Impact of Asphalt Binder Grades on PMED Software Predicted Distresses in New Flexible Pavements

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Abstract

The AASHTOWare Pavement ME Design (PMED) software is a comprehensive design and analysis tool, which can predict different types of distresses in pavements for various design inputs. Asphalt binder grades or properties is one of the key inputs into software for the design and analysis of flexible pavements. The TAC ME Pavement Design Subcommittee conducted several design trials to evaluate the impact of nine different asphalt binder grades (PG 52 to PG 70 and PG-28 to PG-40) on the predicted distresses in 11 different climatic areas across Canada. The aim of these design trials was to assess the impacts of varied asphalt binder performance grade (PG) on the predicted distresses including their trends and practical significance.

The analyses of trial results indicated that softer binders in terms of reduced low temperature grades, reduce the predicted thermal cracking (TC) in some climatic areas. Increased high temperature grades, with no change in low temperature grade, generally result in reduction of thermal cracks, which seem to be unreasonable. The predicted rut depths in asphalt concrete (AC) layer increase with reduced low temperature grades and reduce with increased high temperature grades, as expected. The predicted bottom-up fatigue cracking (BUFC) and top-down fatigue cracking (TDFC) increase with reduced low temperature grades, and they also reduce with increased high temperature grades, which are unexpected. Some inconsistencies in predicted distresses among the climatic areas were also observed. The mean or maximum air temperatures are statistically significant variables for BUFC and TDFC with logical trends. However, the sensitivity of climatic conditions on the predicted TDFC was low. The PMED software predicted surface smoothness, in terms of international roughness index (IRI), mostly depended on the predicted rutting and cracking. This paper presents the details of these trial results, analyses and findings.

Introduction

Asphalt binder has a critical role in flexible pavements, significantly influencing the long-term performance of AC (also known as hot mixed asphalt or HMA) layer. The durability of AC layer largely depends on the integrity between the asphalt binder and aggregates including the type of aggregates used, in addition to other external factors such as traffic loads, exposed temperature and moisture conditions. The performance of asphalt binder and AC mix is also highly sensitive to temperature variation, loading rate/type (e.g., fast, slow and standing) and binder aging conditions. At low temperatures and under fast repeated loads, asphalt mixtures exhibit linear viscoelastic behaviour. In contrast, under high temperatures and sustained heavy loads, they transition to exhibit nonlinear visco-elastoplastic behaviour. Pavement surfaces are also subjected to significant diurnal and seasonal temperature variations, resulting in repeated cycles of thermal expansion and contraction. These expansion and contraction cycles induce thermal stresses, particularly during cooling, when contraction in the asphalt layer is restrained by underlying layers. This generates tensile stresses that are most pronounced near the top surface of AC. Thus, binder's ability to resist the induced tensile stresses is a key factor in preventing thermal cracking[1]. The selection of asphalt binder grades for a project should account for the behaviours under both low and high pavement temperatures to withstand thermal cracking, fatigue cracking and rutting in the project climatic and traffic loading conditions.

The design framework in the AASHTOWare Pavement ME Design (PMED) software integrates mechanistic models to simulate pavement responses (e.g., stresses, strains and deformation) with empirical transfer functions that predict the initiation and progression of pavement distresses over time[2]. PMED software accommodates a broad spectrum of input parameters including traffic, material properties, layer thicknesses, subgrade characteristics and climate data to predict different types of pavement distresses. However, despite its advanced analytical capabilities, PMED's reliability is often constrained by its sensitivity to some input parameters. Among these, the properties of asphalt binder have emerged as one of the most influential factors for flexible pavement designs.

Given the critical role of asphalt binder in ensuring desirable performance of flexible pavements, this study investigated the effect of varied asphalt binder performance grades (PG) on PMED software predicted distresses in diverse climatic conditions across Canada. Key performance indicators evaluated include International Roughness Index (IRI), AC layer rutting, thermal cracking (TC), bottom-up fatigue cracking (BUFC) and top-down fatigue cracking (TDFC).

Background

The Strategic Highway Research Program (SHRP) introduced performance-based specifications for asphalt binder and mixture design, focusing on improving resistance to rutting, fatigue cracking, and thermal cracking under a wide range of environmental and traffic loading conditions[3,4.] The core of SuperPave is the Performance Grade (PG) binder classification system. This system evaluates the binder's ability to perform within specific temperature ranges to ensure that the selected binder resists rutting at high temperatures, maintains flexibility at low temperatures to resist thermal cracking, withstands fatigue cracking at intermediate temperatures, and performs adequately over time.

NCHRP Project 1-47 explored the sensitivity of PMED software predictions to input variability and found that high-temperature binder grades significantly influence predicted performance[5]. Similarly, thermal cracking was shown to be highly sensitive to binder grade[6].

The Transportation Association of Canada (TAC) ME Pavement Design Subcommittee (Subcommittee) has been evaluating the AASHTOWare PMED software since 2007 to understand the impacts of different input parameters on distress predictions for various pavement types and evolutions of the software. The trials have covered a range of pavement types and variations of design inputs, which noted some inconsistencies and low sensitivity issues for predicted distresses due to some input parameters. Building upon this foundation, this study conducted an in-depth investigation using the PMED software v.3.0 to assess the impacts of varied asphalt binder grades. A total of nine binder grades were selected, covering a wide spectrum of high and low-temperatures. The study also evaluated the sensitivity of predicted distresses to binder grade selection across various climate conditions, using data from 11 weather stations distributed across Canada, aiming to improve understanding of the behaviour of different asphalt binders and reliability of PMED software.

Findings from Literature Review

Asphalt binder performance plays a critical role in flexible pavement design, influencing key distresses such as AC layer rutting, fatigue cracking and thermal cracking. The SuperPave Performance Grading (PG) system classifies asphalt binders according to their rheological behaviour at both high and low service temperatures. The findings from the SHRP-A-369 report[7] demonstrated that higher PG grade (e.g., PG 76-22) binders provide a superior rutting resistance at high temperatures, while lower PG grade binders improve resistance to thermal cracking in colder climates.

Schwartz et al.[5] conducted an extensive sensitivity analysis of the Mechanistic-Empirical Pavement Design Guide (MEPDG) performance predictions to evaluate the influence of varied inputs on predicted pavement distresses. The study emphasizes on accurately characterizing inputs like asphalt mixture properties (including asphalt binder) for reliable pavement performance prediction. Study completed by Bari and Witczak[8] emphasized on the importance of using laboratory-measured dynamic modulus for different binder grades to improve prediction models.

Several studies indicated that the PMED software may underpredict the fatigue resistance benefits of polymer-modified binders, primarily due to limitations in its calibration procedures. Khattak and Baladi[9] developed predictive models for fatigue and permanent deformation in polymer-modified asphalt mixtures, demonstrating that the rheological and mechanical properties of these mixtures are significantly influenced by both the type and concentration of the polymer modifier. Their study concluded that the enhanced fatigue life observed in polymer-modified mixtures is primarily attributable to improvements in binder rheology—an effect that is not fully represented in conventional pavement performance models. Furthermore, Souliman and Kaloush[10] evaluated the extended fatigue life of rubber- and polymer-modified asphalt mixtures through flexural bending beam fatigue tests. Their findings revealed that these modified mixtures exhibit a significantly longer fatigue life compared to conventional mixtures, highlighting the need for incorporating models that reflect these empirical observations to provide more accurate predictions. Difenderfer[11] reported that stiffer binders reduce both fatigue cracking and rutting.

Numerous other studies (e.g., Qadi et al.[12], Zhu et al.[13] and Junaid et al.[14]) have explored the effects of binder source variation, crude refining process variation, additive contents and aging on pavement performance. However, limited studies have directly assessed how asphalt binder properties influence predicted pavement distresses in mechanistic-empirical design models like PMED.

Scope, Objectives and Significance

A literature scan presented in the previous sections indicated that numerous studies have focused on the effects of variation of binder sources, crude refining process, additive contents and aging on pavement performance. A limited studies have focused on how asphalt binder properties influence predicted distresses in pavements. No studies have focused on asphalt binder PG variations on the predicted distresses using the PMED software. In this study, design trials were completed to examine the effects of nine different asphalt binder grades in the AC layer on the PMED software predicted distresses. The PG of asphalt binders chosen for the study are the most commonly used ones in Canadian climate. The design trial matrix also included 11 weather stations throughout Canada. All other design inputs remained unchanged to determine the true impact of each binder grade in different climates.

The objective of this paper is to present the details of design trials, analysis and findings. The information provided may assist agencies and interested individuals in evaluating the suitability of the PMED software and understanding the impact of selecting an asphalt binder grade on pavement performance.

Software Versions and General Design Inputs

All participants utilized the PMED software version 3.0 with the global calibration coefficients for all design trials. The general design inputs for the design trials are summarized in Table 1. The varied design inputs for different trial runs include varied performance grade (PG) of asphalt binders that are typically used in

Canada. Design trials for each binder grade also included varied climatic data from 11 weather stations across Canada. Details of climatic data and binder grades are presented in next sections of this paper.

Table 1. General design inputs for design trials

Inputs		Value Used
Climate Data		MERRA-2 from 11 weather stations across Canada
Truck Traffic		Two-way 7,500 trucks/day (3,000 trucks/day on the design lane of a four-lane divided highway) and 2% annual growth rate
Vehicle Class Distribution and Axle Load Spectra		Manitoba Level 1
Traffic Speed		100 km/h
Design Life		20 years
Initial IRI		0.9 m/km
Design Reliability		90% for all distress types
HMA Properties		Manitoba SP12.5 mixes with nine different asphalt binder grades. All other design input parameters such as asphalt mix volumetric properties (density = 2276 kg/m3, VMA = 17.2%, AV = 6.9%), asphalt cement content (4.8%) and aggregate gradations (finer than 9.50 mm = 80.6%, 4.75 mm = 52.6% and 0.075 mm = 2.8%) remained unchanged. Poisons ratio, reference temperature, thermal conductivity and heat capacity remained unchanged to software default values in all design trials
Asphalt Binder Grades		Nine different binders
Pavement Structures	AC Surface	150 mm thick SP12.5
	Base	200 mm thick granular base (MB GBC-I) with an annual representative resilient modulus (Mr) value of 225 MPa
	Subbase	300 mm thick crushed rock (MB CR-M50) subbase with an annual representative Mr value of 200 MPa
Subgrade		MB high plastic clay (AASHTO A-7-6) with an annual representative resilient modulus (Mr) value of 35.0 MPa

Selected Weather Stations and Summary of Climate Data

MERRA-2 climate data from 11 weather stations across Canada with varied climatic input parameters were selected for the design trials presented in this study. Figure 1 shows the geographic location of the weather stations. The red dots indicate relatively warmer climates, while the blue dots indicate relatively colder climates in Canadian context. Table 2 presents the list of weather stations and the summary of the key climatic parameters. It should be noted here that some of the climatic parameters (such as minimum air temperature, frost depths and annual number of wet days) in the MERRA-2 climate database seem to be unreasonable as they do not match with actual observations.

Figure 1. Geographic locations of weather stations across Canada

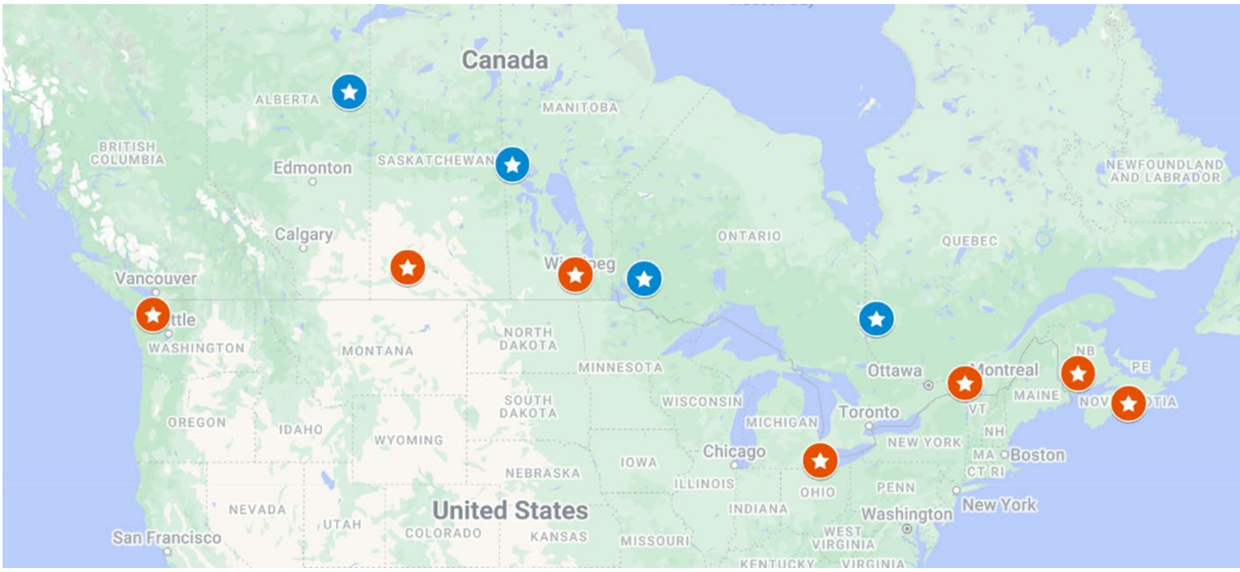


Table 2. List of weather stations and summary of key climatic parameters over the design life

Weather Station	Annual Air Temp. (°C)			Mean Annual			
	Min.	Max.	Mean	Precipitation (mm)	Number of Wet Days	FI (°C-days) (FD, m)	No. Freeze-Thaw Cycles
Victoria, BC	-15.4	29.4	10.9	1502	332	11 (0.5)	7.2
Fort McMurray, AB	-47.1	36.9	0.2	630	337	2081 (4.4)	66.5
Swift Current, SK	-42.1	37.9	4.9	451	274	999 (2.0)	108.6
Winnipeg, MB	-45.9	38.3	3.5	605	302	1754 (3.2)	67.6
The Pas, MB	-48.1	37.9	0.5	590	329	2357 (7.5)	58.9
Wheatley, ON	-21.7	31.6	9.6	1092	304	301 (2.0)	52.0
Waldhof, ON	-48.9	33.6	1.3	858	335	2131 (4.1)	56.8
Rouyn, QC	-45.7	31.1	2.0	1226	350	1794 (2.7)	67.3
Montreal, QC	-41.5	36.7	6.2	1379	326	1100 (2.2)	70.8
Fredericton, NB	-36.2	31.8	5.0	1389	345	1028 (1.6)	81.2
Halifax, NS	-20.1	27.1	7.3	1647	340	315 (1.1)	70.0

FI = Freezing Index, FD = Frost Depth

Trial Matrix and Varied Design Inputs

As indicated earlier, asphalt binder performance grades have significant contributions to AC mix field performance in terms of resistance to rutting, fatigue cracking and thermal cracking. The selected binder for a project shall meet the pavement performance requirements at both low and high temperatures under varied traffic loads and loading impact conditions. As such, the selected asphalt binder grades vary widely across Canada and elsewhere. This study included typical asphalt binders that are in use across Canada to withstand both low pavement temperatures during the winter and high pavement temperatures during the summer.

To assess the impact of low pavement temperature, the low temperature grades of asphalt binder were varied from -22 °C to -40 °C keeping the high temperature grade constant at 58 °C. Alternatively, to assess the impact of high pavement temperature, the high temperature grades of asphalt binder were varied from 52 °C to 70 °C keeping the low temperature grade constant at -28 °C and -34 °C. These led to the selection of nine grades (PG 58-22, 58-28, 58-34, 58-40, PG 52-28, 64-28, 70-28, 64-34 and 70-34) of asphalt binder. Accordingly, nine design trials for each weather station and a total of 99 design trials for 11 weather stations across Canada were conducted for this study. Table 3 presents the design trial matrix for each weather station.

Table 3. Design trial matrix for each weather station

Trial #	Asphalt Binder Grade	Purpose
1	PG 58-22	Assess the impact of asphalt binder low temperature grades (with a commonly used high temperature grade) on the predicted distresses
2	PG 58-28	
3	PG 58-34	
4	PG 58-40	
5	PG 52-28	Assess the impact of asphalt binder high temperature grades (with a basic low temperature grade of asphalt binder) on the predicted distresses (Note: PG-28 grade is selected because results of design trials have shown that PG-34 binder provides the same amount of thermal cracking in almost all climatic areas across Canada)
(2)	PG 58-28	
6	PG 64-28	
7	PG 70-28	
(3)	PG 58-34	Assess the impact of asphalt binders' high temperature grades together with a typical low temperature grade on the predicted distresses
8	PG 64-34	
9	PG 70-34	

The results from these design trials were then used to assess the impact of varied asphalt binder grades on the predicted distresses in different climatic conditions. The suitability of the PMED software in predicting pavement performance and surface distresses as practically expected or experienced was also assessed through the analysis of the trends of predicted distresses.

Results, Analysis and Discussion

Tables 4a and 4b present the summary of results from design trials completed in this study. A detailed analysis and discussion are presented in the following sections using graphical trends of the predicted distresses. Only the trends of predicted distresses for representative number of weather stations with differing climatic conditions, from the pool of 11 weather stations that are used in this study, are presented in some figures for an ease of understanding and tracking the changes in trends resulting from the change in asphalt binder grades.

Table 4a. Predicted distresses: Victoria, Fort McMurray, Swift Current, Winnipeg, The Pas and Wheatly

Project Location	Design No.	Trial AC Binder	IRI (m/km)	HMA Rutting (mm)	Total Rutting (mm)	BUFC (%)	TC (m/km)	TDFC (%)
Victoria, BC	1	PG 58-22	2.32	5.07	11.72	28.63	40.97	14.89
	2	PG 58-28	2.34	5.39	12.07	30.32	40.97	15.45
	3	PG 58-34	2.38	5.98	12.68	32.80	40.97	15.13
	4	PG 58-40	2.43	6.87	13.59	36.75	40.97	13.04
	5	PG 52-28	2.41	6.82	13.52	34.02	40.97	15.19
	6	PG 64-28	2.29	4.53	11.18	27.38	40.97	14.94
	7	PG 70-28	2.26	3.87	10.50	24.79	40.97	14.60
	8	PG 64-34	2.32	4.95	11.63	29.69	40.97	15.55
	9	PG 70-34	2.29	4.31	10.97	27.42	40.97	15.20
Fort McMurray, AB	1	PG 58-22	3.10	12.79	19.60	49.20	588.92	15.52
	2	PG 58-28	2.99	13.41	20.25	52.70	347.74	16.71
	3	PG 58-34	2.86	14.31	21.19	56.60	40.97	18.27
	4	PG 58-40	2.92	15.23	22.15	60.71	40.97	18.74
	5	PG 52-28	3.13	17.76	24.69	60.41	287.99	18.27
	6	PG 64-28	2.77	10.21	16.98	43.49	218.38	15.60
	7	PG 70-28	2.58	8.14	14.88	40.68	42.15	15.00
	8	PG 64-34	2.72	11.23	18.05	48.20	40.97	17.14
	9	PG 70-34	2.61	8.77	15.54	42.28	40.97	16.08
Swift Current, SK	1	PG 58-22	2.66	4.24	10.88	24.03	588.92	15.61
	2	PG 58-28	2.57	4.55	11.21	25.61	416.26	16.82
	3	PG 58-34	2.37	5.15	11.84	28.31	41.17	18.23
	4	PG 58-40	2.41	5.73	12.45	30.94	40.97	18.64
	5	PG 52-28	2.54	5.78	12.47	29.16	271.00	18.23
	6	PG 64-28	2.51	3.73	10.37	22.80	396.66	15.70
	7	PG 70-28	2.36	2.96	9.59	19.62	169.87	15.10
	8	PG 64-34	2.33	4.28	10.94	25.54	41.32	17.29
	9	PG 70-34	2.30	3.44	10.10	22.59	41.08	16.21
Winnipeg, MB	1	PG 58-22	2.70	4.31	10.98	25.63	588.92	15.63
	2	PG 58-28	2.72	4.93	11.62	28.21	558.78	16.82
	3	PG 58-34	2.44	5.57	12.30	31.36	42.67	18.24
	4	PG 58-40	2.48	6.22	12.97	34.32	40.97	18.68
	5	PG 52-28	2.74	6.29	13.02	32.39	493.00	18.24
	6	PG 64-28	2.64	3.77	10.45	24.51	520.41	15.70
	7	PG 70-28	2.56	3.35	10.01	22.58	419.00	15.10
	8	PG 64-34	2.38	4.37	11.08	27.36	43.20	17.30
	9	PG 70-34	2.34	3.67	10.36	24.79	42.16	16.21
The Pas, MB	1	PG 58-22	2.72	4.74	11.43	26.53	588.92	15.63
	2	PG 58-28	2.69	5.01	11.73	28.09	503.96	16.83
	3	PG 58-34	2.45	5.78	12.52	31.36	40.98	18.27
	4	PG 58-40	2.51	6.73	13.52	35.54	40.97	18.76
	5	PG 52-28	2.77	6.93	13.67	33.20	490.26	18.29
	6	PG 64-28	2.59	4.36	11.05	25.98	383.37	15.72
	7	PG 70-28	2.36	3.90	10.57	24.92	45.41	15.10
	8	PG 64-34	2.40	4.70	11.43	27.88	40.97	17.32
	9	PG 70-34	2.37	4.21	10.91	26.13	40.97	16.23
Wheatly, ON	1	PG 58-22	2.35	4.51	11.16	26.73	40.97	15.50
	2	PG 58-28	2.38	4.86	11.54	28.95	40.97	16.57
	3	PG 58-34	2.43	5.63	12.33	32.28	40.97	17.65
	4	PG 58-40	2.49	6.59	13.33	36.45	40.97	17.89
	5	PG 52-28	2.49	6.84	13.55	34.63	40.97	17.99
	6	PG 64-28	2.35	4.24	10.89	26.30	40.97	15.57
	7	PG 70-28	2.31	3.49	10.12	23.22	40.97	15.00
	8	PG 64-34	2.37	4.54	11.22	28.63	40.97	16.96
	9	PG 70-34	2.35	4.09	10.75	26.44	40.97	16.08

Table 4b. Predicted distresses: Waldhof, Rouyn, Montreal, Fredericton and Halifax

Project Location	Design No.	Trial AC Binder	IRI (m/km)	HMA Rutting (mm)	Total Rutting (mm)	BUFC (%)	TC (m/km)	TDFC (%)
Waldhof, ON	1	PG 58-22	2.82	6.33	13.03	32.28	588.92	15.63
	2	PG 58-28	2.76	6.81	13.54	34.12	432.70	16.83
	3	PG 58-34	2.59	7.97	14.73	38.97	40.98	18.27
	4	PG 58-40	2.64	8.75	15.55	42.79	40.97	18.73
	5	PG 52-28	2.85	9.46	16.23	41.38	388.85	18.27
	6	PG 64-28	2.64	5.60	12.30	30.94	331.30	15.70
	7	PG 70-28	2.50	4.93	11.62	28.95	168.22	15.08
	8	PG 64-34	2.49	5.99	12.73	33.10	40.98	17.30
	9	PG 70-34	2.45	5.30	12.01	30.74	40.97	16.21
Rouyn, QC	1	PG 58-22	3.19	14.76	21.58	52.80	567.00	15.52
	2	PG 58-28	2.93	15.27	22.12	55.70	73.12	16.70
	3	PG 58-34	2.96	16.10	22.99	59.20	40.97	18.26
	4	PG 58-40	3.01	16.89	23.82	62.51	40.97	18.71
	5	PG 52-28	3.10	20.24	27.18	62.31	58.04	18.26
	6	PG 64-28	2.77	11.86	18.63	47.00	53.41	15.58
	7	PG 70-28	2.66	9.22	15.96	42.18	43.35	15.01
	8	PG 64-34	2.82	12.77	19.59	52.10	40.97	17.13
	9	PG 70-34	2.70	10.11	16.88	44.39	40.97	16.14
Montreal, QC	1	PG 58-22	2.74	4.33	11.01	26.70	588.92	15.60
	2	PG 58-28	2.73	4.73	11.44	28.84	531.37	16.77
	3	PG 58-34	2.47	5.31	12.05	31.97	43.96	18.11
	4	PG 58-40	2.51	6.02	12.78	35.24	40.97	18.43
	5	PG 52-28	2.74	5.88	12.62	32.90	446.41	18.12
	6	PG 64-28	2.68	3.85	10.53	25.45	525.89	15.67
	7	PG 70-28	2.62	3.11	9.78	22.40	482.04	15.07
	8	PG 64-34	2.42	4.43	11.14	28.42	46.59	17.23
	9	PG 70-34	2.38	3.68	10.38	25.51	45.54	16.17
Fredricton, NB	1	PG 58-22	2.92	14.58	21.42	58.80	45.30	15.44
	2	PG 58-28	2.95	15.08	21.96	61.31	40.97	16.55
	3	PG 58-34	3.01	16.09	23.02	65.51	40.97	18.20
	4	PG 58-40	3.06	17.39	24.35	68.31	40.97	18.58
	5	PG 52-28	3.14	20.64	27.61	68.51	40.97	17.92
	6	PG 64-28	2.81	12.01	18.82	54.10	40.97	15.54
	7	PG 70-28	2.69	9.65	16.40	45.79	40.97	14.95
	8	PG 64-34	2.87	12.76	19.61	58.40	40.97	17.10
	9	PG 70-34	2.76	10.56	17.36	51.30	40.97	16.05
Halifax, NS	1	PG 58-22	2.73	4.74	11.43	26.92	588.92	15.63
	2	PG 58-28	2.35	3.66	10.34	25.28	40.97	16.66
	3	PG 58-34	2.38	4.11	10.82	27.55	40.97	17.87
	4	PG 58-40	2.41	4.59	11.32	30.11	40.97	17.98
	5	PG 52-28	2.39	4.46	11.17	28.09	40.97	17.87
	6	PG 64-28	2.33	3.02	9.68	22.05	40.97	15.66
	7	PG 70-28	2.36	3.90	10.57	25.21	45.41	15.10
	8	PG 64-34	2.36	3.57	10.26	25.57	40.97	17.08
	9	PG 70-34	2.33	2.96	9.63	22.60	40.97	16.17

IRI = International roughness index, BUFC = bottom-up fatigue cracking, TC = transverse cracking, TDFC = top-down fatigue cracking

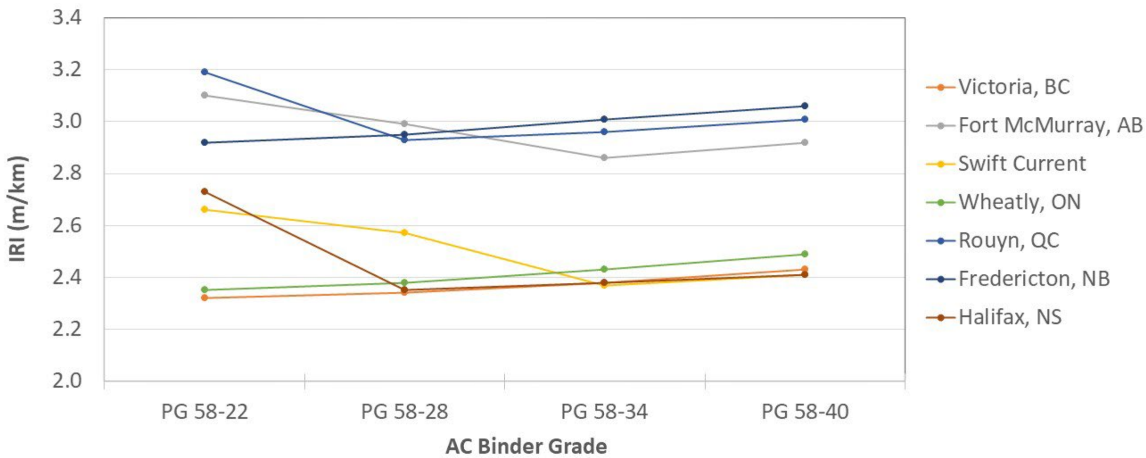
Effect of Varied Asphalt Binder Type

The trends of the PMED software predicted distresses for different asphalt binder grades are presented in Figures 2 to 7 and discussed below.

Impact of Binder Grades on predicted IRI

Figure 2a shows the trends of predicted IRI for the use of progressively softer binders with reduced low binder temperature grades to resist thermal cracking, with no change in binder high temperature grade, (i.e., PG 58-22, 58-28, 58-34 and PG 58-40 binders). Figure 2a and Table 4 show that a decrease in binder low temperature grade from -22 to -28 results in a reduction of IRI for some climatic areas and increase of IRI for some other climatic areas. Similar trends are observed with further reduction of low temperature grade from -28 to -34. However, an increase of IRI is observed for the PG 58-40 binder as compared to PG 58-34 binder in all climatic areas. These trends reflect inconsistencies in predicted IRI values.

Figure 2a. Effect of asphalt binder low temperature grades (along with PG 58) on predicted IRI



When progressively stiffer binders with increased high temperature grades (i.e., PG 52-28, 58-28, 64-28 and 70-28 binders) are selected to withstand rutting, keeping the low temperature grade unchanged at – 28, all climatic areas see a reduction of IRI, as shown in Figure 2b. However, some inconsistencies are noted for a few climatic areas. For example, Swift Current experiences an increase in IRI for PG 58-28 binder as compared to the PG 52-28 binder, while Halifax experiences an increase in IRI for PG 70-28 binder as compared to the PG 64-28 binder. In general, moderate climatic areas (with moderate summer and winter temperatures) experience lower IRI as compared to extreme climates with high summer and low winter temperatures.

Figure 2b: Effect of asphalt binder high temperature grades (along with PG -28) on predicted IRI

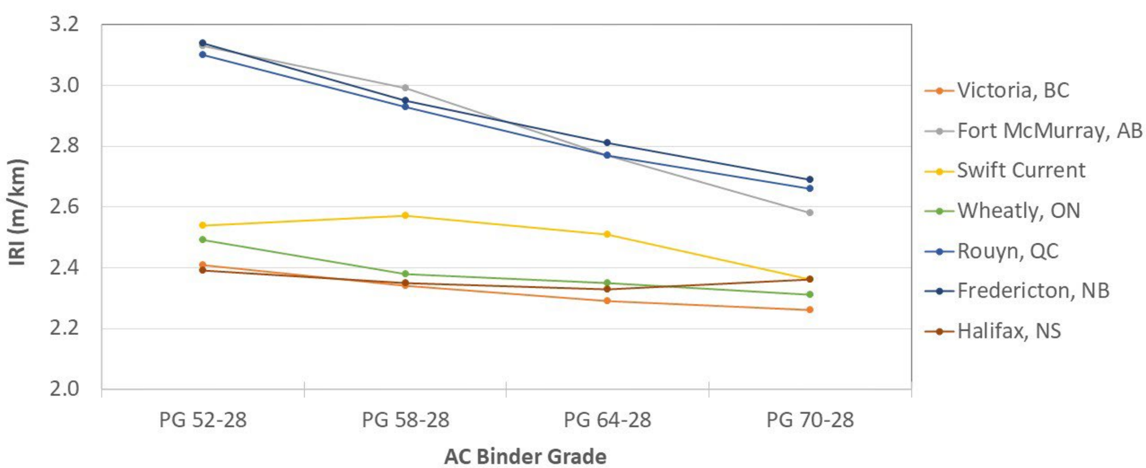
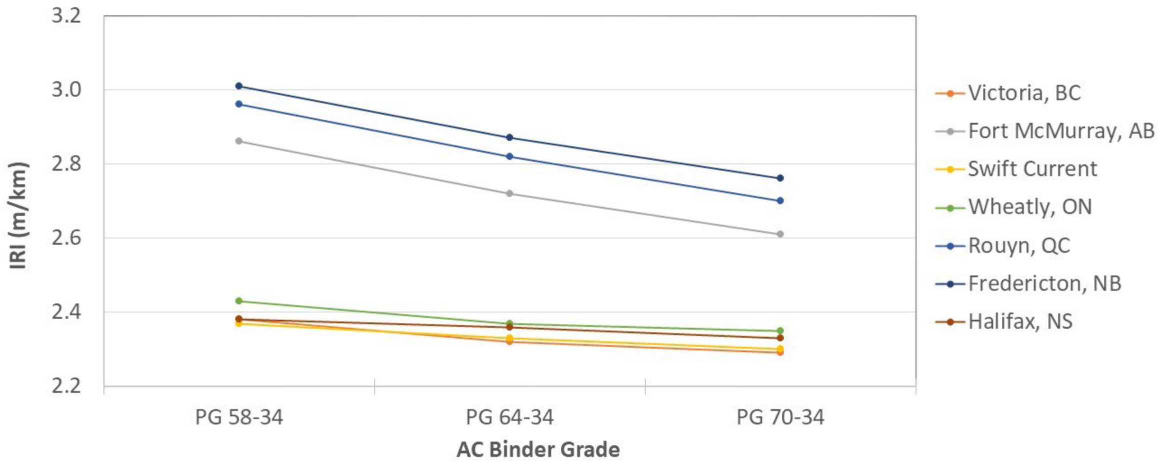


Figure 2c shows the trends of predicted IRI in selected climatic areas for increased high temperature grades in combination with a reduced (from –28 °C to –34 °C) low temperature grade (i.e., PG 58-34, 64-34 and 70-34), which were selected to address both rutting and thermal cracking. As shown in figure, after reducing asphalt binder low temperature grade, the predicted IRI progressively reduces with the selection of stiffer asphalt binders in all climatic areas. Inconsistencies in predicted IRI are noted between PG 58-28 and PG 58-34 binders for some climatic areas. An in-depth assessment of all predicted distresses indicated that the inconsistencies in IRI are generally related to the inconsistencies in predicted other distresses.

Figure 2c. Effect of asphalt binder high temperature grades (along with PG -34) on predicted IRI



A statistical analysis for the PMED software predicted IRI encompassing all the relevant variables (i.e., predicted rutting, thermal cracking, fatigue cracking, freezing index and precipitation) that are included in the IRI prediction model was conducted to determine the statistically significant variables. The gradation and plasticity of subgrade soils were excluded from this statistical analysis because they remained unchanged in all design trials. This analysis has shown that the predicted total rutting has the most significant influence on the predicted (calculated) IRI followed by the total fatigue cracking (BUFC plus TDFC) and predicted transverse cracking. The freezing index and amount of precipitation have minimal effect on the predicted IRI.

Impact of Binder Grades on Predicted HMA Thermal Cracking

The trends of the predicted thermal cracking (TC) in AC (HMA) layer for the variations of asphalt binder grades in selected climatic areas are shown in Figures 3a, 3b and 3c. As shown in Figure 3a, the use of progressively softer (i.e., PG 58-22, 58-28, 58-34, 58-40) binders, which are selected to resist thermal cracking, with no change in binder high temperature grade, result in a reduction of the predicted HMA thermal cracking in colder climatic areas (with low daily minimum temperatures). This trend is reasonable as softer binders maintain flexibility at lower temperatures, allowing better stress relaxation and reducing crack formation. The predicted thermal cracking is unaffected in areas with warmer (higher than –22 °C) winter temperatures, e.g., in Victoria and Wheatly, when using progressively softer binders, as expected. However, there are some inconsistent predictions for some climatic areas. For example, the predicted TC remains unchanged at 41 m/km for both PG 58-34 and PG 58-40 binders in The Pas (MB) and Rouyn (QC) despite that the winter temperatures are –48.1° C and –45.7 °C, respectively.

Figure 3a: Effect of asphalt binder low temperature grades (along with PG 58) on thermal cracking

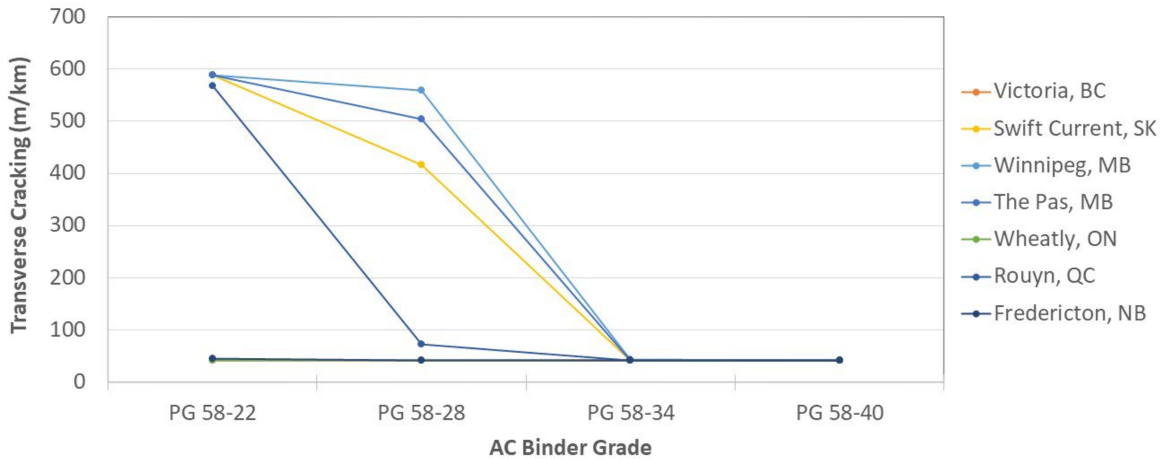


Figure 3b show that when progressively stiffer (i.e., PG 52-28, 58-28, 64-28 and 70-28) asphalt binders are selected to withstand AC layer rutting by keeping the binder low temperature grade unchanged at –28, there is an initial increase in thermal cracking with a stiffer (PG 58-28) binder as compared to a softer (PG 52-28) binder, which is reasonable for the colder climates. However, there are gradual reduction of predicted thermal cracking in all the colder climatic areas with stiffer (i.e., PG 64-28 and PG 70-28) binders than the PG 58-28 binder, which are unexpected. The predicted thermal cracking remains unaffected with stiffer binders in warmer climatic areas (e.g., in Victoria, Wheatly and Halifax), except that there is an increase in TC for PG 70-28 binder in Halifax.

Figure 3b. Effect of asphalt binder high temperature grades (along with PG -28) on thermal cracking

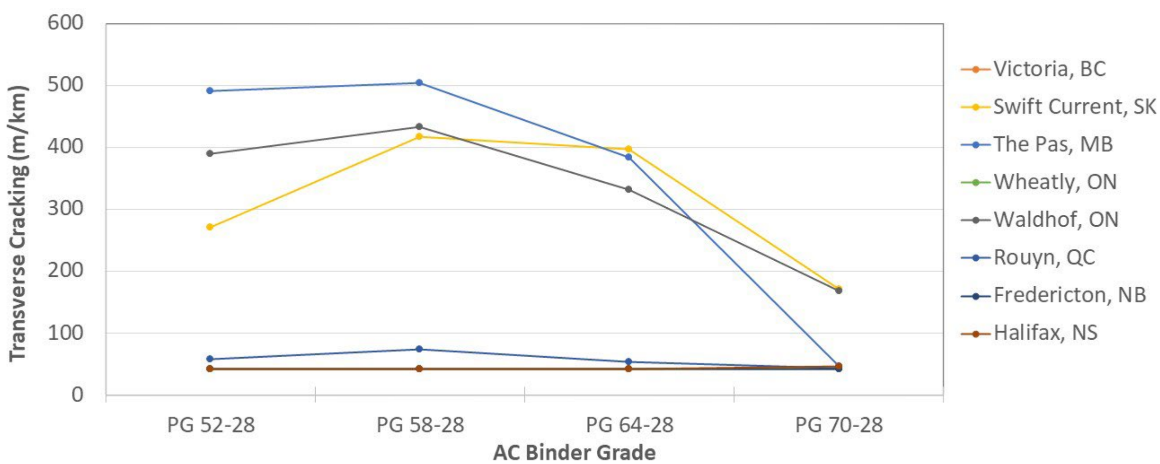
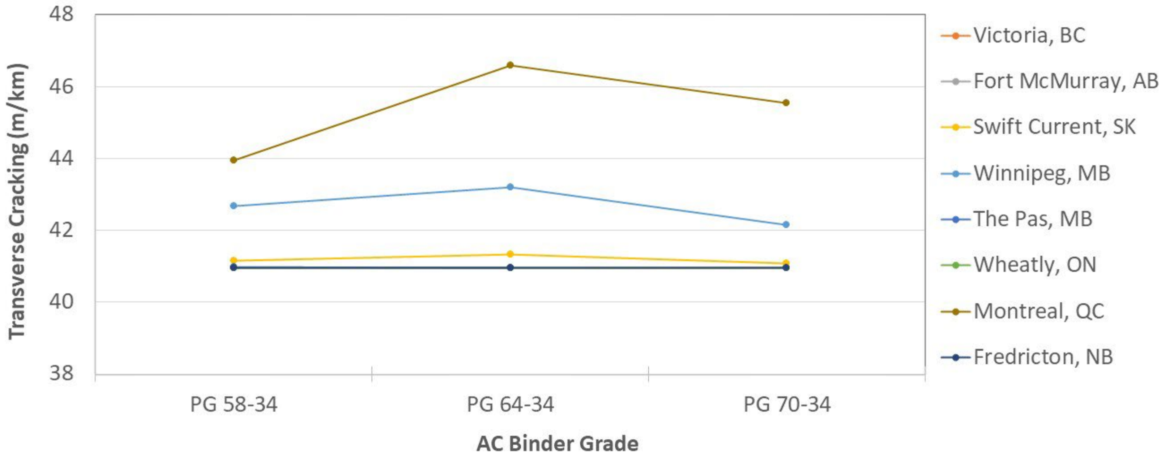


Figure 3c shows that the use stiffer asphalt binders with a reduced low temperature grade (i.e., PG 58-34, 64-34 and 70-34 binders) results in little to no effect on the predicted HMA thermal cracking in all climatic conditions, except for Montreal, Winnipeg, and Swift Current. In these three climatic areas, there are increase in TC for PG 64-34 binder than the PG 58-34 binder and then there are decrease in TC with further stiffer PG 70-34 binder than the PG 64-34 binder.

Figure 3c. Effect of asphalt binder high temperature grades (along with PG -34) on thermal cracking

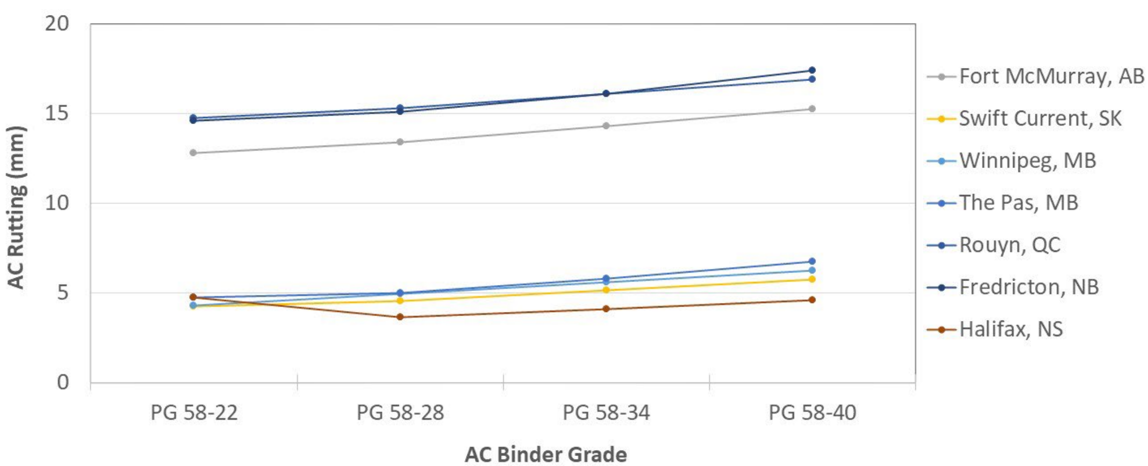


Overall, the trends of predicted TC have appeared to be inconsistent among binder grades and climatic areas, and a PG -34 grade seems to be adequate to provide resistance to thermal cracking in almost all climatic areas in Canada. A statistical analysis encompassing binder low and high temperature grades and minimum (winter) air temperature showed that all three parameters are statistically significant for predicting the thermal cracking. However, an increased high binder temperature grade results in a reduction of thermal cracking, which does not seem to be reasonable.

Impact of Binder Grades on Predicted HMA Layer Rutting

Figure 4a shows that the use of progressively softer (i.e., PG 58-22, 58-28, 58-34 and 58-40) binders in terms of reduced binder low temperature grades, keeping the binder high temperature grade unchanged at 58, results in a gradual increase in the predicted HMA layer rutting (AC layer deformation) in each climatic area, except for Halifax. For Halifax, there is a reduction in AC layer rutting with PG 58-28 (softer) binder than the PG 58-22 (stiffer) binder.

Figure 4a. Effect of asphalt binder low temperature grades (along with PG 58) on HMA layer rutting



Alternatively, when progressively stiffer (i.e., PG 52-28, 58-28, 64-28 and 70-28) binders to withstand rutting are used, keeping the binder low temperature grade unchanged at -28, there is a gradual reduction in the predicted HMA layer rutting in each climatic area, except for Halifax, as shown in Figure 4b. For Halifax, there is an increase in rutting with stiffer PG 70-28 binder than the relatively softer PG 64-28 binder. The reason for such deviation is unclear.

Figure 4b. Effect of asphalt binder high temperature grades (along with PG -28) on HMA layer rutting

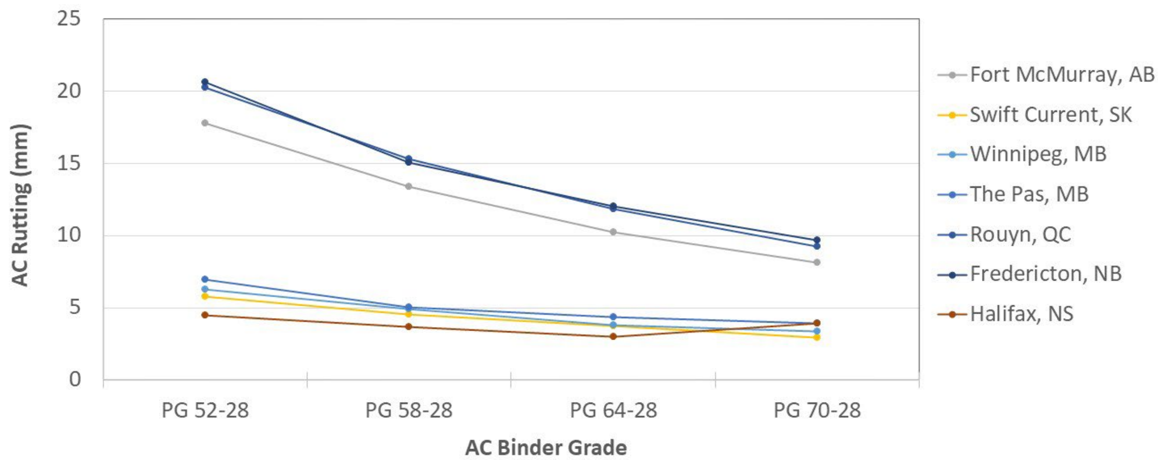
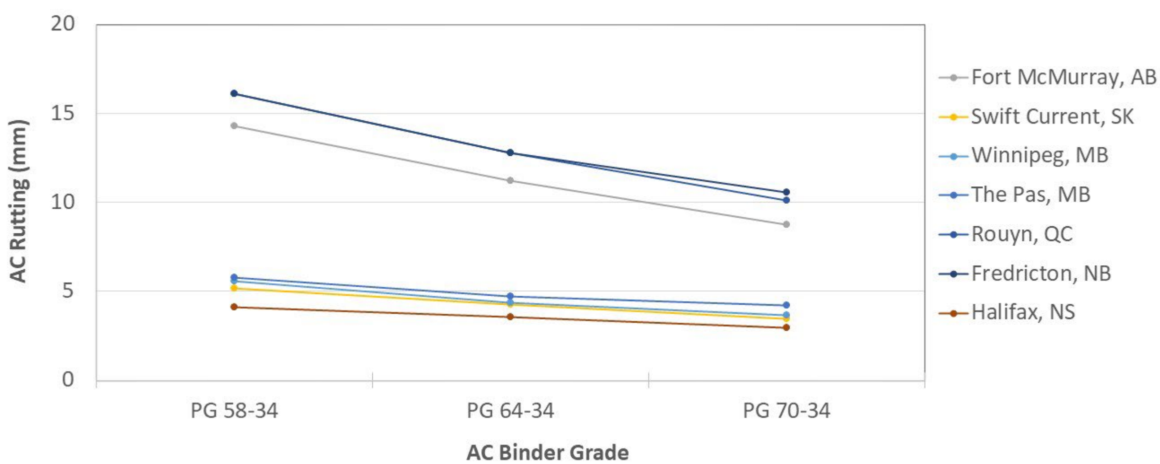


Figure 4c shows that the predicted AC layer rutting reduces with increased high binder temperature grades in all climatic areas when a reduced low binder temperature grade (-34 instead of –28) is used.

Figure 4c. Effect of asphalt binder high temperature grades (along with PG -34) on HMA layer rutting



When the predicted HMA layer rutting values are compared among climatic areas for a given asphalt binder grade, Fredericton and Rouyn with moderate summer temperatures are shown to provide the highest amount of rutting. The lowest amount of HMA layer rutting is observed for Halifax with low summer temperature. However, Swift Current, Winnipeg and The Pas with high summer temperatures provide a similar low amount of rutting as Halifax. Given that the properties of the HMA layer and base/subbase/subgrade remained unchanged in all design trials, the reason(s) for such trends of the predicted HMA rutting among climatic areas could not be explained based on the available data.

A statistical analysis with several combinations of variables including asphalt binder high and low temperature grades, high and low air temperatures and precipitation showed that only the asphalt binder high temperature grade is statistically significant parameter for AC layer rutting. An increased binder high temperature grade results in a reduction of HMA layer rutting, which is reasonable.

Impact of Binder Grades on Predicted Total Rutting

The trends of the predicted total rutting for the variations of asphalt binder grades are shown in Figures 5a, 5b and 5c. As shown in the figures, the predicted total rutting (total permanent deformation of pavements) follows similar trends as the HMA layer rutting. The total rutting of unbound aggregate base and subbase layers, and subgrade remained fairly constant at 6.63 to 6.97 mm (average 6.74 mm) in all design trials, which are not unexpected given that the input parameters for these layers and materials remained unchanged.

Figure 5a. Effect of asphalt binder low temperature grade (along with PG 58) on predicted total rutting

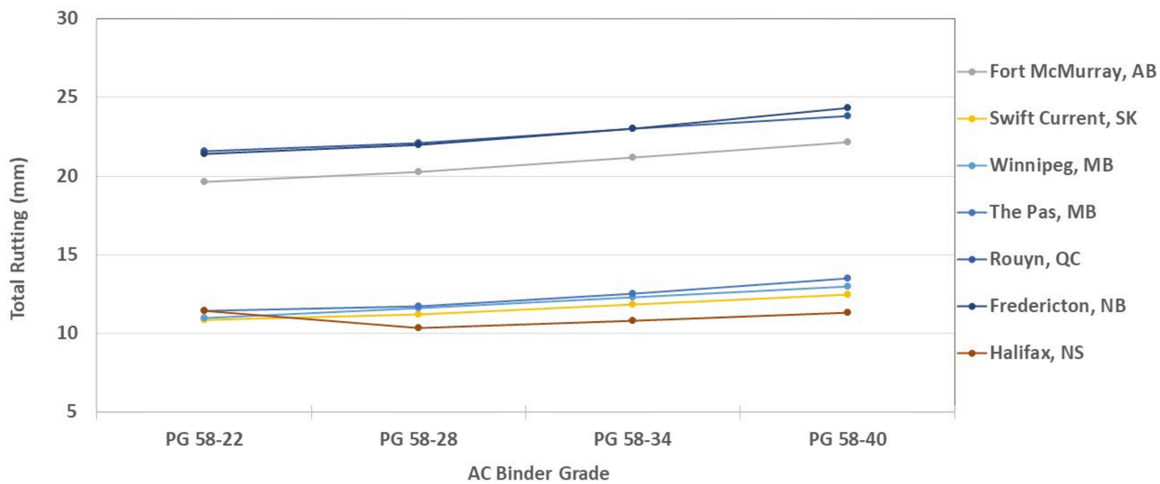


Figure 5b. Effect of asphalt binder high temperature grades (along with PG -28) on total rutting

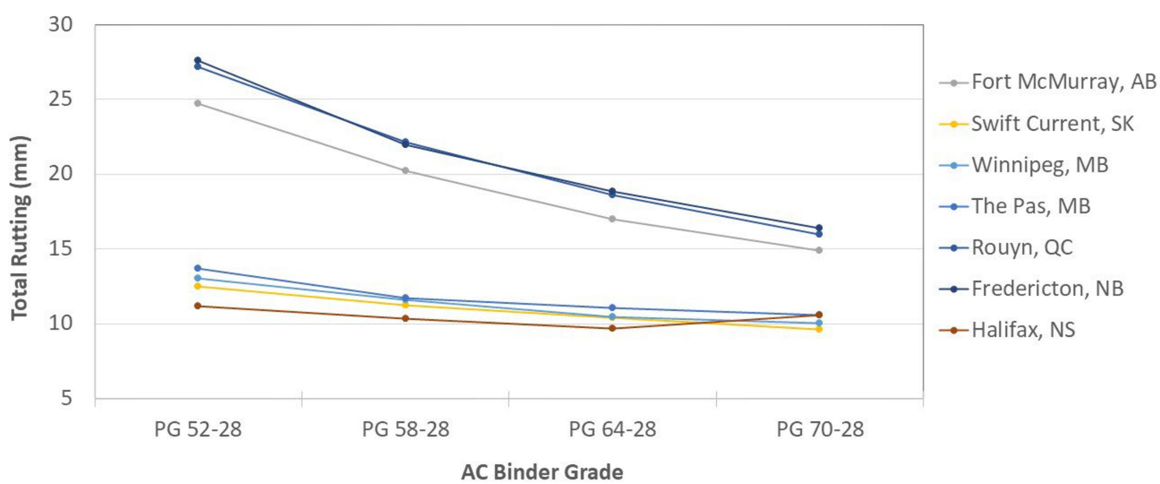
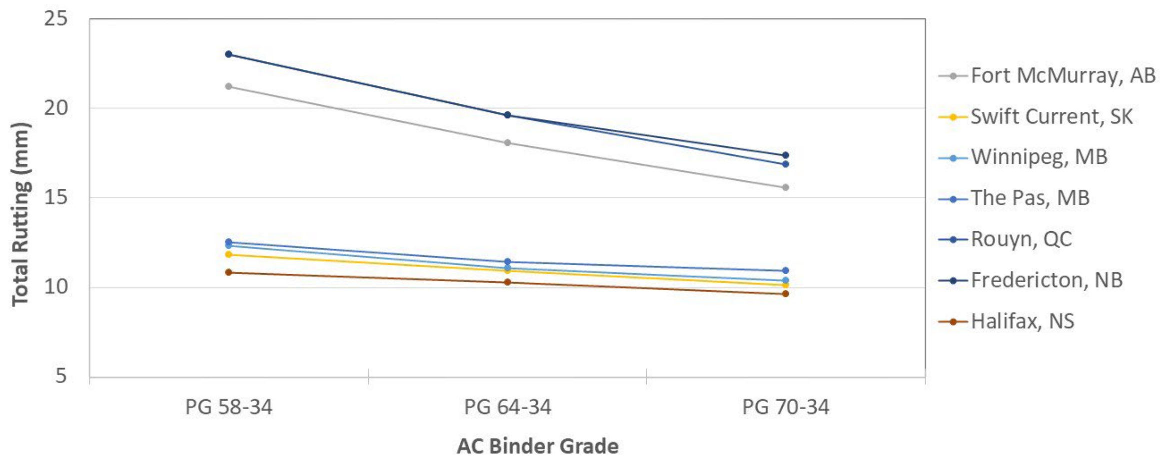


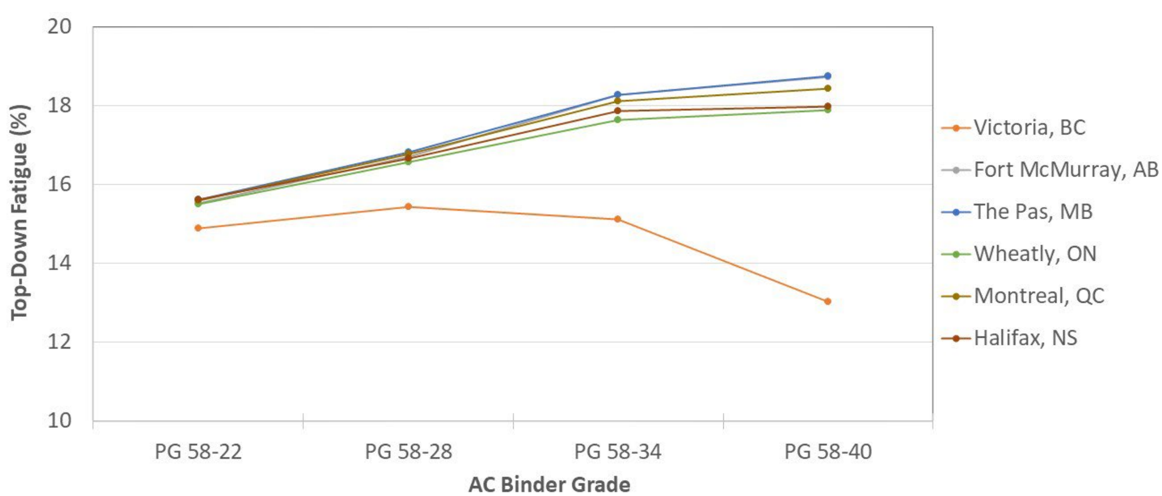
Figure 5c. Effect of asphalt binder high temperature grades (along with PG -34) on predicted total rutting



Impact of Binder Grades on Predicted Top-Down Fatigue Cracking (TDFC)

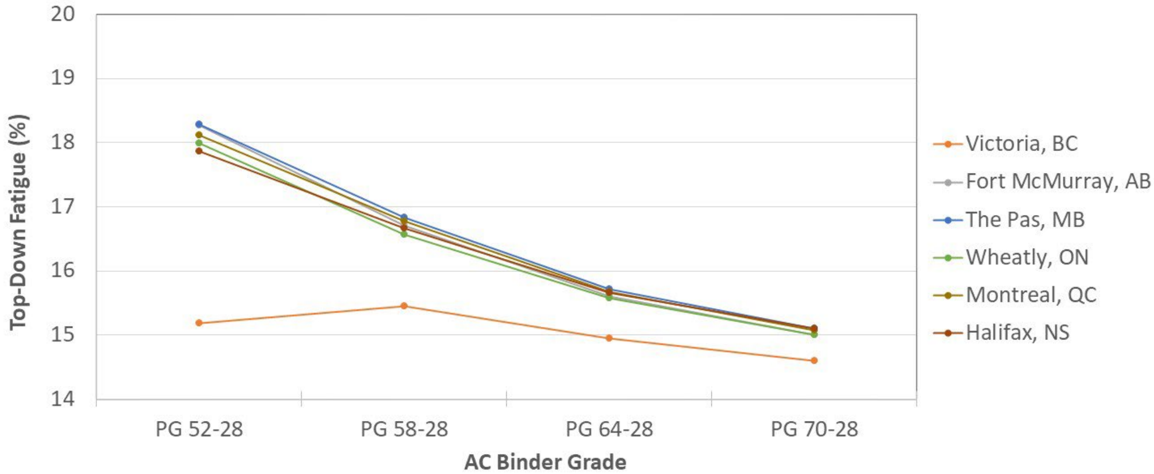
The trends of the PMED software predicted TDFC in HMA for the variations of asphalt binder grades are shown in Figure 6a, 6b and 6c. As shown in Figure 6a, the predicted TDFC increases for progressively softer (i.e., PG 58-22, 58-28, 58-34 and 58-40) binders in terms of low temperature grades for a given high temperature grade of 58 for all climatic areas apart from Victoria. Victoria sees a decrease in TDFC when selecting PG 58-34 and PG 58-40 binders as compared to PG 58-28 binder. The increase in TDFC with the selection of softer asphalt binder does not seem to be reasonable as softer/flexible HMA mixes for colder climates provide increased flexibility and resistance to cracking.

Figure 6a. Effect of asphalt binder low temperature grades (along with PG 58) on predicted TDFC



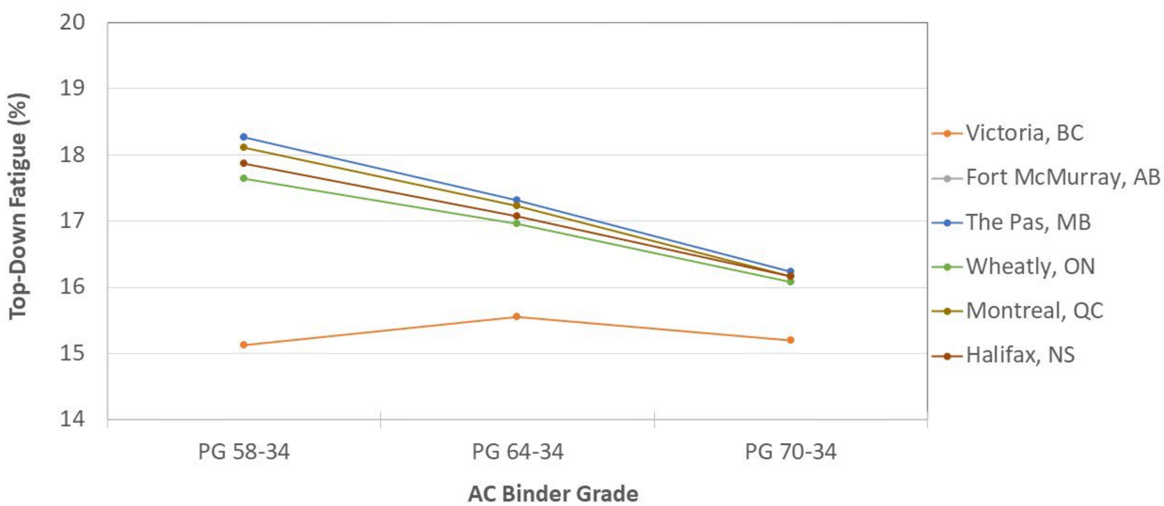
When progressively stiffer binders, in terms of increased binder high temperature grades, with no change in binder low temperature grade (i.e., PG 52-28, 58-28, 64-28 and 70-28 binders) are used, the PMED software predicted TDFC reduces for all climate areas, except for Victoria, as shown in Figure 6b. For Victoria, there is an increase in predicted TDFC for a change in asphalt binder grade from PG 52-28 to PG 58-28. The general reduction of TDFC with stiffer asphalt binder grade does not seem to be reasonable as asphalt mixes with stiffer binders may exhibit low tensile strength and low resistance to fatigue cracking.

Figure 6b. Effect of asphalt binder high temperature grades (along with PG -28) on predicted TDFC



The use of increased binder high temperature grades with a reduced binder low temperature grade from PG-28 to PG-34 (i.e., PG 58-34, 64-34 and 70-34 binders) also resulted in a decreasing trend of predicted TDFC for all climatic areas, except for Victoria, as shown in Figure 6c. For Victoria, there is an increase in the predicted TDFC for changing binder high temperature grade from PG 58-34 to PG 64-34, but a reduction of TDFC for increasing the high temperature grade from 64-34 to 70-34. The trends of predicated TDFC, as shown in Figures 6a-6c, indicate that varying climatic conditions have minor impacts on the TDFC, except for Victoria (BC), which has inconsistent trends of predicted TDFC.

Figure 6c. Effect of asphalt binder high temperature grades (along with PG -34) on predicted TDFC



A statistical analysis showed that asphalt binder high and low temperature grades and mean or maximum air temperatures are statistically significant variables for the prediction of TDFC. A stiffer binder in terms of increased high temperature grade results in a reduction of TDFC. A softer binder in terms of reduced low temperature grade results in an increase of TDFC. A higher mean or maximum air temperatures, thereby pavement temperatures, results in a minor reduction of TDFC, but it seems to be practical trend. Further investigation is required to identity the reasons for the observed variations of predicted TDFC with change of binder grades.

Impact of Binder Grades on Predicted Bottom-Up Fatigue Cracking (BUFC)

The trends of the predicted BUFC in HMA for the variations of asphalt binder grades are shown in Figure 7a, 7b and 7c. As shown in Figure 7a, the predicted BUFC increases with the use of progressively softer (i.e., PG 58-22, 58-28, 58-34 and 58-40) binders in terms of reduced low temperature grades, for the given high temperature grade of 58, in all climatic areas. The increase in BUFC with the use of softer binders is unexpected because softer HMA mixes in colder climates generally provide increased flexibility and resistance to fatigue cracking.

Figure 7a. Effect of asphalt binder low temperature grades (along with PG 58) on predicted BUFC

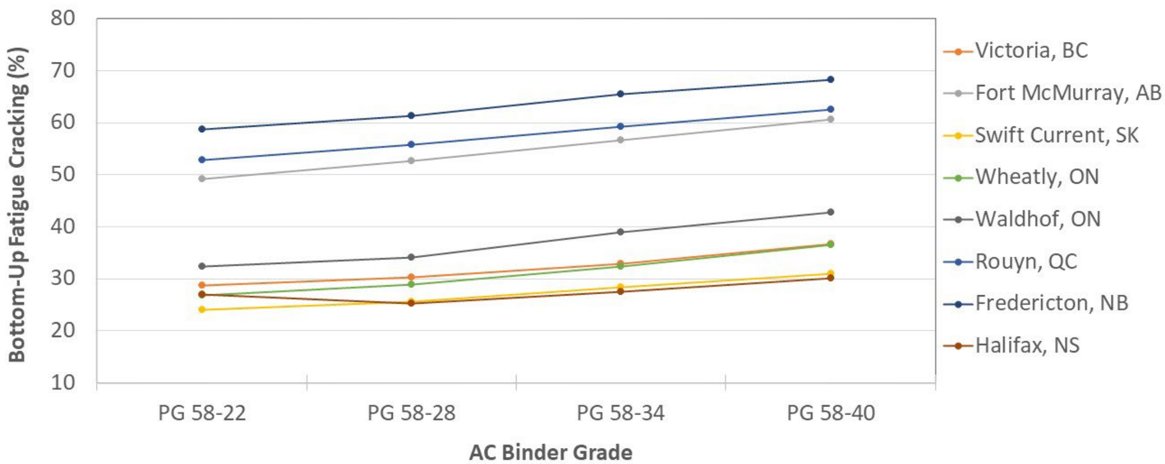
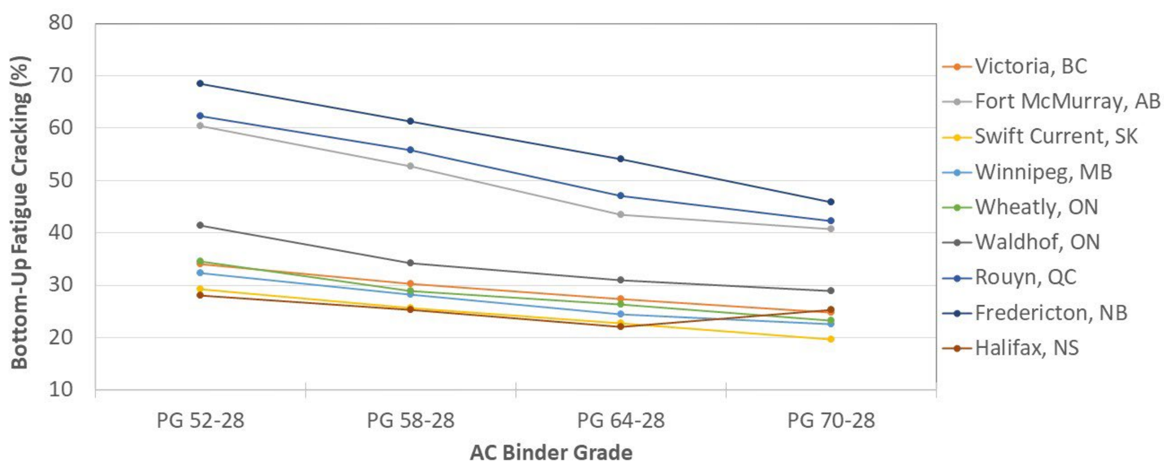


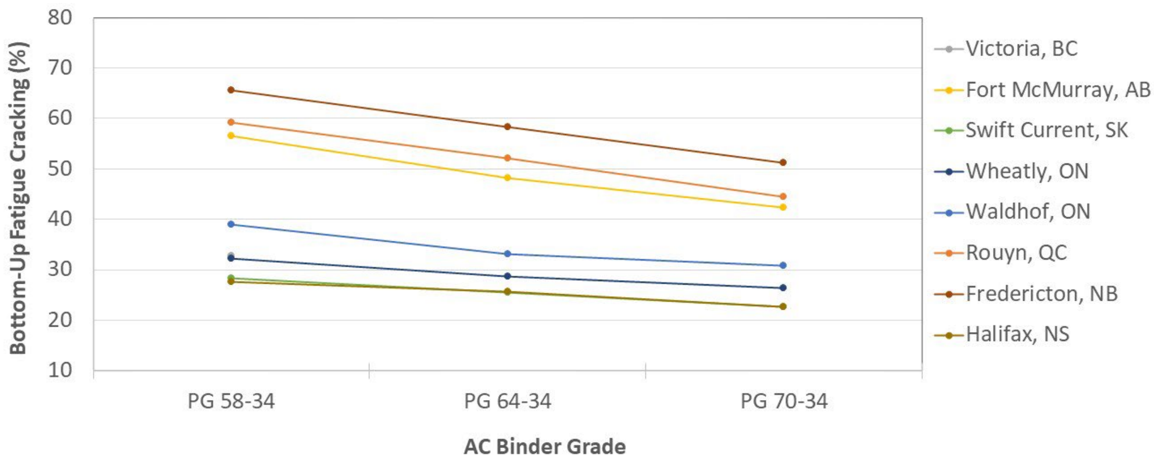
Figure 7b shows that progressively stiffer (i.e., PG 52-28, 58-28, 64-28 and 70-28 binders, for a given low temperature grade of –28, results in reduction of predicted BUFC for all climate areas, except for Halifax. There is an increase in predicted BUFC for PG 70-28 binder as compared to PG 64-28 binder in Halifax.

Figure 7b. Effect of asphalt binder high temperature grades (along with PG -28) on predicted BUFC



The use of stiffer (i.e., PG 58-34, 64-34 and 70-34) binder grades with increased binder high temperature grades and with a reduced binder low temperature grade, also resulted in reduction of BUFC in all climatic areas, as shown in Figure 7c. The predicted BUFC for PG-34 binders are higher than PG-28 binders further indicating that softer binders result in increased fatigue cracking.

Figure 7c. Effect of asphalt binder high temperature grades (along with PG -34) on predicted BUFC



The trends of PMED software predicated BUFC, as shown in Figures 7a-7c, indicate that varying climatic conditions have noticeable impacts on the predicted fatigue cracking. A statistical analysis including binder grades and climatic parameters showed that asphalt binder high and low temperature grades and mean or maximum air temperatures are statistically significant variables for the prediction of BUFC, as in the case of TDFC. A stiffer binder in terms of increased high binder temperature grade results in a reduction of BUFC. A softer binder in terms of reduced low temperature grade results in an increase of BUFC. A higher mean or maximum air temperatures, thereby pavement temperatures, results in a noticeable reduction of BUFC and it seems to be a practical trend. Further investigation is required to identity the reasons for the observed variations of predicted BUFC with change of binder grades.

Summary and Conclusions

A performance graded asphalt binder selected based on local climatic and traffic loading conditions are known to significantly contribute to flexible pavement performance in terms of enhanced resistance to cracking and rutting. AASHTOWare PMED software is a modern and sophisticated pavement design and analysis tool. However, it's implementation in Canada is hindered due to some unexpected outcomes and inconsistency between software versions. This study attempted to assess the suitability of the latest version of PMED software in predicting the performance of asphalt binders with varied PG in different climatic conditions across Canada. Design trials were completed encompassing nine different asphalt binders in 11 different climatic areas. This paper presented the details of the design trials, results and analyses. Based on the assessment and analyses of results, the following conclusions can be drawn:

1) Softer binders with reduced low temperature grades, selected to withstand AC thermal cracking, resulted in a reduction of predicted thermal cracking in very cold climatic areas (daily minimum temperatures less than –22 °C) with some inconsistent predictions. The effect of stiffer asphalt binders in terms of increased high temperature grade on predicted thermal cracking was inconsistent. A PG -34 grade binder was shown to be adequate to provide resistance to thermal cracking in almost all cold climatic areas in Canada.

2) Softer binders in terms of reduced low temperature grades resulted in an increase of predicted AC layer rutting in each climatic area, except for Halifax. Stiffer binders in terms of increased high temperature grades, selected to withstand rutting, provided a reduction of predicted AC layer rutting in each climatic area, except for Halifax. The variation of AC layer rutting among climatic areas could not be explained based on the climatic data. The asphalt binder high temperature grade was shown to be the only statistically significant variable for predicting AC layer rutting within the scope of design trials.
3) The predicted total rutting followed similar trends as the HMA layer rutting with a total of 6.63 to 6.97 mm (average 6.74 mm) rutting in granular base, subbase and subgrade.
4) In general, a stiffer binder in terms of increased high temperature grade resulted in a reduction of BUFC. A softer binder in terms of reduced low temperature grade resulted in an increase of BUFC. Further investigation is required to identify the reasons for the observed variations of predicted BUFC with change of binder grades. A higher mean or maximum air temperatures, thereby pavement temperatures, resulted in a noticeable reduction of BUFC and it seems to be a practical trend.
5) The predicted TDFC followed similar trends as the BUFC. However, more inconsistency among climatic areas and a smaller effect of climatic parameters were observed for the PMED software predicted TDFC than the predicted BUFC.
6) The predicted IRI mostly depended on the predicted total rutting, total fatigue cracking (BUFC plus TDFC) and transverse cracking. The influence of freezing index and precipitations on the predicted IRI was minimal.

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