RELIABILITY SENSITIVITY OF PAVEMENT ME DESIGN™

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Paper prepared for presentation at the
Experience with Pavement ME Design session

of the 2014 Annual Conference of the
Transportation Association of Canada
Montreal, Quebec

ACKNOWLEDGEMENT

The decision to prepare and present this paper for the 2014 Transportation Association of Canada Conference was approved by the Pavement ME User Group members. Particular acknowledgement is given to those who participated in running various design trials: Marta Juhasz and Kim Edmunds with Alberta Transportation; Hugh Donovan with City of Edmonton; M. Alauddin Ahammed with Manitoba Infrastructure Transportation; Warren Lee with Ministry of Transportation Ontario; Julie Roby and Denis St-Laurent with Ministère des Transports du Québec; and Mark Popik with Thurber Engineering Ltd.

ABSTRACT

Over the past two years, the Canadian User Group for Pavement ME Design™ has run design trials to become more familiar with the software program and to evaluate the sensitivity of the predicted pavement distresses to different input parameters. A project developed by Manitoba Infrastructure and Transportation was used as the pavement design for all these trials. Results from the previously completed design trials have been reported elsewhere. More recently, the User Group has completed trial runs by varying the design reliability to evaluate the sensitivity of the predicted distresses to the variation in the design reliability. The input reliability was varied from 60 percent to 90 percent, in increments of 10 percent, holding all other inputs constant. This created four alternative scenarios for each climate station. Trial runs were completed for several climate stations across Canada. This paper presents the results of these reliability sensitivity trials and highlights the key findings.

INTRODUCTION

Intent on developing a state-of-the-practice mechanistic-empirical design method for the new construction and rehabilitation of pavement, the National Cooperative Highway Research Program (NCHRP) initiated project 1-37A in the late 1990s. The result from this project was a new pavement design methodology known as the Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures (abbreviated as the MEPDG). The MEPDG was recently adopted as the new pavement design standard by the American Association of State Highway and Transportation Officials (AASHTO), in conjunction with its supporting software, Pavement ME Design™ (hereafter referred to as Pavement ME). Compared to other pavement design methodologies, the MEPDG requires a more comprehensive understanding of climatic, material, and traffic inputs. The pavement performance prediction outputs obtained from Pavement ME include rutting, IRI, and cracking, as opposed to the output for AASHTO 1993 which simply gave a structural number (SN) [1].

BACKGROUND (PAVEMENT ME USER GROUP AND TRIAL DESIGNS)

In 2008, with the support of the Transportation Association of Canada's Pavements and Soils and Materials Standing Committees, a Canadian Pavement ME Design User Group was formed. The purpose of the User Group is to share knowledge and experiences related to AASHTO's MEPDG and associated software, Pavement ME; identify issues and convey them to AASHTO's Pavement ME Task Force; pursue development of a Canadian user guide; and identify Canadian projects to facilitate Canadian implementation. The User Group is a platform for discussion of challenges and implementation issues with the MEPDG and Pavement ME software.

Over the last two years, in an effort to become better acquainted with the software, the User Group has run trial flexible pavement designs. The initial pavement design was provided by Manitoba Infrastructure and Transportation (MIT). Results from previous design trials have been reported elsewhere [2, 3] and examined the impact of different climate files, construction seasons, asphalt cement grades, truck traffic volumes, and asphalt layer thicknesses.

In the most recent design trials by the User Group, the reliability for each distress was varied from 60 percent to 90 percent in order to evaluate the sensitivity of the predicted distresses to the variation in design reliability. This paper presents the details of these results and examines whether or not the predicted distresses and their variations are realistic and what implications this might have on local calibration.

INITIAL DESIGN INPUTS

Although reported elsewhere, the initial design inputs are summarized in this paper for completeness. The initial trials used a 20-year design life for the new construction of a flexible pavement using Level 3 hierarchical inputs for materials and Level 1 inputs for traffic [3].

Pavement Structure and Materials

The input pavement structure for the initial design trials consisted of 200 mm of asphalt concrete pavement (ACP) over 200 mm granular base course (GBC) and 500 mm granular subbase course (GSBC).

The ACP was comprised of two layers: a 50 mm surface course and a 150 mm binder course. The asphalt cement binder for these initial trials was Performance Graded (PG) 70-40 for the surface course, while a PG 64-34 was selected for the binder course asphalt mix. The assumed unit weight for this material was 2,400 kg/m^3; the in-situ air voids content was 5 percent; the effective binder content was 9.9 percent (by volume); and the Poisson's ratio was 0.35. The gradation of the aggregates in the asphalt mix was: 100 percent passing the 19 mm sieve, 80 percent passing the 9.5 mm sieve, 43 percent passing the 4.75 mm sieve and 5 percent passing the 0.075 mm sieve.

The GBC layer consisted of crushed stone (non-stabilized) with an annual representative resilient modulus (MR) of 207 MPa. Poisson's ration was entered as 0.35; the coefficient of lateral earth pressure was 0.5; and the liquid limit and plasticity index were 17 and 3 respectively. The gradation of the GBC is shown in Table 1.

The GSBC layer consisted of pit run non-plastic sandy gravel (non-stabilized) material with an annual representative resilient modulus (MR) of 172 MPa. Poisson's ratio was 0.35 and the coefficient of lateral earth pressure was 0.5. The gradation of the GSBC is presented in Table 2.

Table 1 - GBC Gradation

Sieve Size (mm)	Percent Passing
19.0	100
4.75	55.0
2.00	38.5
0.425	22.5
0.075	12.0

Table 2 - GSBC Gradation

Sieve Size (mm)	Percent Passing
37.5	100
25.0	90.0
4.75	55.0
0.425	30.0
0.075	12.0

The subgrade soil was characterized as high plastic clay (AASHTO Classification A-7-6) with an annual representative MR value of 30 MPa. The gradation and other properties of the subgrade soil are presented in Table 3.

Table 3 - Subgrade Soil Properties

Characteristic	Property
Percent Passing 4.75 mm	100 %
Percent Passing 2.00 mm	91 %
Percent Passing 0.075 mm	87 %
Liquid Limit	85 %
Plasticity Index	55 %
Maximum Dry Unit Weight	1,341 kg/m^3
Optimum Moisture Content	29.8 %
Poisson's Ratio	0.35
Coefficient of Lateral Earth Pressure	0.5

Traffic

Traffic inputs for the initial trials consisted of an initial two-way Annual Average Daily Truck Traffic (AADTT) of 2,450, with a 50 percent directional traffic split. The growth rate was 2 percent for all classes of trucks. The design direction had two lanes with an 80 percent lane distribution factor for the design lane. The operational speed was input as 80 km/hr. The input vehicle class distribution is shown in Table 4.

Level 1 local input values were used for the monthly adjustment factors, axles per truck, and axle load factors. Although the Pavement ME software does not use Equivalent Single Axle Load (ESAL) for predicting the pavement distresses, the software provides an estimate of the design life ESALs in an output text file. This ESAL estimate is based on the AASHTO 1993 pavement design guide [4]. These traffic inputs yielded 9.36 million (M) ESAL for a 20 year design life.

Table 4 - Vehicle Class Distribution

Vehicle Class	Distribution
Class 4	0.96
Class 5	4.24
Class 6	4.13
Class 7	0.28
Class 8	3.38
Class 9	51.42
Class 10	19.39
Class 11	1.26
Class 12	1.19
Class 13	13.75

Performance Criteria

Designs using Pavement ME are evaluated based on the acceptance/rejection of predicted performance. User specified pavement performance criteria govern the designs. The user specifies levels of pavement distresses that can be tolerated for the selected level of reliability [5]. For the trial designs run by the User Group, the default values within Pavement ME were used for the distress threshold values (performance criteria) and design reliability (unless otherwise indicated). The default distress threshold values are shown below in Table 5:

Table 5 - Default Distress Threshold Values [6]

Performance Criteria	Value
Initial IRI (m/km)	1.0
Predicted Terminal IRI (m/km)	2.7
Permanent Deformation - Total Pavement (mm)	19
Asphalt Concrete Bottom-up Fatigue Cracking (%)	25
Asphalt Concrete Thermal Cracking (m/km)	189.4
Asphalt Concrete Top-down Fatigue Cracking (m/km)	378.8
Permanent Deformation - Asphalt Concrete only (mm)	6
Reliability (for all performance criteria) (%)	90

Calibration

The mechanistic-empirical design procedure relies on pavement distress prediction models (also referred to as transfer functions). These models may require calibration and validation with local data for more accurate performance predictions. Pavement ME software models were originally calibrated with the observed field performance data from the Long Term Pavement Performance (LTPP) program experiment sites across North America [7]. The default coefficients for different models in the software are called "global calibration factors". The trial designs run by the User Group used these global calibration factors since no Canadian agency has yet completed calibration.

PREVIOUS TRIAL RESULTS

A brief summary of results from the previous design trials by the User Group is presented below. The details of these trials were presented in "TAC Pavement ME User Group – Canadian Climate Trials" [2] and "Sensitivity of Pavement ME Design to Climate and Other Factors" [3].

Canadian Weather Stations

The first trials run by the Pavement ME User Group involved running trials for various Canadian weather stations. The results of these trials showed that for the majority of weather stations the predicted distresses are below the threshold values. The exception was the Terminal IRI values which exceeded the target (threshold) for most of the weather stations. The User Group also noted slight discrepancies between information presented in the output files and the information presented in the software climate tab. These discrepancies led the User Group to question the repeatability of results.

Verification and Validation

The slight discrepancies noted during the Canadian weather station trials raised the question among the User Group of whether the same input file, run on different machines, would result in the same output. To test this, a few User Group members ran the same input file. The resulting output files and climate tab summaries all matched and thereby verified and validated the repeatability of results. For just this reason, there are 58 verification and validation files, as well as a spreadsheet of expected values, available for download from the Pavement ME software site [8].

Construction Season Variability

The next trials the User Group ran were intended to determine the seasonal effects of modifying the construction and completion dates for a design. Trials were run on 21 weather stations with four varied construction and completion dates each, one for each season. These results showed very slight differences in the predicted distresses. Only one location (The Pas, Manitoba) showed a difference in the pass/fail criteria and even then the increase was slight (on average 3 percent increase in asphalt concrete (AC) thermal cracking when constructed/completed in fall and winter relative to construction/completion in spring and summer).

Performance Graded Asphalt Cement Sensitivity Results

These trials focused on the sensitivity of predicted distresses to varying PG asphalt cement binders. An additional two weather stations from the southern United States (US) were included in the analysis. The User Group varied the type of asphalt cement binder in the trial designs; the grades included in this study were PG 70-40, PG 64-40, PG 64-34, PG 58-34, and PG 58-28. Results showed that the predicted AC thermal cracking increased and exceeded performance criteria value as the PG low temperature grade was increased from -40°C to -28°C. Increasing the high temperature grade (from 58°C to 70°C) increased the predicted AC thermal cracking amount. The predicted bottom-up and top-down fatigue cracking was found to decrease with an increase in the high temperature grade while a decrease in the low temperature grade increased the predicted fatigue cracking. The changes in the predicted AC layer rutting due to a change in the binder grade were insignificant for a given weather station. As the high temperature PG grade increased, there were marginal decreases to the predicted rutting. A change in the low temperature grade appeared to have more effect on the predicted rutting compared to a change in the high temperature grade. Weather stations with higher values of thermal cracking also appeared to have higher predicted IRI values.

Asphalt Thickness Sensitivity Results

For these trials, AC layer thickness was varied from 100 mm to 250 mm, in increments of 50 mm. All other design inputs remained the same, while a PG 58-34 was used as the asphalt binder for both AC layers. The predicted AC layer rutting varied slightly with the variation of pavement thickness. However, the AC top-down fatigue cracking decreased significantly with the increased AC thickness. The predicted bottom-up fatigue cracking results also decreased when the AC thickness was increased. Through these trials, the User Group determined that an appropriate AC thickness likely falls between 150 mm and 200 mm (for 25 percent bottom-up fatigue cracking at 90 percent reliability).

Truck Volume Sensitivity Results

All the trials discussed above assumed a two-way AADTT of 2,450 (approximately 9.4 M ESALs as calculated by Pavement ME). The trials for truck volume sensitivity were run with varying AADTT of 1,500, 3,000, and 5,000 (5.7 M, 13.4 M, 19.1 M ESALs respectively). Results from these trials showed that the AC thermal cracking was not impacted by increasing truck volumes, while the AC bottom-up fatigue cracking did increase with increased truck volumes. The predicted AC layer rutting was shown to nearly double with the increase in AADTT from 1,500 to 5,000. Most of this increase in rutting was occurring in the AC layer rather than the total pavement structure. The predicted top-down fatigue cracking also nearly doubled with an increase in truck volume from 1,500 to 5,000.

DESIGN RELIABILITY SENSITIVITY TRIALS

The most recent trials the User Group has run involve evaluating the sensitivity of the predicted pavement distresses to variation in design reliability. Increasing the design reliability essentially increases the factor of safety of a design. It would stand to reason that higher reliability values will result in increased predicted distresses.

Design Inputs

These trials assumed an AADTT of 2,450; 150 mm ACP in two layers – a 50 mm surface course and a 100 mm binder course; and performance graded asphalt cement binder of PG 58-34 for both layers of ACP. Trials were run using 60, 70, 80, and 90 percent reliability. All other inputs were as noted above and were held constant.

Design Reliability Sensitivity Results

As expected, all the predicted distress values increased with an increase in reliability with the greatest impact of increasing the reliability being on fatigue cracking (both bottom-up and top-down). The summary of bottom-up fatigue cracking, AC thermal cracking, and top-down fatigue cracking are presented in Tables 6, 7, and 8, respectively. Figures 1 and 2 show the results for bottom-up and AC thermal cracking graphically for select weather stations.

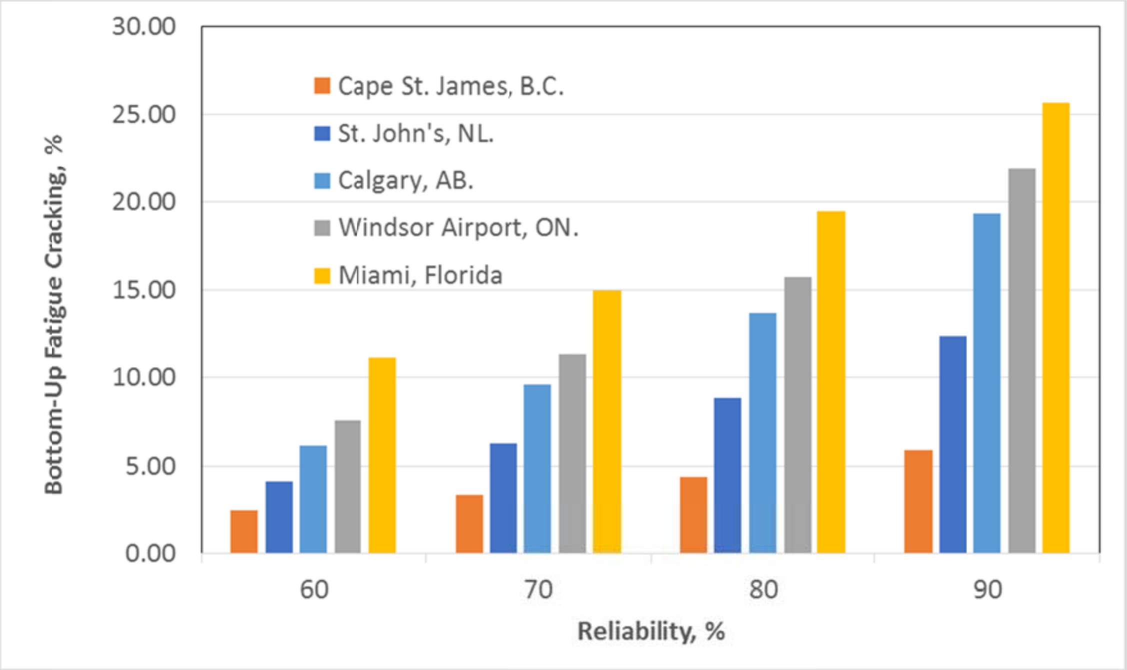

Figure 1 – Variation of AC Bottom-Up Fatigue Cracking

For both top-down and bottom-up fatigue cracking, as the reliability increased from 60 to 90 percent, the predicted distress generally tripled for all weather stations other than the US ones which only doubled. This is not unexpected given that previous trials indicated that a total AC thickness of 150 mm is an under-design at 90 percent reliability. For weather stations with significant AC thermal cracking (chosen arbitrarily as > 50 m/km), increasing the reliability over the range generally increased the thermal cracking prediction by 50 percent.

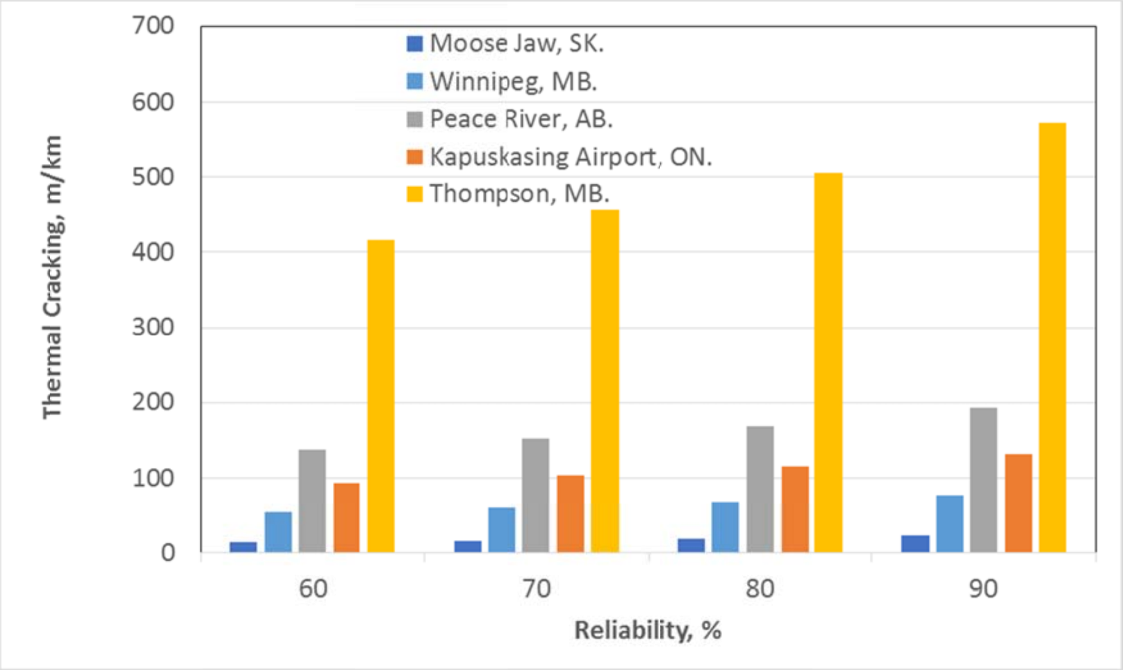

Figure 2 – Variation of AC Thermal Cracking

With respect to AC layer permanent deformation (rutting), as presented in Table 9, increasing the reliability increased the predicted distress by approximately 23 to 33 percent or about 2 to 4 mm with the exception being the warmer US weather stations. Figure 3 shows the variation of the predicted AC layer rutting with the variation of reliability for selected weather stations. As shown in Figure 3 and Table 9, the increase in the predicted rutting for the AC layer with increasing reliability level is relatively small and consistent across all weather stations. Generally the increase in total pavement deformation, as reported in Table 10, was minor at only 1 to 2 mm when accounting for the increase in AC layer rutting.

Table 11 show the roughness (IRI) predictions for changing reliability. Recognizing that the IRI predictions are dependent on the other distress predictions and the site factor, interestingly, the percentage increase in IRI for increased reliability from 60 to 90 percent was consistent at approximately 25 to 26 percent across all weather stations.

Recognizing that the 150 mm AC layer thickness is likely an under-design at 90 percent reliability, the large increase in the predicted bottom-up and top-down fatigue cracking over the reliability range could also indicate large standard errors and lower accuracy of these distress prediction models. Conversely, the variability (i.e. standard error) for the AC layer rutting model is small and may mean that this model is more accurate than others. The implications could be that a local calibration effort for the asphalt layer rutting model need only focus on bias making it easier to calibrate than other distress models where the standard error may be larger. The low variability in the IRI prediction does not necessarily imply an accurate model because a positive error in one model may be compensated by a negative error in another model.

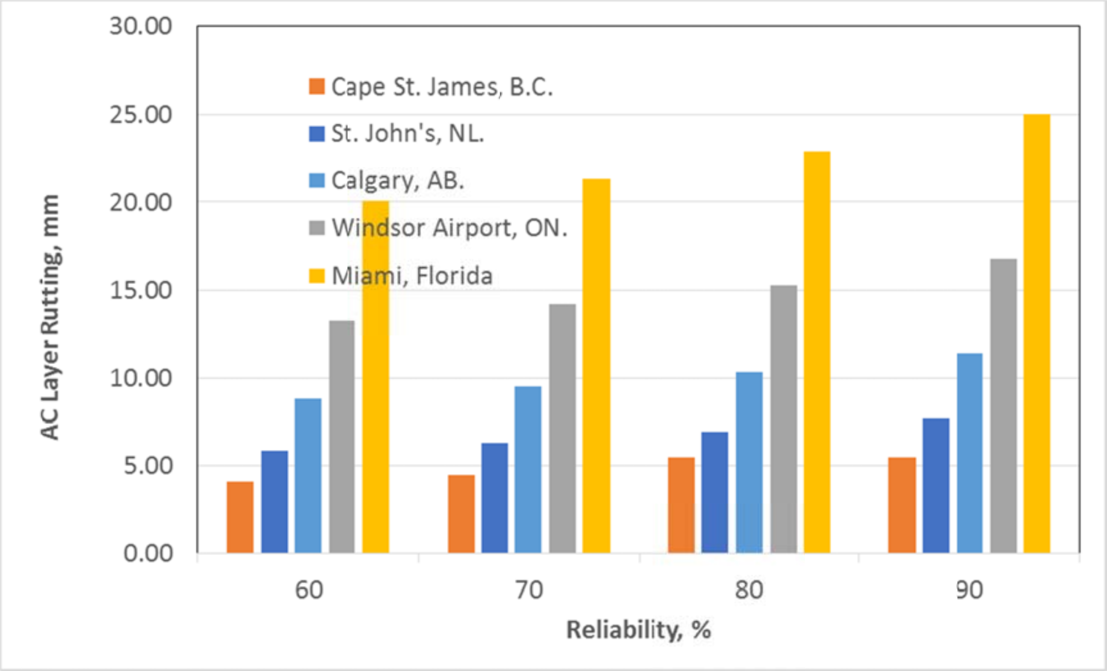

Figure 3 – Variation of AC Layer Permanent Deformation (Rutting)

CONCLUSIONS

The trial runs by the Canadian Pavement ME User Group have been done with the intention of gathering data and gaining familiarity with the Pavement ME software. Trials allow comparison of the influence of select design input parameters on predicted distresses with respect to the Canadian conditions. This is done with the acknowledgement of the limitations in some of the selected input values as well as the absence of local calibration factors.

Overall, the results aligned with the expected outcome of the impact of increased design reliability on the predicted performance. However, reliability appears to play a more significant role in the prediction of some distresses (such as fatigue cracking) than others (such as the rutting and IRI). Further investigation will be required to determine the applicability of the predicted distress values and their quantitative or percentile variations to local conditions. A local calibration effort would likely be able to explain or validate the variations in addition to determining the local bias for each model.

An understanding of the mechanisms of different distresses and influences of different input parameters on the prediction models is also required. As such, the User Group is considering developing an in-depth model analysis strategy before conducting any further sensitivity trials. This involves evaluating one particular distress prediction model at a time and determining what impacts the selected model prior to forming a plan for further design trials. The results from this are expected to further assist in determining the requirement and the feasibility of local calibration of the distress prediction models.

Table 6 - Summary of Predicted AC Bottom-Up Fatigue Cracking

Reliability (%) Weather station	60	70	80	90
Cape St. James, B.C.	2.42	3.33	4.40	5.89
Castlegar, B.C.	7.22	10.97	15.36	21.56
Kamloops, B.C.	7.59	11.37	15.80	21.94
Smith River, B.C.	5.77	9.08	12.95	18.31
Vancouver, B.C.	6.13	9.60	13.67	19.31
Medicine Hat, AB.	6.99	10.71	15.06	21.10
Peace River, AB.	6	9.42	13.42	18.97
Calgary, AB.	6.13	9.61	13.68	19.33
Fort McMurray, AB.	6.59	10.22	14.47	20.37
Kindersley, SK.	6.68	10.34	14.62	20.56
Moose Jaw, SK.	6.88	10.58	14.91	20.91
Regina, SK.	6.70	10.37	14.65	20.60
Uranium City, SK.	6.31	9.86	14.01	19.77
Winnipeg, MB.	6.93	10.64	14.98	21.00
Brandon, MB.	6.79	10.47	14.78	20.76
The Pas, MB.	6.67	10.32	14.60	20.53
Thompson, MB.	6.34	9.89	14.06	19.83
Windsor Airport, ON.	7.57	11.35	15.78	21.91
Toronto Int'l Airport, ON. (Jan 2000-Jan 2007)	7.46	11.23	15.65	21.78
Ottawa Int'l Airport, ON.	7.14	10.88	15.26	21.33
Thunder Bay Airport, ON.	6.49	10.1	14.46	20.35
Kapuskasing Airport, ON.	6.38	9.94	14.12	19.91
Baie-Comeau, QC.	5.24	8.23	11.73	16.58
Montreal (04712), QC.	7.09	10.83	15.20	21.26
Quebec City, QC.	6.83	10.52	14.84	20.83
Fredericton, N.B.	6.78	10.46	14.77	20.74
Goose Bay, NL.	5.29	8.31	11.86	16.77
St. John's, NL.	4.10	6.29	8.84	12.39
Halifax, N.S.	6.00	9.42	13.42	18.97
Charlottetown, P.E.I.	6.11	9.58	13.64	19.27
Phoenix, Arizona	11.96	15.79	20.27	26.49
Miami, Florida	11.14	14.97	19.45	25.66

Table 7 - Summary of Predicted AC Thermal Cracking

Reliability (%) Weather station	60	70	80	90
Cape St. James, B.C.	1.17	2.22	3.44	5.15
Castlegar, B.C.	1.17	2.22	3.44	5.15
Kamloops, B.C.	1.17	2.22	3.44	5.15
Smith River, B.C.	441.23	485.35	536.97	608.57
Vancouver, B.C.	1.17	2.22	3.44	5.15
Medicine Hat, AB.	6.89	8.51	10.41	13.05
Peace River, AB.	138.36	152.84	169.80	193.31
Calgary, AB.	1.74	2.87	4.18	6.00
Fort McMurray, AB.	177.57	195.90	217.34	247.08
Kindersley, SK.	17.71	20.39	23.53	27.89
Moose Jaw, SK.	13.89	16.20	18.90	22.65
Regina, SK.	92.69	102.71	114.43	130.70
Uranium City, SK.	441.23	485.35	536.97	608.57
Winnipeg, MB.	53.83	60.05	67.32	77.42
Brandon, MB.	120.79	133.56	148.50	169.22
The Pas, MB.	129.31	142.92	158.83	180.91
Thompson, MB.	415.36	456.94	505.60	573.09
Windsor Airport, ON.	1.17	2.22	3.44	5.15
Toronto Int'l Airport, ON. (Jan 2000-Jan 2007)	1.17	2.22	3.44	5.15
Ottawa Int'l Airport, ON.	1.06	2.11	3.35	5.06
Thunder Bay Airport, ON.	10.6	12.59	14.92	18.15
Kapuskasing Airport, ON.	93.52	103.62	115.44	131.83
Baie-Comeau, QC.	2.35	3.54	4.92	6.84
Montreal (04712), QC.	1.02	2.07	3.30	5.01
Quebec City, QC.	1.20	2.27	3.52	5.26
Fredericton, N.B.	1.01	2.06	3.29	5.00
Goose Bay, NL.	5.27	6.74	8.46	10.84
St. John's, NL.	1.17	2.22	3.44	5.15
Halifax, N.S.	1.17	2.22	3.44	5.15
Charlottetown, P.E.I.	1.17	2.22	3.44	5.15
Phoenix, Arizona	1.17	2.22	3.44	5.15
Miami, Florida	1.17	2.22	3.44	5.15

Table 8 - Summary of Predicted AC Top-Down Fatigue Cracking

Reliability (%) Weather station	60	70	80	90
Cape St. James, B.C.	119.75	210.59	316.90	464.33
Castlegar, B.C.	210.90	317.80	442.90	620.92
Kamloops, B.C.	231.10	339.75	466.91	643.25
Smith River, B.C.	189.30	293.95	416.43	586.29
Vancouver, B.C.	206.52	312.98	437.58	610.37
Medicine Hat, AB.	215.08	322.39	447.99	622.16
Peace River, AB.	193.44	298.49	421.42	591.90
Calgary, AB.	190.55	295.34	417.97	588.04
Fort McMurray, AB.	213.18	320.29	445.64	619.48
Kindersley, SK.	207.19	313.76	438.49	611.46
Moose Jaw, SK.	214.41	321.63	447.10	621.11
Regina, SK.	208.99	315.68	440.53	613.68
Uranium City, SK.	200.00	305.78	429.57	601.25
Winnipeg, MB.	220.00	327.71	453.78	628.60
Brandon, MB.	213.56	320.67	446.02	619.86
The Pas, MB.	212.32	319.33	444.56	618.23
Thompson, MB.	198.19	303.84	427.49	598.98
Windsor Airport, ON.	249.57	359.55	488.26	666.76
Toronto Int'l Airport, ON. (Jan 2000-Jan 2007)	245.95	355.69	484.13	662.25
Ottawa Int'l Airport, ON.	233.92	342.74	470.11	646.74
Thunder Bay Airport, ON.	205.46	311.82	440.34	613.49
Kapuskasing Airport, ON.	203.65	309.89	434.23	606.66
Baie-Comeau, QC.	179.10	282.36	403.22	570.82
Montreal (04712), QC.	229.88	338.44	465.49	641.69
Quebec City, QC.	221.04	328.85	455.03	630.01
Fredericton, N.B.	221.60	329.42	455.59	630.58
Goose Bay, NL.	177.63	280.75	401.43	568.79
St. John's, NL.	157.39	257.30	374.22	536.37
Halifax, N.S.	203.17	309.29	433.49	605.74
Charlottetown, P.E.I.	206.33	312.79	437.39	610.18
Phoenix, Arizona	359.36	474.33	608.88	795.49
Miami, Florida	521.95	640.67	779.61	972.30

Table 9 - Summary of Predicted AC Layer Permanent Deformation (Rutting)

Reliability (%) Weather station	60	70	80	90
Cape St. James, B.C.	4.12	4.48	5.50	5.50
Castlegar, B.C.	13.67	14.63	15.75	17.30
Kamloops, B.C.	14.70	15.72	16.91	18.56
Smith River, B.C.	7.02	7.58	9.15	9.15
Vancouver, B.C.	8.79	9.47	10.25	11.34
Medicine Hat, AB.	11.70	12.54	13.53	14.90
Peace River, AB.	8.42	9.07	9.83	10.88
Calgary, AB.	8.83	9.50	10.29	11.38
Fort McMurray, AB.	9.53	10.25	11.09	12.25
Kindersley, SK.	10.09	10.84	11.72	12.93
Moose Jaw, SK.	10.77	11.56	12.48	13.77
Regina, SK.	10.11	10.86	11.74	12.96
Uranium City, SK.	8.32	8.96	10.76	10.76
Winnipeg, MB.	10.83	11.62	12.55	13.84
Brandon, MB.	10.07	10.82	11.70	12.91
The Pas, MB.	9.56	10.28	11.12	12.29
Thompson, MB.	8.46	9.11	9.87	10.92
Windsor Airport, ON.	13.26	14.19	15.29	16.81
Toronto Int'l Airport, ON. (Jan 2000-Jan 2007)	12.88	13.79	14.86	16.35
Ottawa Int'l Airport, ON.	11.43	12.26	13.23	14.58
Thunder Bay Airport, ON.	9.5	10.21	11.05	12.21
Kapuskasing Airport, ON.	9.27	9.97	10.79	11.93
Baie-Comeau, QC.	6.75	7.29	7.93	8.81
Montreal (04712), QC.	11.56	12.39	13.37	14.73
Quebec City, QC.	10.48	11.25	12.16	13.41
Fredericton, N.B.	10.09	10.84	11.71	12.93
Goose Bay, NL.	7.03	7.60	9.16	9.16
St. John's, NL.	5.85	6.33	6.90	7.68
Halifax, N.S.	8.08	8.71	9.44	10.46
Charlottetown, P.E.I.	8.33	8.97	9.73	10.77
Phoenix, Arizona	32.82	34.77	37.05	40.21
Miami, Florida	20.04	21.34	22.87	24.99

Table 10 - Summary of Predicted Total Pavement Permanent Deformation (Rutting)

Reliability (%) Weather station	60	70	80	90
Cape St. James, B.C.	13.83	14.45	15.48	16.18
Castlegar, B.C.	24.37	25.47	26.75	28.53
Kamloops, B.C.	25.53	26.68	28.02	29.89
Smith River, B.C.	17.32	18.08	18.98	20.22
Vancouver, B.C.	19.14	19.99	20.98	22.36
Medicine Hat, AB.	22.30	23.30	24.46	26.08
Peace River, AB.	18.75	19.58	20.55	21.90
Calgary, AB.	19.20	20.05	21.05	22.43
Fort McMurray, AB.	20.03	20.92	21.96	23.41
Kindersley, SK.	20.65	21.56	22.64	24.13
Moose Jaw, SK.	21.37	22.32	23.43	24.98
Regina, SK.	20.66	21.58	22.66	24.15
Uranium City, SK.	18.79	19.62	20.59	21.93
Winnipeg, MB.	21.44	22.39	23.51	25.06
Brandon, MB.	20.65	21.57	22.64	24.13
The Pas, MB.	20.11	21.00	22.04	23.49
Thompson, MB.	18.93	19.77	20.75	22.11
Windsor Airport, ON.	24.01	25.09	26.36	28.1
Toronto Int'l Airport, ON. (Jan 2000-Jan 2007)	23.62	24.68	25.92	27.63
Ottawa Int'l Airport, ON.	22.09	23.07	24.23	25.83
Thunder Bay Airport, ON.	19.94	20.83	21.98	23.3
Kapuskasing Airport, ON.	19.7	20.58	21.6	23.02
Baie-Comeau, QC.	16.94	17.69	18.57	19.79
Montreal (04712), QC.	22.20	23.19	24.35	25.96
Quebec City, QC.	21.04	21.98	23.07	24.59
Fredericton, N.B.	20.63	21.54	22.62	24.10
Goose Bay, NL.	17.30	18.07	18.96	20.20
St. John's, NL.	15.90	16.60	17.43	18.57
Halifax, N.S.	18.42	19.24	20.19	21.51
Charlottetown, P.E.I.	18.70	19.53	20.50	21.84
Phoenix, Arizona	44.59	46.62	48.99	52.28
Miami, Florida	31.48	32.89	34.55	36.86

Table 11 - Summary of Predicted Terminal IRI

Reliability (%) Weather station	60	70	80	90
Cape St. James, B.C.	2.00	2.14	2.30	2.52
Castlegar, B.C.	2.31	2.47	2.65	2.91
Kamloops, B.C.	2.31	2.46	2.64	2.89
Smith River, B.C.	2.44	2.60	2.79	3.06
Vancouver, B.C.	2.15	2.29	2.46	2.70
Medicine Hat, AB.	2.25	2.41	2.59	2.83
Peace River, AB.	2.26	2.41	2.59	2.84
Calgary, AB.	2.18	2.33	2.50	2.74
Fort McMurray, AB.	2.33	2.49	2.67	2.92
Kindersley, SK.	2.23	2.38	2.55	2.80
Moose Jaw, SK.	2.25	2.40	2.58	2.82
Regina, SK.	2.28	2.44	2.62	2.87
Uranium City, SK.	2.47	2.63	2.82	3.09
Winnipeg, MB.	2.29	2.45	2.63	2.88
Brandon, MB.	2.31	2.47	2.65	2.90
The Pas, MB.	2.30	2.46	2.64	2.89
Thompson, MB.	2.47	2.63	2.82	3.09
Windsor Airport, ON.	2.32	2.48	2.66	2.92
Toronto Int'l Airport, ON. (Jan 2000-Jan 2007)	2.31	2.46	2.64	2.89
Ottawa Int'l Airport, ON.	2.29	2.44	2.62	2.87
Thunder Bay Airport, ON.	2.23	2.38	2.57	2.81
Kapuskasing Airport, ON.	2.29	2.45	2.63	2.88
Baie-Comeau, QC.	2.16	2.31	2.48	2.72
Montreal (04712), QC.	2.29	2.45	2.63	2.88
Quebec City, QC.	2.24	2.39	2.57	2.82
Fredericton, N.B.	2.25	2.41	2.59	2.83
Goose Bay, NL.	2.18	2.32	2.50	2.74
St. John's, NL.	2.12	2.27	2.44	2.67
Halifax, N.S.	2.20	2.35	2.53	2.77
Charlottetown, P.E.I.	2.20	2.35	2.53	2.77
Phoenix, Arizona	2.65	2.83	3.03	3.31
Miami, Florida	2.42	2.58	2.77	3.03

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