistic-Empirical Pavement Design Guide (M-EPDG), E* represents a level 1 hierarchical input. It is also remains a parameter with which most practitioners have little experience.

In anticipation of the future implementation of the M-EPDG, Alberta Transportation has undertaken several years of E* testing of select asphalt concrete pavement mixtures. The intent of this testing was to develop some background on the range of values that might be expected and to confirm any differences between different mix types.

In 2009, initial E* testing work was presented. This paper compares all of Alberta Transportation's current E* test results to those from the Witczak predictive equation, documents Alberta Transportation's efforts at quantifying axle load spectra and other inputs for the M-EPDG software, and provides a sensitivity analysis of M-EPDG project output on the basis of actual versus predicted E* values. The findings of this work highlight the significance of E* values across the spectrum of temperatures and loading times and the importance of understanding asphalt mix behaviour across the full spectrum of operating conditions of in-service asphalt pavements.

RÉSUMÉ

Le module dynamique (E*) d'un enrobé bitumineux caractérise sa réponse de rigidité sous chargement sinusoïdal. Un paramètre clé dans le guide de design mécanistique empirique de la chaussée (DMEC) représente un input hiérarchique de niveau 1. C'est aussi un paramètre avec lequel la plupart des praticiens ont peu d'expérience.

En anticipation de la future implémentation du DMEC, Transports Alberta a entrepris plusieurs années de tests d'enrobés choisis de béton bitumineux. Le but de ces tests est de développer des données sur l'étendue des valeurs que l'on peut attendre et de confirmer toutes différences entre différents types d'enrobés.

En 2009, le travail des essais E* a été présenté. Cet exposé compare tous les résultats courants des essais E* de Transports Alberta à ceux de l'équation prophétique de Witczak, documente les efforts de Transports Alberta à quantifier les spectres des charges axiales et autres données pour le programme DMEC et fournit une analyse de sensibilité des données des projets DMEC sur la base des valeurs E* actuelles versus celles prédites. Les résultats de ce travail soulignent l'importance des valeurs E* à travers le spectre de températures et les temps de chargement et aussi l'importance de comprendre le comportement des enrobés bitumineux dans le spectre complet des conditions d'opération des revêtements bitumineux en service.

1.0 INTRODUCTION

The dynamic modulus (E*) of an asphalt mix characterizes its stiffness response under sinusoidal loading. A key input parameter into the Mechanistic-Empirical Pavement Design Guide (M-EPDG), E* represents a Level 1 hierarchical input. It is also remains a parameter with which most pavement designers have little experience.

In anticipation of the future implementation of the M-EPDG, Alberta Transportation undertook three years of E* testing of select asphalt concrete pavement mixtures. The intent of this testing was to develop some background on the range of values that might be expected and to confirm any differences between different mix types.

In addition to materials characterization, the traffic inputs, including axle load spectra, are a further significant change from current pavement design practices. Weigh-In-Motion (WIM) data from the six Alberta sites has been processed and preliminary comparisons to the M-EPDG defaults are also provided.

2.0 E* TEST DATA

In 2009, initial E* testing work was presented at CTAA [1]. That work provided a comparison of E* test results to the Witczak predictive equation for all mixes tested at 25 Hz and 21.1°C. It was generally found that the predictive equation under-predicted E* by about 15 percent at that frequency and temperature. For the 25 mixes tested, a comparison of all E* results to the predictive equation is provided in Figure 1.

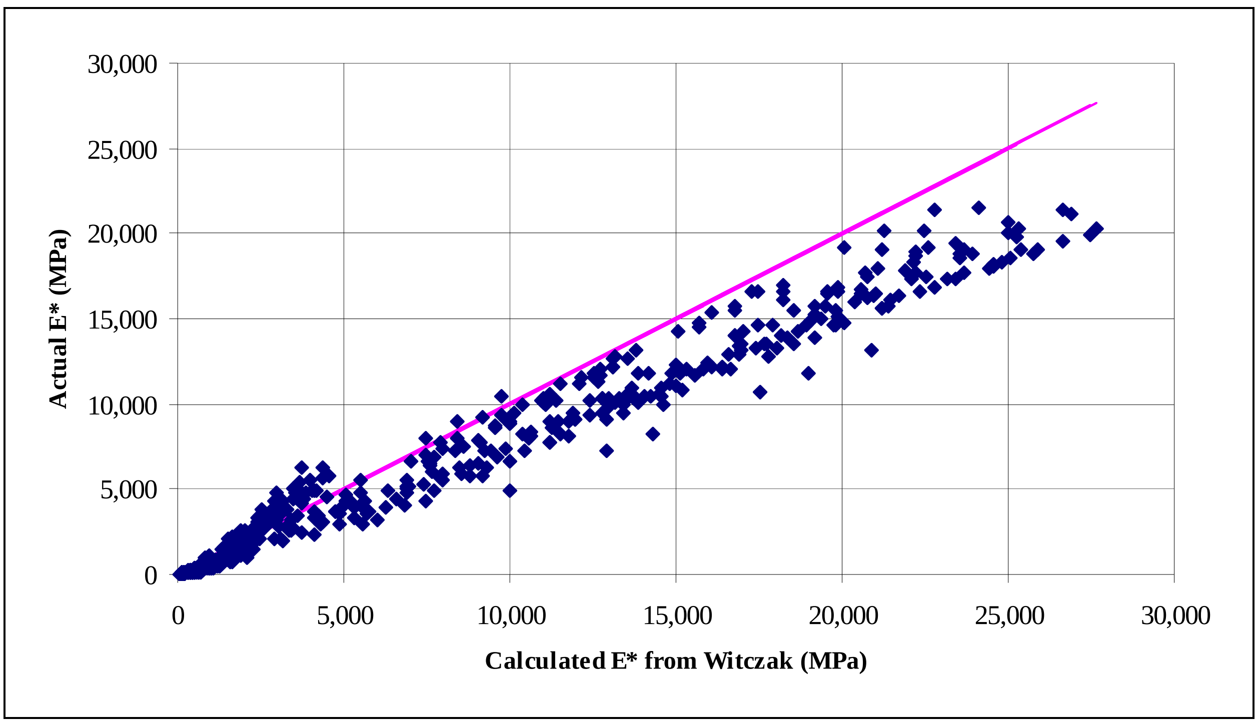

Figure 1. Comparison of E* Test Results to Witczak Predictive Equation

In general, it can be seen that the predictive equation over-predicts E*. On a whole, the average over-prediction by the Witczak equation is 28 percent. However, when the percentage of over-prediction is plotted as in Figure 2, it can be seen that the differences are in fact more significant at the lower modulus values. Of note as well is that the obvious straight line outliers below the line of equality in Figure 1, which are the same outliers in Figure 2 between 10,000 and 23,000 MPa at around 40 percent over-prediction, are all related to a PG 70-28 modified asphalt binder tested at 4.4°C. The as-tested viscosity at this temperature was quite high and this affects the results of the Witczak predictive equation since viscosity is a required input. Additionally, the majority of the outliers above the line of equality in Figure 1, which are also those below zero percent in Figure 2, are related to testing at 21°C. This explains why the initial department work [1] reported that the predictive equation was under-predicting E* at 25 Hz and 21.1°C. The reasons for these under-predictions are not yet readily apparent as they span multiple projects, years of testing, frequencies, mix types and asphalt cement grades.

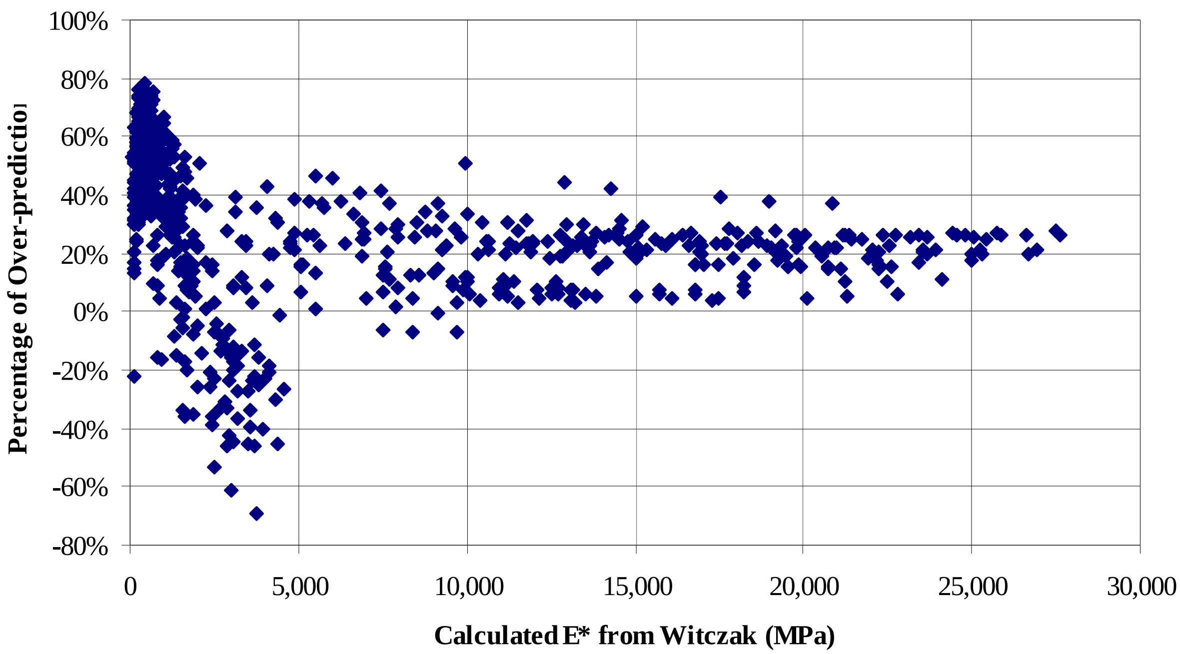

Figure 2. Percentage of Over-prediction of Witczak Predictive Equation

It is important to note that there is some concern with the reasonableness of the department's E* test results at 54.4°C and lower frequencies given that many results are lower than 100 MPa which would be softer than many unbound materials. All E* results have been run through complex plane and Black space diagrams to confirm their validity [2]. This work suggests no major issues although the odd data outliers have been noted.

Figure 3 provides a master curve comparison of the department tested E* results to that from the E* results from the Witczak predictive equation for the H1 mix type and PG 58-34 asphalt cement from the department's Stony Trail (Highway 201:08) project. The master curves were generated using the M-EPDG software and actual complex modulus data (G*) for the asphalt binder. Figure 3 also includes the master curves generated by the software by simply inputting mix gradation and using G* data and Superpave binder grade.

Consistent with the results from Figure 2, the master curve of the department E* is comparable at higher modulus values but divergent at lower modulus from the master curve from the Witczak E* predictive values. The master curve from the Witczak E* predictive values is very similar to but not exactly the same as that from the gradation only data. Although the viscosity curves are identical (because of the same G* data), the master curve shift factors are not the same. This could be due to a number of reasons such as rounding differences between the department's database to calculate E* versus the M-EPDG.

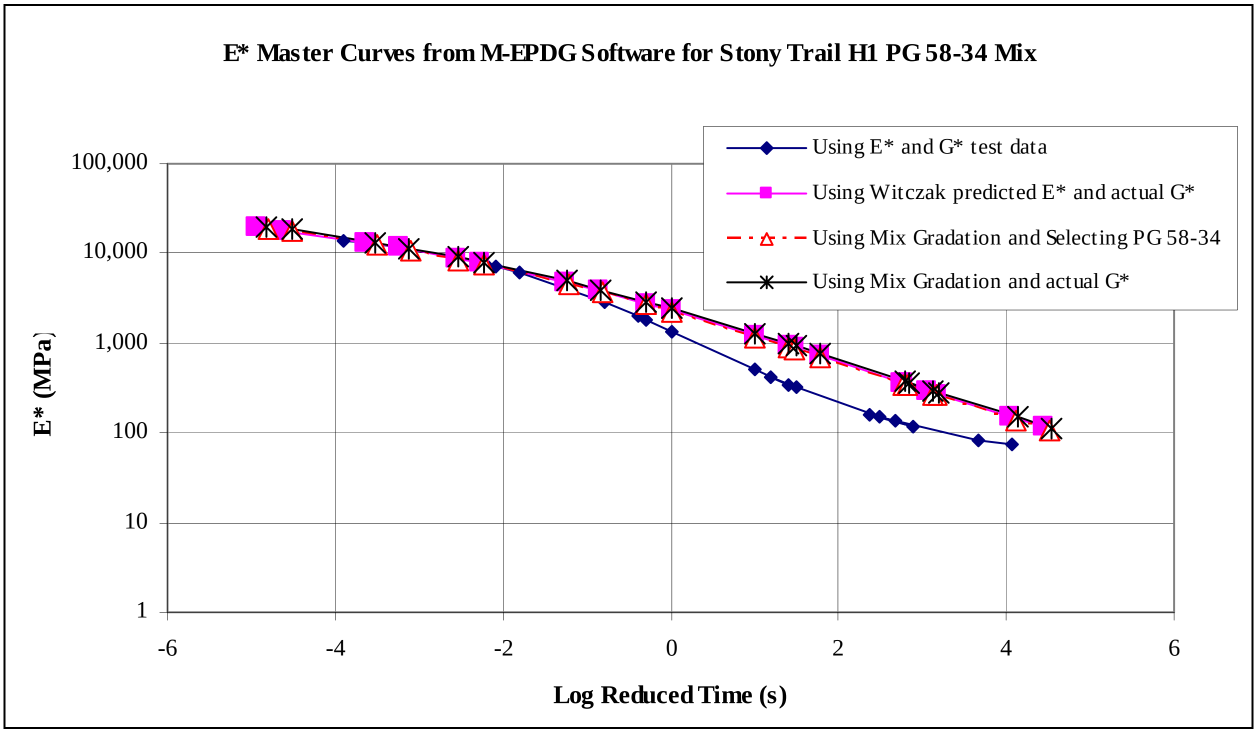

Figure 3. Comparison of M-EPDG Generated Master Curves

3.0 SENSITIVITY OF M-EDPG OUTPUTS TO E*

Project runs were done using the M-EPDG software to test the sensitivity of the outputs to E* values. The project modeled is the newly constructed Stony Trail project (Highway 201:08) in the Calgary area. The project pavement design is 240 mm of asphalt concrete pavement (ACP) on 450 mm of Granular Base Course (GBC), of which the GBC and 150 mm first stage Asphalt Concrete Pavement (ACP) have been constructed to date.

3.1 Project Inputs

A detailed M-EPDG input file containing the below described inputs is provided in Appendix A. The file is in US Customary units as the software is not yet metric compatible.

3.1.1 Project Analysis Parameters

Project analysis parameters were based on typical department values, engineering judgement and design criteria in the M-EPDG Manual of Practice [3]. An initial IRI value of 0.9 mm/m was chosen based on as-constructed data. The performance limit for IRI was based on the department trigger IRI for rehabilitation of 1.9 mm/m for this functional class of highway. Because the department has little experience with surface down cracking, the default value of 380 m/km (2000 ft/mile) was used. A value of 10 percent was chosen for bottom up alligator cracking. The thermal cracking analysis parameter value was set at 10 cracks per kilometre which was deemed to be a reasonable level for this type of new construction and recognizing that the modified PG 58-34 asphalt used on this project should be able to withstand thermal cracking in this area. It is important to note that 10 cracks per kilometre translates to 384 feet of cracking per mile based on 2 lanes in the design direction and 3.7 m (12 ft) lane widths. Permanent deformation limits were set at 13 mm within the asphalt layer and 19 mm total. Reliability levels were set at 95 percent.

3.1.2 Traffic Inputs

Truck traffic inputs were based on using M-EPDG default axle load spectra, hourly and monthly adjustment factors but adjusting the vehicle class distribution percentages and using the design traffic growth rate of four percent compounded. The vehicle class distribution percentages were adjusted such that the M-EPDG 20 year flexible ESAL output matched the department calculated 20-year design equivalent single axle loads of 11.6 million. Given that this highway is a 4 lane divided highway, a 50 percent directional split and an 85 percent design lane split were chosen as per department practice. Note that Section 4.0 discusses some of Alberta's actual axle load spectra data but for these initial project runs default traffic data was used.

3.1.3 Climate Inputs

An integrated climatic model (.icm) file was generated for use by interpolating between the Calgary airport and Springbank airport climate files. The water table depth was assumed to be 3 m based on discussion with department geotechnical personnel, although a water table depth of half this made no difference to the predicted performance.

In general the relatively low number of sites, at 27, and geographic location and age of the data within the climate files available for Alberta will make it difficult to generate quality .icm files for various areas around the province. This is likely also true for many regions in Canada.

3.1.4 Material Inputs

Project borehole data collected at the preliminary design stage was used to characterize the subgrade (low plastic clay) and for Atterberg limit input, although the default gradation within the software was used. A typical department design value of 30 MPa was selected as the subgrade strength. For analysis purposes, the subgrade was split into 2 layers, with the bottom layer being uncompacted and semi-infinite (i.e. natural soil), and the top layer being a 600 millimetre compacted layer which would be the minimum depth of compacted grade as per department requirements.

Project Quality Assurance (QA) data was used for GBC gradation. The GBC thickness was split into two layers to account for decompaction of the bottom six inches based on Figure 12-2 of the Manual of

Practice [3] and the strength of the bottom 150 mm of GBC was also based on Figure 12-2. An assumed GBC strength of 210 MPa was used for the upper 300 mm of GBC based on a typical department strength coefficient (a_i) of 0.14 (note the M-EPDG software converts an a_i of 0.14 to 210 MPa or 30,000 psi).

Actual E* and G* test data were used for the ACP layers with other ACP inputs being based on first stage project QA data. ACP thermal cracking inputs (tensile strength and creep compliance) were also used as data is from actual department test results, which appear reasonable when compared to the M-EPDG defaults.

3.2 Project Output Comparison

A number of different projects runs were put through the M-EPDG software to determine the sensitivity of the outputs. The "base case" used the inputs as described above which would be a Level 1 hierarchical input level for the ACP. A Level 2 project was run and this used the gradation data for the ACP but still used the G* data – in this case the M-EPDG software would use Witczak's predictive equation to determine E*. A Level 3 project was also run and this used the gradation data and simply the Superpave asphalt binder type (a PG 58-34) instead of the G* data. Other variations with respect to asphalt grade and mix type (i.e. using the same mix type but a 120-150A asphalt cement; using a L1 mix type and a 200-300A asphalt cement) were also run through the M-EPDG software to determine the sensitivity of the predicted distress. The reliability summaries of these project runs are shown in Table 1 and have been converted to metric. The distress summary for the "base case" project is provided in Appendix B (in U.S. Customary units).

Subgrade rutting and IRI met the performance criteria but not at the desired reliability; subgrade rutting reliability ranged from 15 to 45 percent while and IRI reliability was typically 40 to 45 percent. Of note is that the first month of total rutting (see Appendix B) of 6.9 mm, 6.4 mm of which is predicted to be below the ACP, is high, does not match with in-field observations for this project, and is similar to the early age rutting over-prediction that has been reported elsewhere [4].

All other distresses met the performance criteria at the desired reliability. The results in Table 1 show that the M-EPDG outputs, for the Stony Trail project, are relatively insensitive to using actual E* data versus the predicted E* from gradation data inputs. Rutting prediction does appear to be sensitive to mix type and asphalt grade.

4.0 COMPARISON OF ALBERTA TRANSPORTATION AXLE LOAD DATA TO M-EPDG DEFAULTS

Alberta Transportation owns six weigh-in-motion (WIM) scales across the province and these have been collecting data since September 2004. A map of these locations is provided in Figure 4. The WIM sensors cover all lanes in both directions at their respective sites, with four sites having two lanes in each direction and two sites having one lane in each direction.

Table 1. M-EPDG Output Comparison

Performance Criteria	Distress Targets	Stony Trail Project Predicted Distress						
		Level 1, tested E* and G*	Level 2, gradation and G* (predicted E*)	Level 3, gradation and PG 58-34 (predicted E*)	Level 1, 120-150A[1] asphalt	Level 1, L1[2] 200-300A asphalt	Level 1, 40 MPa subgrade	Level 1, First Stage (150 mm ACP, 450 mm GBC)
Terminal IRI (mm/m)	1.9	2.0	1.9	1.9	1.9	2.2	1.9	2.2
ACP Surface Down Cracking (Long. Cracking) (m/km)	380 (2000 ft/mile)	0	0	0	0	0.2	0	0.2
ACP Bottom Up Cracking (Alligator Cracking) (%)	10	0.7	0.5	0.5	0.2	0.2	0.6	5.1
ACP Transverse Cracking (length of cracks m/km)	384	0	0	0	0	0	0	0
Rutting (ACP Only) (mm)	13.0	6.6	4.8	5.1	5.1	13.2	6.6	8.9
Rutting (Total Pavement) (mm)	19.0	22.0	19.6	20.0	20.3	29.2	19.6	29.0

[1] Mix input volumetric values unchanged from Level 1 project inputs despite different mix type and asphalt grade.
[2] L1 is a low traffic mix; volumetrics unchanged but E* values increased where required to meet minimum input requirements.

Note: IRI is the International Roughness Index
ACP is Asphalt Concrete Pavement
GBC is Granular Base Course

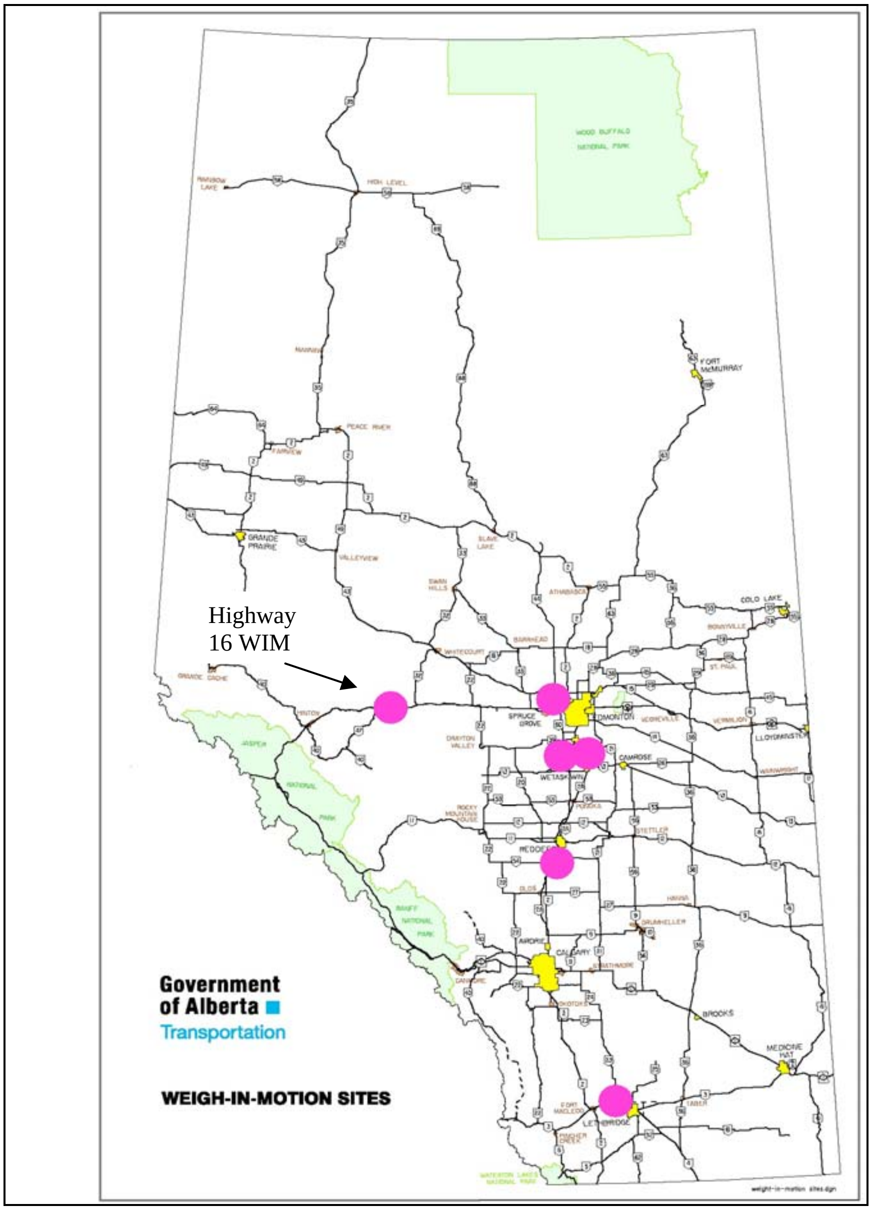

Figure 4. Location of Alberta Transportation Weigh-in-Motion (WIM) Sites

In early 2010, 2009 WIM data processed for M-EPDG input was obtained for all sites. Table 2 compares the average of the 4 lanes from the highway 16 WIM site to the M-EPDG defaults for axles per truck. The comparison shows that the defaults are not that different from actual data with the exception of Class 4 (busses), Class 11 (five axles or less multi-trailer trucks) and Class 13 (seven axles or more multi-trailer trucks) vehicles.

Table 3 provides the highway 16 WIM monthly adjustment factors (MAF). Of note is that the M-EPDG defaults are 1 for every month and truck class. The data in Table 3 shows that the actual MAF are somewhat different from the MEPDG defaults.

Table 2. Comparison of M-EPDG Defaults for Axles per Truck to 2009 Highway 16 WIM

	M-EDPG Defaults				Highway 16 WIM site (average of 4 lanes)			
FHWA Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0	1.29	0.72	0	0
Class 5	2	0	0	0	2.01	0.35	0.04	0
Class 6	1.02	0.99	0	0	1	1	0	0
Class 7	1	0.26	0.83	0	1	0	1	0
Class 8	2.38	0.67	0	0	2.31	0.71	0	0
Class 9	1.13	1.93	0	0	1.03	1.98	0.01	0
Class 10	1.19	1.09	0.89	0	1	1	1	0
Class 11	4.29	0.26	0.06	0	3.50	0.13	0	0
Class 12	3.52	1.14	0.06	0	4	1	0	0
Class 13	2.15	2.13	0.35	0	1.03	1.79	1.05	0

Note: WIM is Weigh in Motion and M-EPDG is the Mechanistic-Empirical Pavement Design Guide.

Table 3. 2009 Highway 16 WIM Monthly Adjustment Factors per Truck Class

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1.31	0.71	1.22	1.29	0.92	1.09	1.26	1.88	1.32	1.30
February	1.19	0.58	1.04	1.14	0.79	0.94	1.13	0.19	0.43	1.06
March	0.97	0.84	1.18	1.22	0.77	0.89	1.09	0.00	0.78	0.94
April	0.63	0.71	0.69	0.46	0.66	0.86	0.62	0.19	0.55	0.76
May	0.75	0.84	0.77	0.61	0.97	0.91	0.68	0.38	0.62	0.78
June	0.93	1.19	1.00	0.97	1.00	1.03	1.04	0.75	1.26	0.92
July	0.88	1.63	0.99	1.00	1.34	1.10	0.88	1.31	1.83	0.92
August	0.95	1.77	0.85	0.91	1.17	1.12	0.93	0.94	0.87	0.99
September	1.01	1.28	0.97	0.97	1.20	1.03	0.99	2.06	0.46	0.99
October	1.11	1.00	1.04	0.85	0.94	1.05	1.12	1.13	1.26	1.03
November	1.03	0.70	0.92	1.07	1.04	0.94	1.08	0.00	0.50	1.00
December	1.26	0.77	1.33	1.53	1.21	1.05	1.20	0.19	2.12	1.34

Note: WIM is Weigh in Motion.

Based on the department's Traffic Volume, Vehicle Classification, Travel and ESAL Statistics Report [5], which indicates that vehicle class percentages in the vicinity of the highway 16 WIM station are 0.3 percent for busses, 5.0 percent for single unit trucks and 17.8 percent for tractor trailer trucks, select default M-EPDG vehicle classification distributions were chosen for comparison purposes. Table 4 compares these M-EPDG defaults to the data for the highway 16 WIM site. The comparison indicates that for highway 16 there are a higher percentage of Class 10 vehicles (six or more axle single trailer trucks) and Class 13 vehicles (seven or more axle multi-trailer trucks), and less Class 9 vehicles (5 axle single trailer trucks).

Table 4. M-EPDG Default Vehicle Class Distributions vs. 2009 Highway 16 WIM Data

	M-EPDG Default Distributions, Principle Arterial Interstate and Defense Routes, %				**Highway 16 WIM Distribution, %**
Class	Predominately single Trailer Trucks	High percentage of single-trailer truck with some single-unit trucks	Mixed truck traffic with a higher percentage of single-trailer trucks	Mixed truck traffic with about equal percentages of single-unit and single-trailer trucks	
4	0.9	1.7	1.8	0.8	3.4
5	14.2	19.3	24.6	33.6	24.6
6	3.5	4.6	7.6	6.2	3.8
7	0.6	0.9	0.5	0.1	1.4
8	6.9	6.7	5.0	7.9	0.7
9	54.0	44.8	31.3	26.0	16.4
10	5.0	6.0	9.8	10.5	21.8
11	2.7	2.6	0.8	1.4	0.0
12	1.2	1.6	3.3	3.2	0.2
13	11.0	11.8	15.3	10.3	27.7

Note: WIM is Weigh in Motion.

Figure 5. M-EPDG Default Axle Load Factors vs. 2009 Highway 16 WIM, Class 5, Single Axles

Figures 5 through 10 compare select axle load distributions from the Highway 16 WIM site to the defaults within the M-EPDG. For the sake of avoiding unit conversions, the data is presented in the default software unit of pounds. The comparisons show that the M-EPDG defaults are not that dissimilar from the Highway 16 WIM station with generally somewhat higher axle loads from the WIM station which in not unexpected given the allowable higher axle weights in Canada when compared to the United States.

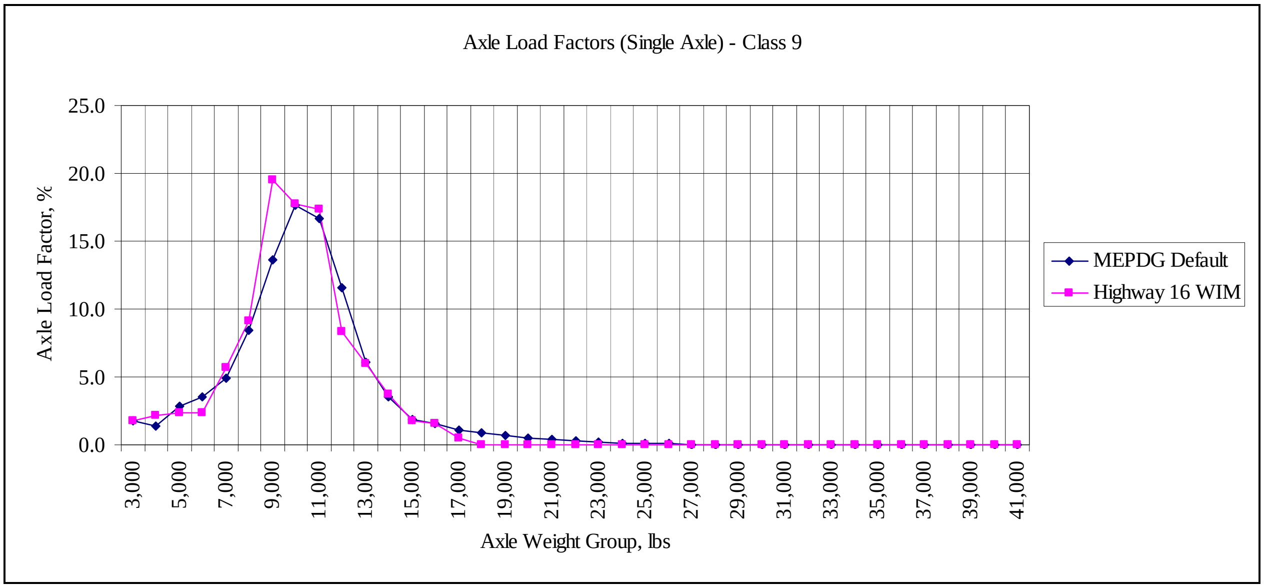

Figure 6. M-EPDG Default Axle Load Factors vs. 2009 Highway 16 WIM, Class 9, Single Axles

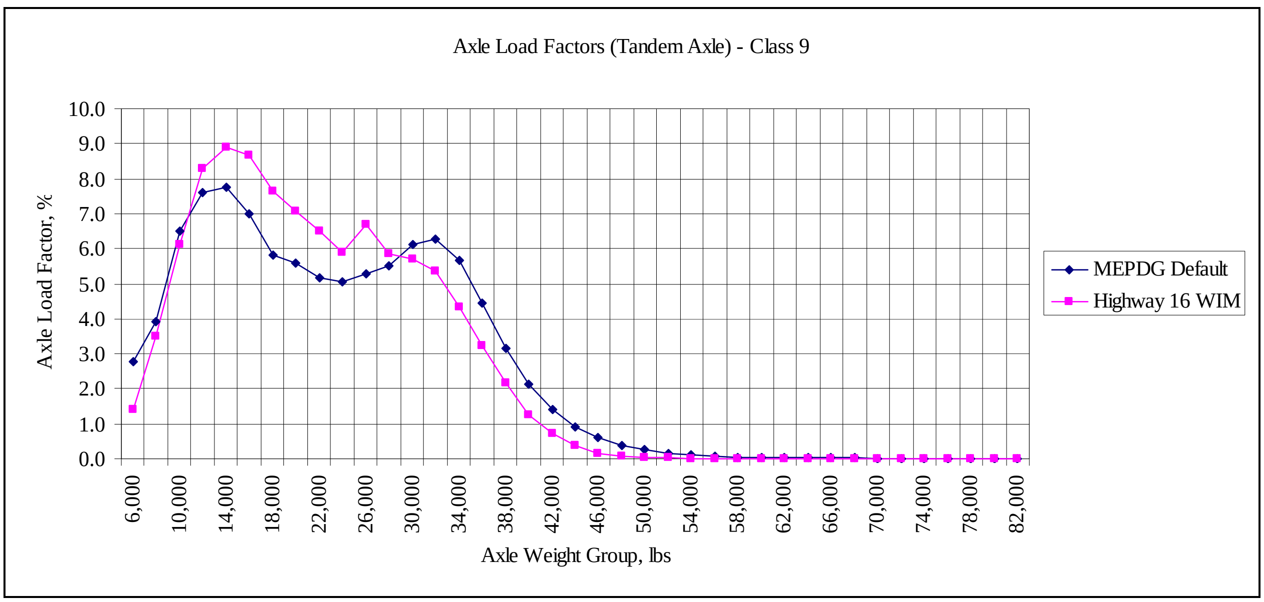

Figure 7. M-EPDG Default Axle Load Factors vs. Highway 16 WIM, Class 9, Tandem Axles

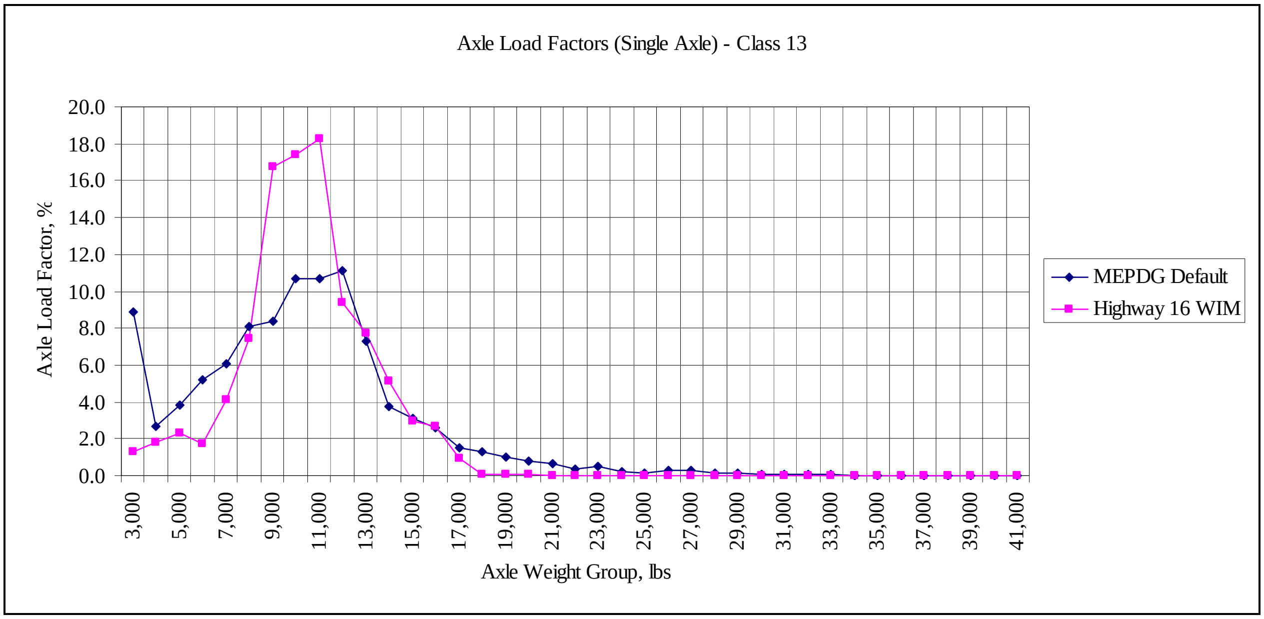

Figure 8. M-EPDG Default Axle Load Factors vs. Highway 16 WIM, Class 13, Single Axles

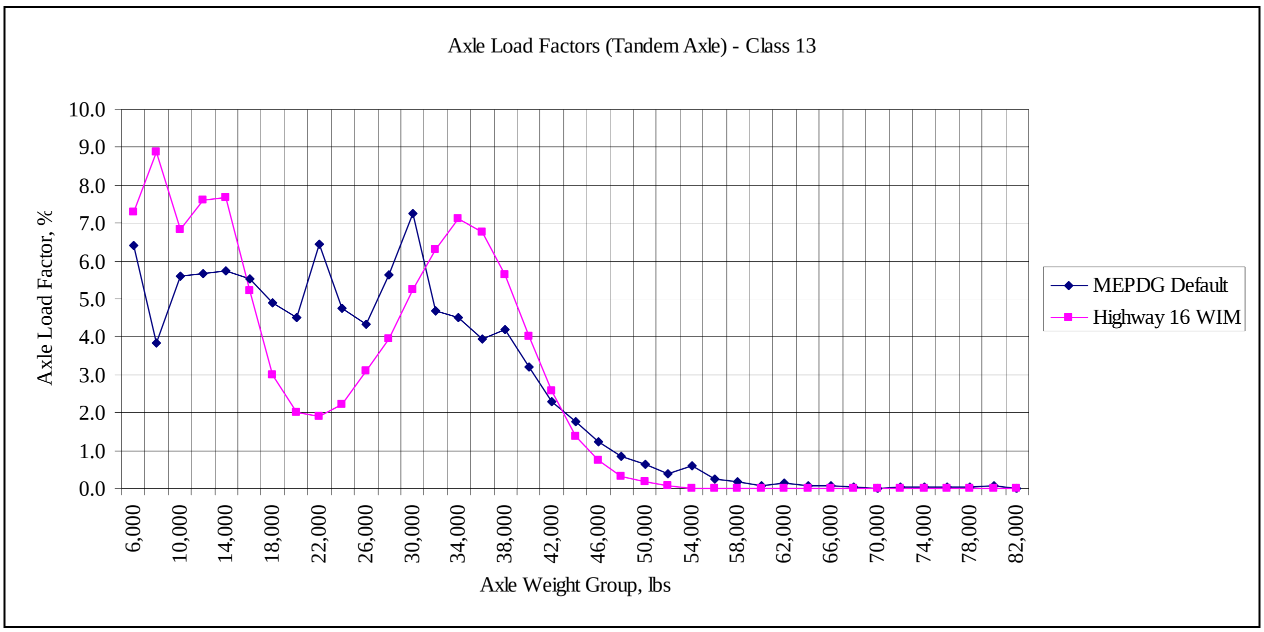

Figure 9. M-EPDG Default Axle Load Factors vs. Highway 16 WIM, Class 13, Tandem Axles

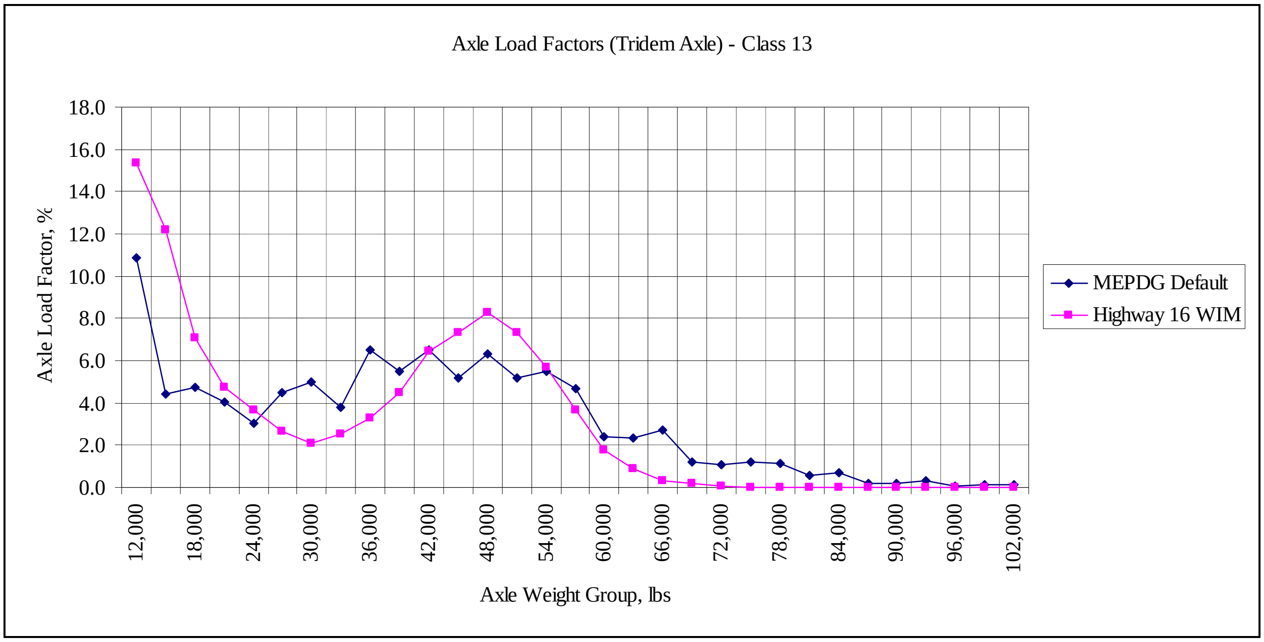

Figure 10. M-EPDG Default Axle Load Factors vs. Highway 16 WIM, Class 13, Tridem Axles

5.0 CONCLUSIONS

Based on the comparison the Alberta Transportation E* data to the results from the Witczak predictive equation, the Witczak predictive equation over-predicts E* particularly at low temperatures. Despite this difference, for the Stony Trail project example, the M-EPDG outputs do not appear overly sensitive to actual versus predicted E* values. Further work is required to confirm the reasonableness of all Alberta Transportation's E* test results.

With respect to M-EPDG default truck traffic data, based on very limited comparisons, the M-EPDG defaults for axles per truck and monthly adjustment factors appear to compare reasonably well to actual Alberta data. Vehicle class distribution data appears to indicate a tendency toward more multi-trailer vehicles in Alberta. Axle load distribution data appears to indicate that the software defaults compare reasonably well to actual WIM data but are generally slightly lower. Additional work is required to determine the significance and sensitivity of any traffic related differences.

APPENDIX A – M-EPDG Input Summary for Stony Trail Project

General Information		Description: Stoney Trail (Hwy 201:08) project 7265/07 (Sarcee Trail to Country Hills Blvd)
Design Life	20 years	
Base/Subgrade construction:	July, 2009	
Pavement construction:	August, 2009	
Traffic open:	September, 2009	
Type of design	Flexible	
Analysis Parameters		

Performance Criteria	Limit	Reliability
Initial IRI (in/mi)	57	
Terminal IRI (in/mi)	120	95
AC Surface Down Cracking (Long. Cracking) (ft/mile):	2000	95
AC Bottom Up Cracking (Alligator Cracking) (%):	10	95
AC Thermal Fracture (Transverse Cracking) (ft/mi):	384	95
Permanent Deformation (AC Only) (in):	0.51	95
Permanent Deformation (Total Pavement) (in):	0.75	95
Reflective cracking (%):	100	

Location:	Calgary, AB
Project ID:	201:08 (7265/07)
Section ID:	Sarcee Trail to Country Hills Blvd
	Principal Arterials - Interstate and Defense Routes
Date:	1/20/2010
Station/milepost format:	Latitude/Longitude
Station/milepost begin:	51.1522/114.1653
Station/milepost end:	51.1447/114.2039
Traffic direction:	West bound
Default Input Level	
Default input level	Level 3, Default and historical agency values.

Traffic	
Initial two-way AADTT:	1704
Number of lanes in design direction:	2
Percent of trucks in design direction (%):	50
Percent of trucks in design lane (%):	85
Operational speed (mph):	62.136

Traffic -- Volume Adjustment Factors

Monthly Adjustment Factors **(Level 3, Default MAF)**

	Vehicle Class								
Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12
January	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
February	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
March	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
April	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
May	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
June	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
July	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
August	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
September	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
October	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
November	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
December	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Vehicle Class Distribution		**Hourly truck traffic distribution**			
(Level 1, Site Specific Distribution)		by period beginning:			
AADTT distribution by vehicle class		Midnight	2.3%	Noon	5.9%
Class 4	0.9%	1:00 am	2.3%	1:00 pm	5.9%
Class 5	10.0%	2:00 am	2.3%	2:00 pm	5.9%
Class 6	3.5%	3:00 am	2.3%	3:00 pm	5.9%
Class 7	2.0%	4:00 am	2.3%	4:00 pm	4.6%
Class 8	2.0%	5:00 am	2.3%	5:00 pm	4.6%
Class 9	30.0%	6:00 am	5.0%	6:00 pm	4.6%
Class 10	19.0%	7:00 am	5.0%	7:00 pm	4.6%
Class 11	16.2%	8:00 am	5.0%	8:00 pm	3.1%
Class 12	1.2%	9:00 am	5.0%	9:00 pm	3.1%
Class 13	15.2%	10:00 am	5.9%	10:00 pm	3.1%
		11:00 am	5.9%	11:00 pm	3.1%

Traffic Growth Factor

Vehicle Class	Growth Rate	Growth Function
Class 4	4.0%	Compound
Class 5	4.0%	Compound
Class 6	4.0%	Compound
Class 7	4.0%	Compound
Class 8	4.0%	Compound
Class 9	4.0%	Compound
Class 10	4.0%	Compound
Class 11	4.0%	Compound
Class 12	4.0%	Compound
Class 13	4.0%	Compound

Traffic -- Axle Load Distribution Factors

Level 3:	Default

Traffic -- General Traffic Inputs

Mean wheel location (inches from the lane marking):	18
Traffic wander standard deviation (in):	10
Design lane width (ft):	12

Number of Axles per Truck

Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0.00	0.00
Class 5	2.00	0.00	0.00	0.00
Class 6	1.02	0.99	0.00	0.00
Class 7	1.00	0.26	0.83	0.00
Class 8	2.38	0.67	0.00	0.00
Class 9	1.13	1.93	0.00	0.00
Class 10	1.19	1.09	0.89	0.00
Class 11	4.29	0.26	0.06	0.00
Class 12	3.52	1.14	0.06	0.00
Class 13	2.15	2.13	0.35	0.00

Axle Configuration

Average axle width (edge-to-edge) outside dimensions,ft):		8.5
Dual tire spacing (in):		12
Axle Configuration		
	Tire Pressure (psi) :	120
Average Axle Spacing		
	Tandem axle(psi):	51.6
	Tridem axle(psi):	49.2
	Quad axle(psi):	49.2

Climate	
icm file:	N:\Highways\Technical Papers\CTAA 2010\Influence of Dynamic Modulus\MEPDG runs\Stoney Trail\Calgary and Springbank.icm
Latitude (degrees.minutes)	51.11
Longitude (degrees.minutes)	-114.02
Elevation (ft)	330
Depth of water table (ft)	10
Structure--Design Features	
HMA E* Predictive Model:	NCHRP 1-37A viscosity based model.
HMA Rutting Model coefficients:	NCHRP 1-37A coefficients
Endurance Limit (microstrain):	None (0 microstrain)
Structure--Layers	
Layer 1 -- Asphalt concrete	
Material type:	Asphalt concrete
Layer thickness (in):	5.9
General Properties	
General	
Reference temperature (F°):	70
Volumetric Properties as Built	
Effective binder content (%):	11.47
Air voids (%):	4.3
Total unit weight (pcf):	148.5
Poisson's ratio:	0.35 (user entered)
Thermal Properties	
Thermal conductivity asphalt (BTU/hr-ft-F°):	0.67
Heat capacity asphalt (BTU/lb-F°):	0.23
Asphalt Mix	
Number of temperatures:	5
Number of frequencies:	6

Temperature	Mixture E* (psi)					
°F	25	10	5	1	0.5	0.1
14	2630874	2442762	2290231	1920580	1755383	1368231
39.92	1534782	1318676	1161263	821876.3	694727.2	432645.4
69.98	623079	478187	388215.7	209916.9	162731.5	80132.94
100.04	204453.8	136460.5	98286.74	39720.8	30201.54	17095.03
129.92	52116.63	38531.5	30409.42	21610.51	18323.01	13778.52

Asphalt Binder	
Option:	Superpave binder test data

Temperature	Angular frequency = 10 rad/sec	
°F	G*, psi	Delta (°)
40	8445700	36.04
69.98	620020	55.67
100.04	49096	69.05
129.92	5669.3	77.99

Thermal Cracking Properties	
Average Tensile Strength at 14ºF:	483
Mixture VMA (%)	15.77
Aggreagate coeff. thermal contraction (in./in.)	0.000005
Mix coeff. thermal contraction (in./in./ºF):	0.000013

		Load Time (sec)	Low Temp. -4ºF (1/psi)	Mid. Temp. 14ºF (1/psi)	High Temp. 32ºF (1/psi)					
		14	8.29E-07	9.07E-07	4.29E-06					
		23	8.99E-07	1.13E-06	4.82E-06					
		38	1.03E-06	1.08E-06	6.3E-06					
		61	1.12E-06	1.4E-06	8.54E-06					
		99	1.29E-06	1.6E-06	1.19E-05					
		104	1.27E-06	1.77E-06	1.21E-05					
		114	1.32E-06	1.79E-06	1.26E-05					
Layer 2 -- Asphalt concrete										
	Material type:					Asphalt concrete				
	Layer thickness (in):					3.7				
	General Properties									
		General								
		Reference temperature (F°):				70				
		Volumetric Properties as Built								
		Effective binder content (%):				8.44				
		Air voids (%):				5.07				
		Total unit weight (pcf):				148.6				
		Poisson's ratio:				0.35 (user entered)				
	Thermal Properties									
	Thermal conductivity asphalt (BTU/hr-ft-F°):						0.67			
	Heat capacity asphalt (BTU/lb-F°):						0.23			
	Asphalt Mix									
		Number of temperatures:				5				
		Number of frequencies:				6				
		Temperature		Mixture E* (psi)						
		°F		25	10	5	1	0.5	0.1	
		14		2693641	2512440	2365372	2019602	1867506	1517385	
		39.92		1503896	1315879	1173790	859735.4	736598.3	515077.4	
		69.98		686125.2	538138.4	457932.5	271317.3	224711.8	124152.3	
		100.04		224373.4	146198	112259.2	63768.26	52503.66	34132.21	
		129.92		61786.08	45638.54	36791.24	26106.79	23109.35	17791.3	
	Asphalt Binder									
		Option:				Superpave binder test data				
		Temperature		Angular frequency = 10 rad/sec						
		°F		G*, psi		Delta (°)				
		40		8445700		36.04				
		69.98		620020		55.67				
		100.04		49096		69.05				
		129.92		5669.3		77.99				
Layer 3 -- Crushed stone										
	Unbound Material:					Crushed stone				
	Thickness(in):					11.7				
	Strength Properties									
		Input Level:				Level 2				
		Analysis Type:				ICM inputs (ICM Calculated Modulus)				
		Poisson's ratio:				0.35				
		Coefficient of lateral pressure,Ko:				0.5				
		Modulus (input) (psi):				30000				

ICM Inputs	
Gradation and Plasticity Index	
Plasticity Index, PI:	1
Liquid Limit (LL)	6
Compacted Layer	Yes
Passing #200 sieve (%):	9
Passing #40	22.3
Passing #4 sieve (%):	41.4
D10(mm)	0.09253
D20(mm)	0.3285
D30(mm)	1.361
D60(mm)	9.701
D90(mm)	17.32

Sieve	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	9
#100	12.3
#80	
#60	
#50	19.2
#40	
#30	25.3
#20	
#16	28.7
#10	
#8	
#4	41.4
3/8"	58.4
1/2"	79.4
3/4"	93
1"	
1 1/2"	
2"	
2 1/2"	
3"	
3 1/2"	
4"	

Calculated/Derived Parameters	
Maximum dry unit weight (pcf):	128.2 (derived)
Specific gravity of solids, Gs:	2.70 (derived)
Saturated hydraulic conductivity (ft/hr):	0.03644 (derived)
Optimum gravimetric water content (%):	7.1 (derived)
Calculated degree of saturation (%):	60.9 (calculated)
Soil water characteristic curve parameters:	Default values

Parameters	Value
a	6.043
b	2.1046
c	0.66759
Hr.	118

Layer 4 -- Crushed stone	
Unbound Material:	Crushed stone
Thickness(in):	6
Strength Properties	
Input Level:	Level 3
Analysis Type:	ICM inputs (ICM Calculated Modulus)
Poisson's ratio:	0.35
Coefficient of lateral pressure,Ko:	0.5
Modulus (input) (psi):	15000

ICM Inputs		
	Gradation and Plasticity Index	
	Plasticity Index, PI:	1
	Liquid Limit (LL)	6
	Compacted Layer	Yes
	Passing #200 sieve (%):	9
	Passing #40	22.3
	Passing #4 sieve (%):	41.4
	D10(mm)	0.09253
	D20(mm)	0.3285
	D30(mm)	1.361
	D60(mm)	9.701
	D90(mm)	17.32
	Sieve	Percent Passing
	0.001mm	
	0.002mm	
	0.020mm	
	#200	9
	#100	12.3
	#80	
	#60	
	#50	19.2
	#40	
	#30	25.3
	#20	
	#16	28.7
	#10	
	#8	
	#4	41.4
	3/8"	58.4
	1/2"	79.4
	3/4"	93
	1"	
	1 1/2"	
	2"	
	2 1/2"	
	3"	
	3 1/2"	
	4"	
	Calculated/Derived Parameters	
	Maximum dry unit weight (pcf):	128.2 (derived)
	Specific gravity of solids, Gs:	2.70 (derived)
	Saturated hydraulic conductivity (ft/hr):	0.03644 (derived)
	Optimum gravimetric water content (%):	7.1 (derived)
	Calculated degree of saturation (%):	60.9 (calculated)
	Soil water characteristic curve parameters:	Default values
	Parameters	Value
	a	6.043
	b	2.1046
	c	0.66759
	Hr.	118
Layer 5 -- CL		
Unbound Material:		CL
Thickness(in):		24
Strength Properties		
	Input Level:	Level 2
	Analysis Type:	ICM inputs (ICM Calculated Modulus)
	Poisson's ratio:	0.35
	Coefficient of lateral pressure,Ko:	0.5
	Modulus (input) (psi):	4351

ICM Inputs		
	Gradation and Plasticity Index	
	Plasticity Index, PI:	16
	Liquid Limit (LL)	33
	Compacted Layer	Yes
	Passing #200 sieve (%):	70.5
	Passing #40	83.3
	Passing #4 sieve (%):	94
	D10(mm)	0.0002557
	D20(mm)	0.0006541
	D30(mm)	0.001673
	D60(mm)	0.02798
	D90(mm)	1.695

Sieve	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	70.5
#100	
#80	77.7
#60	
#50	
#40	83.3
#30	
#20	
#16	
#10	90.8
#8	
#4	94
3/8"	95.7
1/2"	96.3
3/4"	97.3
1"	97.9
1 1/2"	98.4
2"	98.8
2 1/2"	
3"	
3 1/2"	99.3
4"	99.3

Calculated/Derived Parameters	
Maximum dry unit weight (pcf):	107.5 (derived)
Specific gravity of solids, Gs:	2.70 (derived)
Saturated hydraulic conductivity (ft/hr):	1.998e-005 (derived)
Optimum gravimetric water content (%):	17.7 (derived)
Calculated degree of saturation (%):	84.1 (calculated)
Soil water characteristic curve parameters:	Default values

Parameters	Value
a	112
b	0.6568
c	0.19258
Hr.	500

Layer 6 -- CL		
Unbound Material:		CL
Thickness(in):		Semi-infinite
Strength Properties		
	Input Level:	Level 2
	Analysis Type:	ICM inputs (ICM Calculated Modulus)
	Poisson's ratio:	0.35
	Coefficient of lateral pressure,Ko:	0.5
	Modulus (input) (psi):	4351

ICM Inputs		
Gradation and Plasticity Index		
Plasticity Index, PI:	16	
Liquid Limit (LL)	33	
Compacted Layer	No	
Passing #200 sieve (%):	70.5	
Passing #40	83.3	
Passing #4 sieve (%):	94	
D10(mm)	0.0002557	
D20(mm)	0.0006541	
D30(mm)	0.001673	
D60(mm)	0.02798	
D90(mm)	1.695	

Sieve	Percent Passing
0.001mm	
0.002mm	
0.020mm	
#200	70.5
#100	
#80	77.7
#60	
#50	
#40	83.3
#30	
#20	
#16	
#10	90.8
#8	
#4	94
3/8"	95.7
1/2"	96.3
3/4"	97.3
1"	97.9
1 1/2"	98.4
2"	98.8
2 1/2"	
3"	
3 1/2"	99.3
4"	99.3

Calculated/Derived Parameters	
Maximum dry unit weight (pcf):	106.7 (derived)
Specific gravity of solids, Gs:	2.70 (derived)
Saturated hydraulic conductivity (ft/hr):	2.101e-005 (derived)
Optimum gravimetric water content (%):	17.7 (derived)
Calculated degree of saturation (%):	82.4 (calculated)
Soil water characteristic curve parameters:	Default values

Parameters	Value
a	112
b	0.6568
c	0.19258
Hr.	500

Distress Model Calibration Settings - Flexible		
AC Fatigue		Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
	k1	0.007566
	k2	3.9492
	k3	1.281
AC Rutting		Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
	k1	-3.35412
	k2	1.5606
	k3	0.4791
	Standard Deviation Total Rutting (RUT):	0.24*POWER(RUT,0.8026)+0.001

Thermal Fracture			Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
		k1	1.5
		Std. Dev. (THERMAL):	0.1468 * THERMAL + 65.027
CSM Fatigue			Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
		k1	1
		k2	1
Subgrade Rutting			Level 3: NCHRP 1-37A coefficients (nationally calibrated values)
	Granular:		
		k1	2.03
	Fine-grain:		
		k1	1.35
AC Cracking			
	AC Top Down Cracking		
		C1 (top)	7
		C2 (top)	3.5
		C3 (top)	0
		C4 (top)	1000
		Standard Deviation (TOP)	200 + 2300/(1+exp(1.072-2.1654*log(TOP+0.0001)))
	AC Bottom Up Cracking		
		C1 (bottom)	1
		C2 (bottom)	1
		C3 (bottom)	0
		C4 (bottom)	6000
		Standard Deviation (TOP)	1.13+13/(1+exp(7.57-15.5*log(BOTTOM+0.0001)))
CSM Cracking			
		C1 (CSM)	1
		C2 (CSM)	1
		C3 (CSM)	0
		C4 (CSM)	1000
		Standard Deviation (CSM)	CTB*1
IRI			
	IRI HMA Pavements New		
		C1(HMA)	40
		C2(HMA)	0.4
		C3(HMA)	0.008
		C4(HMA)	0.015
	IRI HMA/PCC Pavements		
		C1(HMA/PCC)	40.8
		C2(HMA/PCC)	0.575
		C3(HMA/PCC)	0.0014
		C4(HMA/PCC)	0.00825

APPENDIX B – M-EPDG Distress Summary for Stony Trail Project

Pavement age Mo	Yr	Month	Longitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
1	0.08	September	0	0.0026	0	0.022	0.272	67.9	22043	98.39
2	0.17	October	0	0.0043	0	0.023	0.3	69	44086	100.17
3	0.25	November	0	0.0054	0	0.024	0.314	69.6	66129	101.03
4	0.33	December	0	0.0062	0	0.024	0.322	70	88171	101.57
5	0.42	January	0	0.0067	0	0.024	0.328	70.2	110214	101.98
6	0.5	February	0	0.0077	0	0.024	0.336	70.6	132257	102.54
7	0.58	March	0	0.009	0	0.024	0.344	71	154300	103.11
8	0.67	April	0	0.0113	0	0.025	0.358	71.5	176343	103.97
9	0.75	May	0	0.0146	0	0.031	0.38	72.5	198386	105.4
10	0.83	June	0	0.0183	0	0.045	0.409	73.7	220428	107.23
11	0.92	July	0	0.022	0	0.059	0.436	74.8	242471	108.88
12	1	August	0	0.0253	0	0.065	0.451	75.4	264514	109.84
13	1.08	September	0	0.0277	0	0.067	0.458	75.8	287439	110.39
14	1.17	October	0	0.0294	0	0.067	0.462	76	310363	110.71
15	1.25	November	0	0.0301	0	0.067	0.464	76.1	333288	110.89
16	1.33	December	0	0.0308	0	0.067	0.466	76.2	356212	111.07
17	1.42	January	0	0.0316	0	0.067	0.468	76.3	379137	111.26
18	1.5	February	0	0.0322	0	0.067	0.469	76.5	402061	111.45
19	1.58	March	0	0.0331	0	0.067	0.471	76.6	424986	111.65
20	1.67	April	0	0.035	0	0.067	0.475	76.8	447910	111.95
21	1.75	May	0	0.0381	0	0.068	0.48	77.1	470835	112.36
22	1.83	June	0	0.0425	0	0.072	0.491	77.6	493760	113.08
23	1.92	July	0	0.047	0	0.084	0.51	78.4	516684	114.33
24	2	August	0	0.0508	0	0.089	0.52	78.9	539609	115.05
25	2.08	September	0	0.0533	0	0.09	0.524	79.1	563450	115.37
26	2.17	October	0	0.0547	0	0.09	0.525	79.2	587292	115.56
27	2.25	November	0	0.0554	0	0.09	0.526	79.3	611133	115.71
28	2.33	December	0	0.0562	0	0.09	0.527	79.4	634975	115.86
29	2.42	January	0	0.057	0	0.09	0.528	79.5	658816	116.03
30	2.5	February	0	0.0578	0	0.09	0.529	79.6	682658	116.19
31	2.58	March	0	0.0589	0	0.09	0.53	79.8	706499	116.36
32	2.67	April	0	0.0607	0	0.091	0.532	79.9	730341	116.58
33	2.75	May	0	0.063	0	0.091	0.534	80.1	754182	116.85
34	2.83	June	0	0.0664	0	0.094	0.541	80.4	778024	117.33
35	2.92	July	0	0.0706	0	0.101	0.552	80.9	801866	118.13
36	3	August	0	0.0748	0	0.109	0.565	81.5	825707	119
37	3.08	September	0	0.0783	0	0.111	0.57	81.8	850502	119.42
38	3.17	October	0	0.0793	0	0.111	0.571	81.9	875297	119.59
39	3.25	November	0	0.0801	0	0.111	0.572	82	900093	119.75
40	3.33	December	0	0.0807	0	0.111	0.572	82.1	924888	119.9
41	3.42	January	0	0.0813	0	0.111	0.573	82.3	949683	120.07
42	3.5	February	0	0.0825	0	0.111	0.574	82.4	974478	120.25
43	3.58	March	0	0.0835	0	0.111	0.575	82.5	999273	120.43
44	3.67	April	0	0.0853	0	0.112	0.576	82.6	1024070	120.65

Pavement age Mo	Yr	Month	Longitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
45	3.75	May	0	0.0879	0	0.112	0.578	82.8	1048860	120.91
46	3.83	June	0	0.0915	0	0.113	0.582	83	1073660	121.25
47	3.92	July	0	0.0958	0	0.118	0.59	83.5	1098450	121.85
48	4	August	0	0.1	0	0.123	0.599	83.9	1123250	122.52
49	4.08	September	0	0.103	0	0.124	0.601	84.1	1149040	122.79
50	4.17	October	0	0.105	0	0.124	0.602	84.2	1174820	122.99
51	4.25	November	0	0.105	0	0.124	0.603	84.3	1200610	123.17
52	4.33	December	0	0.106	0	0.124	0.603	84.5	1226400	123.33
53	4.42	January	0	0.107	0	0.124	0.604	84.6	1252180	123.5
54	4.5	February	0	0.108	0	0.124	0.604	84.7	1277970	123.68
55	4.58	March	0	0.109	0	0.124	0.605	84.8	1303760	123.86
56	4.67	April	0	0.111	0	0.124	0.606	85	1329550	124.08
57	4.75	May	0	0.113	0	0.125	0.608	85.1	1355330	124.32
58	4.83	June	0	0.117	0	0.127	0.612	85.4	1381120	124.73
59	4.92	July	0	0.121	0	0.129	0.617	85.7	1406910	125.14
60	5	August	0	0.125	0	0.134	0.624	86.1	1432690	125.69
61	5.08	September	0	0.127	0	0.134	0.625	86.2	1459510	125.91
62	5.17	October	0	0.129	0	0.134	0.626	86.4	1486330	126.12
63	5.25	November	0	0.13	0	0.134	0.626	86.5	1513150	126.29
64	5.33	December	0	0.13	0	0.134	0.627	86.6	1539970	126.48
65	5.42	January	0	0.131	0	0.134	0.627	86.7	1566790	126.64
66	5.5	February	0	0.132	0	0.134	0.628	86.9	1593600	126.85
67	5.58	March	0	0.133	0	0.134	0.628	87	1620420	127.04
68	5.67	April	0	0.135	0	0.134	0.629	87.1	1647240	127.26
69	5.75	May	0	0.139	0	0.135	0.632	87.4	1674060	127.57
70	5.83	June	0	0.143	0	0.136	0.635	87.6	1700880	127.91
71	5.92	July	0	0.146	0	0.137	0.637	87.8	1727700	128.22
72	6	August	0	0.15	0	0.139	0.641	88.1	1754520	128.61
73	6.08	September	0	0.153	0	0.139	0.643	88.2	1782410	128.88
74	6.17	October	0	0.154	0	0.139	0.644	88.4	1810300	129.08
75	6.25	November	0	0.155	0	0.139	0.644	88.5	1838190	129.27
76	6.33	December	0	0.156	0	0.139	0.645	88.7	1866080	129.46
77	6.42	January	0	0.157	0	0.139	0.645	88.8	1893970	129.65
78	6.5	February	0	0.158	0	0.139	0.645	88.9	1921860	129.85
79	6.58	March	0	0.159	0	0.139	0.646	89.1	1949750	130.06
80	6.67	April	0	0.162	0	0.139	0.647	89.2	1977640	130.29
81	6.75	May	0	0.166	0	0.14	0.65	89.4	2005540	130.6
82	6.83	June	0	0.17	0	0.142	0.653	89.7	2033430	131
83	6.92	July	0	0.175	0	0.148	0.662	90.2	2061320	131.65
84	7	August	0	0.18	0	0.151	0.668	90.5	2089210	132.16
85	7.08	September	0	0.183	0	0.152	0.669	90.7	2118220	132.44
86	7.17	October	0	0.184	0	0.152	0.67	90.9	2147220	132.64
87	7.25	November	0	0.185	0	0.152	0.67	91	2176230	132.84
88	7.33	December	0	0.186	0	0.152	0.67	91.1	2205240	133.03
89	7.42	January	0	0.187	0	0.152	0.671	91.3	2234240	133.23
90	7.5	February	0	0.188	0	0.152	0.671	91.4	2263250	133.43

Pavement age Mo	Yr	Month	Longitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
91	7.58	March	0	0.189	0	0.152	0.672	91.5	2292260	133.63
92	7.67	April	0	0.191	0	0.152	0.672	91.7	2321260	133.85
93	7.75	May	0	0.194	0	0.153	0.674	91.9	2350270	134.13
94	7.83	June	0	0.199	0	0.155	0.678	92.2	2379280	134.54
95	7.92	July	0	0.204	0	0.157	0.681	92.4	2408290	134.91
96	8	August	0	0.208	0	0.158	0.683	92.6	2437290	135.23
97	8.08	September	0	0.211	0	0.158	0.685	92.8	2467460	135.52
98	8.17	October	0	0.212	0	0.158	0.686	93	2497630	135.73
99	8.25	November	0	0.213	0	0.158	0.686	93.1	2527790	135.94
100	8.33	December	0	0.214	0	0.158	0.686	93.3	2557960	136.14
101	8.42	January	0	0.214	0	0.158	0.686	93.4	2588130	136.34
102	8.5	February	0	0.216	0	0.158	0.687	93.6	2618300	136.57
103	8.58	March	0	0.217	0	0.158	0.688	93.7	2648460	136.79
104	8.67	April	0	0.219	0	0.158	0.689	93.9	2678630	137.04
105	8.75	May	0	0.222	0	0.158	0.69	94.1	2708800	137.29
106	8.83	June	0	0.227	0	0.159	0.692	94.3	2738960	137.63
107	8.92	July	0	0.233	0	0.162	0.697	94.7	2769130	138.1
108	9	August	0	0.238	0	0.166	0.703	95	2799300	138.64
109	9.08	September	0	0.24	0	0.167	0.704	95.2	2830670	138.89
110	9.17	October	0	0.242	0	0.167	0.704	95.4	2862050	139.11
111	9.25	November	0	0.243	0	0.167	0.705	95.5	2893420	139.32
112	9.33	December	0	0.244	0	0.167	0.705	95.7	2924790	139.53
113	9.42	January	0	0.244	0	0.167	0.705	95.8	2956170	139.73
114	9.5	February	0	0.245	0	0.167	0.705	96	2987540	139.96
115	9.58	March	0	0.247	0	0.167	0.706	96.1	3018910	140.19
116	9.67	April	0	0.248	0	0.167	0.706	96.3	3050290	140.41
117	9.75	May	0	0.252	0	0.167	0.708	96.5	3081660	140.69
118	9.83	June	0	0.257	0	0.168	0.71	96.7	3113040	141.04
119	9.92	July	0	0.262	0	0.171	0.715	97	3144410	141.51
120	10	August	0	0.267	0	0.174	0.719	97.3	3175780	141.94
121	10.1	September	0	0.271	0	0.174	0.72	97.6	3208410	142.23
122	10.2	October	0	0.273	0	0.174	0.721	97.7	3241040	142.46
123	10.3	November	0	0.274	0	0.174	0.721	97.9	3273670	142.68
124	10.3	December	0	0.275	0	0.174	0.721	98	3306300	142.91
125	10.4	January	0	0.276	0	0.174	0.722	98.2	3338930	143.12
126	10.5	February	0	0.277	0	0.174	0.722	98.4	3371560	143.36
127	10.6	March	0	0.278	0	0.174	0.722	98.5	3404190	143.59
128	10.7	April	0	0.281	0	0.174	0.723	98.7	3436810	143.84
129	10.8	May	0	0.286	0	0.175	0.725	98.9	3469440	144.14
130	10.8	June	0	0.29	0	0.176	0.727	99.1	3502070	144.46
131	10.9	July	0	0.297	0	0.18	0.733	99.5	3534700	145.01
132	11	August	0	0.303	0	0.184	0.739	99.9	3567330	145.6
133	11.1	September	0	0.307	0	0.185	0.741	100.2	3601260	145.91
134	11.2	October	0	0.309	0	0.185	0.741	100.3	3635200	146.15
135	11.3	November	0	0.31	0	0.185	0.742	100.5	3669130	146.38
136	11.3	December	0	0.311	0	0.185	0.742	100.7	3703070	146.6

Pavement age Mo	Yr	Month	Longitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
137	11.4	January	0	0.312	0	0.185	0.742	100.8	3737000	146.84
138	11.5	February	0	0.313	0	0.185	0.743	101	3770930	147.07
139	11.6	March	0	0.315	0	0.185	0.743	101.2	3804870	147.31
140	11.7	April	0	0.317	0	0.185	0.743	101.3	3838800	147.55
141	11.8	May	0	0.32	0	0.186	0.744	101.5	3872730	147.82
142	11.8	June	0	0.324	0	0.186	0.746	101.7	3906670	148.12
143	11.9	July	0	0.328	0	0.188	0.748	102	3940600	148.5
144	12	August	0	0.334	0	0.189	0.751	102.3	3974540	148.87
145	12.1	September	0	0.337	0	0.19	0.752	102.5	4009830	149.15
146	12.2	October	0	0.339	0	0.19	0.752	102.6	4045120	149.39
147	12.3	November	0	0.34	0	0.19	0.753	102.8	4080410	149.63
148	12.3	December	0	0.341	0	0.19	0.753	103	4115700	149.87
149	12.4	January	0	0.342	0	0.19	0.753	103.2	4150990	150.11
150	12.5	February	0	0.344	0	0.19	0.754	103.3	4186280	150.35
151	12.6	March	0	0.345	0	0.19	0.754	103.5	4221580	150.59
152	12.7	April	0	0.347	0	0.19	0.754	103.7	4256870	150.84
153	12.8	May	0	0.35	0	0.19	0.755	103.9	4292160	151.11
154	12.8	June	0	0.355	0	0.19	0.757	104.1	4327450	151.43
155	12.9	July	0	0.361	0	0.194	0.762	104.5	4362740	151.96
156	13	August	0	0.367	0	0.197	0.766	104.8	4398030	152.4
157	13.1	September	0	0.37	0	0.197	0.767	105	4434740	152.68
158	13.2	October	0	0.372	0	0.197	0.767	105.2	4471440	152.93
159	13.3	November	0	0.373	0	0.197	0.767	105.4	4508140	153.17
160	13.3	December	0	0.374	0	0.197	0.768	105.5	4544840	153.41
161	13.4	January	0	0.376	0	0.197	0.768	105.7	4581550	153.66
162	13.5	February	0	0.377	0	0.197	0.768	105.9	4618250	153.91
163	13.6	March	0	0.378	0	0.197	0.768	106.1	4654950	154.15
164	13.7	April	0	0.381	0	0.197	0.769	106.2	4691660	154.41
165	13.8	May	0	0.385	0	0.198	0.77	106.5	4728360	154.7
166	13.8	June	0	0.39	0	0.198	0.772	106.7	4765060	155.03
167	13.9	July	0	0.396	0	0.202	0.776	107.1	4801760	155.52
168	14	August	0	0.403	0	0.206	0.782	107.5	4838470	156.07
169	14.1	September	0	0.407	0	0.207	0.783	107.7	4876640	156.38
170	14.2	October	0	0.409	0	0.207	0.783	107.9	4914810	156.63
171	14.3	November	0	0.41	0	0.207	0.784	108	4952980	156.88
172	14.3	December	0	0.411	0	0.207	0.784	108.2	4991150	157.12
173	14.4	January	0	0.412	0	0.207	0.784	108.4	5029320	157.37
174	14.5	February	0	0.414	0	0.207	0.784	108.6	5067490	157.63
175	14.6	March	0	0.415	0	0.207	0.784	108.8	5105660	157.87
176	14.7	April	0	0.417	0	0.207	0.785	108.9	5143840	158.13
177	14.8	May	0	0.421	0	0.207	0.786	109.2	5182010	158.42
178	14.8	June	0	0.429	0	0.209	0.79	109.5	5220180	158.9
179	14.9	July	0	0.436	0	0.215	0.798	110	5258350	159.57
180	15	August	0	0.442	0	0.217	0.8	110.3	5296520	159.93
181	15.1	September	0	0.445	0	0.217	0.8	110.5	5336220	160.2
182	15.2	October	0	0.446	0	0.217	0.801	110.6	5375920	160.46

Pavement age Mo	Yr	Month	Longitudinal Cracking (ft/mi)	Alligator Cracking (%)	Transverse Cracking (ft/mi)	Subtotal AC Rutting (in)	Total Rutting (in)	IRI (in/mi)	Heavy Trucks (cumulative)	IRI at Reliability (in/mi)
183	15.3	November	0	0.448	0	0.217	0.801	110.8	5415610	160.72
184	15.3	December	0	0.449	0	0.217	0.801	111	5455310	160.97
185	15.4	January	0	0.45	0	0.217	0.801	111.2	5495010	161.22
186	15.5	February	0	0.452	0	0.217	0.802	111.4	5534710	161.48
187	15.6	March	0	0.453	0	0.217	0.802	111.6	5574410	161.74
188	15.7	April	0	0.456	0	0.217	0.802	111.8	5614100	162.01
189	15.8	May	0	0.461	0	0.217	0.803	112	5653800	162.32
190	15.8	June	0	0.467	0	0.218	0.806	112.3	5693500	162.69
191	15.9	July	0	0.475	0	0.224	0.813	112.7	5733200	163.31
192	16	August	0	0.483	0	0.228	0.818	113.1	5772900	163.85
193	16.1	September	0	0.487	0	0.228	0.819	113.4	5814180	164.16
194	16.2	October	0	0.49	0	0.228	0.819	113.6	5855470	164.43
195	16.3	November	0	0.491	0	0.228	0.82	113.7	5896750	164.69
196	16.3	December	0	0.493	0	0.228	0.82	113.9	5938040	164.95
197	16.4	January	0	0.494	0	0.228	0.82	114.1	5979320	165.22
198	16.5	February	0	0.496	0	0.228	0.82	114.3	6020610	165.48
199	16.6	March	0	0.498	0	0.228	0.821	114.5	6061900	165.75
200	16.7	April	0	0.501	0	0.228	0.821	114.7	6103180	166.03
201	16.8	May	0	0.505	0	0.228	0.822	114.9	6144470	166.32
202	16.8	June	0	0.511	0	0.229	0.824	115.2	6185750	166.67
203	16.9	July	0	0.518	0	0.233	0.829	115.6	6227040	167.2
204	17	August	0	0.524	0	0.235	0.831	115.9	6268320	167.59
205	17.1	September	0	0.528	0	0.235	0.832	116.1	6311260	167.87
206	17.2	October	0	0.53	0	0.235	0.832	116.3	6354200	168.14
207	17.3	November	0	0.531	0	0.235	0.832	116.5	6397140	168.41
208	17.3	December	0	0.533	0	0.235	0.832	116.7	6440070	168.67
209	17.4	January	0	0.534	0	0.235	0.832	116.9	6483010	168.94
210	17.5	February	0	0.536	0	0.235	0.833	117.1	6525950	169.21
211	17.6	March	0	0.538	0	0.235	0.833	117.3	6568890	169.49
212	17.7	April	0	0.54	0	0.235	0.833	117.5	6611820	169.77
213	17.8	May	0	0.545	0	0.235	0.834	117.7	6654760	170.08
214	17.8	June	0	0.55	0	0.236	0.836	118	6697700	170.41
215	17.9	July	0	0.557	0	0.239	0.84	118.3	6740630	170.9
216	18	August	0	0.563	0	0.24	0.841	118.6	6783570	171.24
217	18.1	September	0	0.57	0	0.24	0.843	118.8	6828230	171.59
218	18.2	October	0	0.572	0	0.24	0.844	119.1	6872880	171.88
219	18.3	November	0	0.574	0	0.24	0.844	119.3	6917540	172.15
220	18.3	December	0	0.576	0	0.24	0.844	119.5	6962190	172.42
221	18.4	January	0	0.577	0	0.24	0.844	119.7	7006850	172.69
222	18.5	February	0	0.579	0	0.24	0.844	119.9	7051500	172.97
223	18.6	March	0	0.581	0	0.24	0.845	120.1	7096160	173.25
224	18.7	April	0	0.584	0	0.24	0.845	120.3	7140810	173.54
225	18.8	May	0	0.591	0	0.241	0.847	120.6	7185460	173.89
226	18.8	June	0	0.599	0	0.243	0.85	120.9	7230120	174.35
227	18.9	July	0	0.607	0	0.247	0.855	121.3	7274770	174.86
228	19	August	0	0.614	0	0.248	0.857	121.6	7319430	175.26

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229	19.1	September	0	0.618	0	0.249	0.859	121.8	7365870	175.59
230	19.2	October	0	0.621	0	0.249	0.859	122	7412310	175.88
231	19.3	November	0	0.623	0	0.249	0.859	122.3	7458750	176.15
232	19.3	December	0	0.624	0	0.249	0.859	122.5	7505190	176.43
233	19.4	January	0	0.626	0	0.249	0.86	122.7	7551630	176.71
234	19.5	February	0	0.628	0	0.249	0.86	122.9	7598070	176.99
235	19.6	March	0	0.63	0	0.249	0.86	123.1	7644520	177.26
236	19.7	April	0	0.633	0	0.249	0.86	123.3	7690960	177.56
237	19.8	May	0	0.638	0	0.249	0.861	123.5	7737400	177.87
238	19.8	June	0	0.647	0	0.251	0.864	123.8	7783840	178.27
239	19.9	July	0	0.657	0	0.256	0.87	124.3	7830280	178.88
240	20	August	0	0.664	0	0.258	0.873	124.6	7876720	179.33

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