Technical Paper

ISSN 1997-1400 Int. J. Pavement Res. Technol. 5(6):379-385

A Comparative Study between the Alberta Transportation Flexible Pavement Design and the MEPDG

Jhuma Saha[1], Somayeh Nassiri[1+], Hamid Soleymani[1], and Alireza Bayat[1]

Abstract: The main objective of this study was to compare the flexible pavement design using the Alberta Transportation Pavement Design (ATPD) procedure to the recently developed Mechanistic Empirical Pavement Design Guide (MEPDG). Findings from this study explore the possibility of MEPDG implementation for pavement design in Alberta, Canada. Six different design cases were defined with three different traffic levels and two different subgrade materials. Each case was designed following the ATPD procedure. The ATPD design thicknesses were then used in the MEPDG for each case to predict the pavement performance reliabilities at the end of the 20-year design life. The design for each case was repeated 27 times, using the climatic files available in the MEPDG for Alberta. It was found that, when using the MEPDG, only the cases with a strong subgrade material and a low level of traffic meet the default limit value for total pavement rutting. Also, all sections designed following the ATPD procedure, when designed using the MEPDG, fail due to excessive International Roughness Index (IRI).

***Key words**: Design; Distress; Pavement; Performance; Rutting.*

Introduction

The Mechanistic Empirical Pavement Design Guide (MEPDG) is a new design tool that is replacing the old American Association of State Highway and Transportation Official's (AASHTO) 1993 Design Guide [1] across the United States and Canada. The new design approach is a significant leap forward in pavement design in many different ways. First, it is mechanistic in the sense that pavement performance is predicted using the pavement structural responses (critical stresses and strains) and established using finite element models. Second, the design is based on incremental damage analysis. The structural responses are used in damage models, which feed directly into empirical pavement performance models. The performance models are used to estimate key distresses observed in flexible, rigid and rehabilitation pavement structures. In contrast to the AASHTO 1993 Guide, in which the pavement design is based on serviceability loss, the pavement design thickness predicted using the MEPDG is established based on the user-defined pavement performance criteria at the desired reliability level. Furthermore, the hierarchical approach adopted for defining the design inputs based on the quality of the available data is another MEPDG innovation that facilitates the design procedure substantially. Although the MEPDG involves more than 100 input parameters, the new design procedure is still practicable, since typical values for each parameter is pre-defined in the software for cases where minimal data is available. The design inputs can be classified into three major categories: traffic, climate and material properties. Unlike the AASHTO 1993 Guide, which uses the equivalent single axle load (ESAL) for traffic characterization, the MEPDG user needs to define a full axle-load spectrum. Climatic data is another important design input which determines the pavement temperature and also seasonal changes in the pavement material properties. Data from more than 1,000 weather stations across the United States, and more recently Canada, is now available for implementation in the MEPDG.

Several studies conducted over the past years aimed at evaluating the pavement design performed using the MEPDG in comparison to the AASHTO 1993 Guide. For instance, a comparative study performed by Schwartz and Carvalho in 2007 showed that following the AASHTO 1993 Guide possibly results in underestimating the required thickness for pavement sections in warm regions. The authors concluded that traffic, especially high traffic levels, is a source of uncertainty in the AASHTO design procedure. This study showed that the AASHTO 1993 Guide may overestimate the pavement performance when traffic levels are well beyond those used in the American Association of State Highway Officials (AASHO) Road Test.

Mulandi et al. in 2006 also conducted a comparative analysis between the AASHTO 1993 Guide and the MEPDG [2]. In this study, five in-service jointed plain concrete pavements (JPCP) in Kansas were redesigned using the MEPDG as both JPCP and Asphalt Concrete (AC) pavement sections. Based on this study, using the MEPDG results in thinner AC sections for all cases. The same result was obtained for four of the five JPCP sections. Only one JPCP design was thicker when using the MEPDG in comparison to the AASHTO 1993 Guide.

In 2011, El-Badawy et al. reanalyzed several flexible pavement sections originally designed following the Idaho Transportation Department (ITD) design guide, using both the AASHTO 1993 Guide and the MEPDG [3]. Their results showed that following the ITD design guide results in significantly overestimated pavement layer thicknesses, particularly for unbound layer(s), while the AASHTO 1993 Guide and the MEPDG show reasonable agreements in the final design.

The current study is another comparative study, which focuses on the conventional flexible pavement design in the Province of

[1] University of Alberta, Department of Civil & Environmental Engineering, Edmonton, AB, Canada T6G 2W2.

[+] Corresponding Author: E-mail somayeh@ualberta.ca

Note: Submitted January 8, 2012; Revised April 30, 2012; Accepted May 8, 2012.

Alberta in Canada. This study investigates the difference in the pavement design using the current Alberta Transportation Pavement Design (ATPD) method and the MEPDG. The ATPD method is based mainly on the AASHTO 1993 Guide, with minor modifications, regarding the AC mix design, structural layers coefficients (a_i) and design reliability levels. For the AC mix design, the Province of Alberta is divided into three different climate zones. The appropriate AC mix design is then selected for each climate zone, based on the design ESAL for the road section. Regarding the layers' coefficients, typical a_i values are recommended in the ATPD Guide for local materials, in lieu of actual laboratory resilient moduli testing. Finally, for the design reliability, four different levels, varying from 75 to 95 percent, are defined in the ATPD, based on the design ESAL for the road section.

This study is the first step in moving toward the implementation of the MEPDG in Alberta. In addition, the possibility of MEPDG implementation in such cold regions as Alberta, with an average annual freezing index (FI) of approximately 1,550 ℃-day, is evaluated. Furthermore, the study provides an evaluation of the sufficiency and accuracy of Alberta's climatic files, which were recently developed for use in the MEPDG.

In order to make comparisons between the final pavement design obtained using the ATPD procedure and the MEPDG, six different design scenarios were defined. These scenarios include different pavement sections with varying traffic levels and subgrade materials. Since traffic is one of the influential input parameters for both the ATPD and the MEPDG, three different traffic levels of 0.3, 4 and 20 million Equivalent Single Axle Load (ESAL) were defined. These three levels of traffic are the threshold values defined in the Alberta Transportation & Utilities (AT & U) Pavement Design Manual for roadways with low, medium and high traffic conditions [4]. In addition, considering the significance of subgrade in the ATPD method, two different subgrade materials, poor and strong with moduli of 25 and 50 MPa, respectively were considered in the study. This resulted in the following six different design scenarios:

- Case 1: Poor subgrade – Low traffic
- Case 2: Poor subgrade – Medium traffic
- Case 3: Poor subgrade – High traffic
- Case 4: Strong subgrade – Low traffic
- Case 5: Strong subgrade – Medium traffic
- Case 6: Strong subgrade – High traffic

To include the effect of climate on the design obtained using the MEPDG, each of the six design scenarios were performed for 27 different locations across Alberta. This selection was made because the Transportation Association of Canada (TAC) recently made data from 27 weather stations across the province available for implementation in the MEPDG. A total of 6 × 27 = 162 runs of the MEPDG software (Version 1.1) was performed. The 20-year MEPDG-predicted reliabilities for pavement performance indicators, such as total permanent pavement deformation (rutting) and the International Roughness Index (IRI) were used to compare the design obtained following the ATPD procedure and the MEPDG.

Pavement Design Using the ATPD

The six different cases were first designed following the ATPD procedure. This included establishing the final design thickness for the AC and granular base course (GBS) for each case. The design inputs required to perform the design were defined as described below.

Table 1. Pavement Design Input Values Used in the ATPD Method.

Parameter	Value
Pavement Design Life (Years)	20
Initial Serviceability	4.2
Terminal Serviceability	2.5
Standard Deviation (S_0)	0.45
Layer Coefficients	a_1: 0.4 (AC Layer) a_2: 0.14 (Base Layer)
Design Reliability (%)	Low and Medium Traffic: 85 High Traffic: 95

Table 2. Pavement Design Thickness Established Using the ATPD Method for Different Cases.

Case Description	AC Thickness (mm)	Granular Base Layer Thickness (mm)
Case-1: Poor Subgrade - Low Traffic	140	220
Case-2: Poor Subgrade - Medium Traffic	180	450
Case-3: Poor Subgrade - High Traffic	250	500
Case-4: Strong Subgrade – Low Traffic	105	200
Case-5: Strong Subgrade - Medium Traffic	160	320
Case-6: Strong Subgrade - High Traffic	240	370

ATPD Input Parameters

Recommendations found in the AT & U Pavement Design Manual [4] were followed for defining the design input parameters and the design criteria required for flexible pavement design. A summary of these inputs is provided in Table 1. As seen in Table 1, these input parameters include the design life, initial and terminal serviceability, layers coefficients and design reliability. The pavement design life was defined as 20 years, which is the typical design life used in Alberta. The ATPD method similar to the AASHTO design procedure is based on the serviceability loss. The initial serviceability for a newly constructed pavement was defined as 4.2. The terminal serviceability at the end of the design life was defined as 2.5. These values were defined based on the suggestions found in the ATPD. The next set of input parameters in Table 2 is the layers' coefficients. Typical values of 0.4 and 0.14 are suggested in the ATPD for AC and GBC, respectively. Finally, the design reliability was defined as 85 and 95 percent for the roads with low/medium and high levels of traffic, respectively according to the ATPD.

Pavement Design Thickness

The six different pavement sections were designed following the

ATPD method, based on the design criteria presented in Table 1. The ATPD method follows the exact same empirical design equation for flexible pavement design, available in the AASHTO 1993. However, the application of the nomograph available in the AASHTO 1993 has been simplified in the ATPD with a series of design charts. These design charts were developed for a suitable range of traffic and effective roadbed resilient modulus values that would be encountered in Alberta. The final design thicknesses for the AC layer and GBC are provided in Table 2. According to Table 2, the minimum design thickness is obtained for Case 4, with a strong subgrade material and a low level of traffic. In this case, the design thickness is established at 105- and 200 mm for the AC layer and the GBC, respectively. On the other hand, the maximum layer thicknesses of 250- and 500 mm were established for the AC and the GBC for Case 3, respectively.

Pavement Design Using The MEPDG

Using the MEPDG, an acceptable design is determined iteratively by changing the pavement layers thicknesses until the allowable criteria for each pavement performance indicator is met [5]. To make the final pavement design established using the two different methods comparable, the AC and base layer thicknesses, established above following the ATPD method were inputted into the MEPDG software. The MEPDG inputs regarding traffic and subgrade were defined in such a way that they would be comparable to the values used in the ATPD procedure.

MEPDG Input Parameters

Traffic

As mentioned previously, three levels of traffic were used in the ATPD procedure. These three levels include low: 0.3 million, medium: 4 million and high: 20 million ESALs. When using the MEPDG software, however, traffic needs to be defined in terms of the Average Annual Daily Traffic (AADT). The following relation is suggested in the AT & U Pavement Design Manual [4], for determination of the AADT based on the ESALs and vice versa.

$$\begin{aligned} &\text{ESALs /day /direction} \\ &= \frac{\text{AADT}}{2}\left[\frac{(\%\text{SUT})}{2}\times 0.881+\frac{(\%\text{TTC})}{2}\times 2.073\right] \end{aligned} \tag{1}$$

In this relation,

%SUT = Percent of Single Unit Trucks in the AADT;

%TTC = Percent of Tractor Trailer Combinations in the AADT;

The values of 0.881 and 2.073 in the relation are the corresponding load equivalency factors used to convert the SUT and TTC, respectively.

Using Eq. (1), the Average Annual Daily Truck Traffic (AADTT) to be used in the MEPDG was estimated for the three different levels and is listed in Table 3. Table 3 also includes a list of all traffic parameters and their corresponding values used in Eq. (1). It is noteworthy that these values were defined based on the respective recommendations found in the AT & U Pavement Design Manual [4] for each road type. Other traffic parameters including the monthly and hourly adjustment factors, vehicle class distribution, axle load distribution factor and general traffic inputs were kept as the default values available in the MEPDG software.

Table 3. Traffic Parameters and Their Corresponding Values.

Parameter	Value
Number of Lanes in Design Direction	Low and Medium Traffic : 1 High Traffic: 2
Percent Truck in Design Direction	50
Percent Truck in Design Lane	Low and Medium Traffic: 100 High Traffic: 85
SUT (%)	70
TTC (%)	30
Percent of AADT as Trucks	15
Annual Growth Rate (%)	5-Compound
Estimated AADTT	Low Traffic: 40 Medium Traffic: 535 High Traffic: 2673

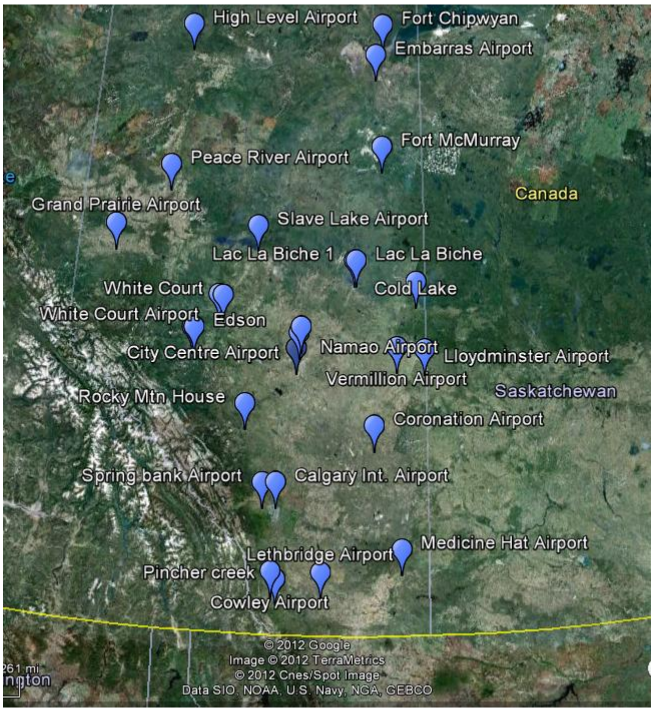

Fig. 1. Geographical Distribution of the MEPDG Climatic Stations from Google Earth.

Climate

A total of 222 climatic data files were collected by the TAC from the weather stations scattered across Canada for implementation in the MEPDG [6]. Data from 27 weather stations across Alberta were used to produce the climatic files for the MEPDG. The geographical distribution of these weather stations across the province is presented on the map from Google presented in Fig. 1.

Out of 27 climatic files for the province, 26 contained more than five years of data and only one file included data for a duration of between two to five years. The duration of available data is of

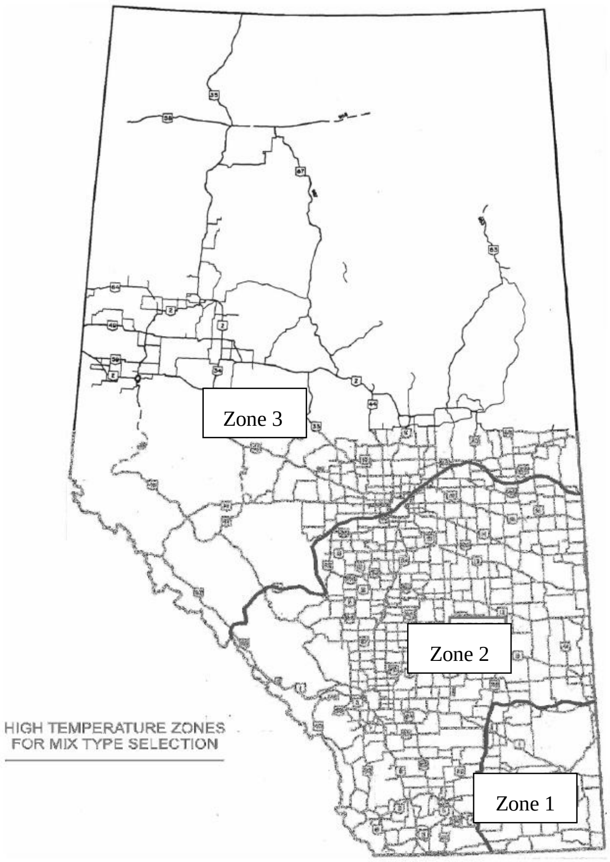

Fig. 2. Different High Temperature Zones for Asphalt Mix Selection [4].

interest, since a minimum of two years of data is required for the computational process in the MEPDG. In addition, a long duration of data, more than 10 years, results in a more reliable prediction of the climate of the site over the design life of the pavement.

Subgrade and Unbound Base Layer Properties

As mentioned previously, the pavement sections were designed with two different types of subgrade material. According to AT & U Pavement Design Manual [4], the threshold values for poor and strong subgrade materials, are 25 and 50 MPa, respectively. The subgrade type was defined as clayey material or A-6 according to AASHTO soil classifications. The base material was defined as granular, A-1-a, with a modulus of 276 MPa. Other material properties including the gradation, liquid limit and plastic limit for the subgrade and base layer were kept as the default values in the MEPDG software.

AC Layer Properties

The procedure available in the AT & U Design Bulletin #13 [7] was followed for selecting the AC mixture type for each of the 27 project sites. In this procedure, the province is divided into three different high-temperature climatic zones as seen in Fig. 2. Once the zone is identified for the project, the AC mix type is selected based on the roadway ESAL level as defined in Table 4. Based on this table, the AC mixes were selected for the six different pavement cases in different locations across Alberta. The results are provided in Table 5. The letter A in front of each binder grade represents the viscosity group for conventional AC binder used in Canada. Based on Alberta Transportation, a binder with the same penetration grade can be classified into Groups A, B, and C as a function of its viscosity. The viscosity change for the conventional AC mixture was ignored in this study when using the MEPDG, since the penetration of the AC binder does change.

It must be noted that binder Type 150-200A is not able to be inputted in the MEPDG software, therefore, binder Type PG 58-28 was used instead wherever required. Other AC mix properties such as asphalt mix/gradation, asphalt general values and thermal properties were kept as the default values already defined in the MEPDG software.

Design Criteria

The design criteria for the pavement performance indicators predicted using the MEPDG is presented in Table 6. These values were remained as the default values already available in the MEPDG software. It is noteworthy that, this study is only a preliminary step toward the implementation of the MEPDG in

Table 4. Selection of Conventional AC Mix Based on AT & U Design Bulletin #13.

High Temperature Zone	Design ESAL (million)				
	< 1.0	1.0 to < 3.0	3.0 to < 6.0	6.0 to < 10.0	≥ 10.0
1	150-200A	150-200A	150-200A	120-150A	120-150A
2	200-300A	200-300A	150-200A	150-200A	120-150A
3	200-300A	200-300A	150-200A	150-200A	150-200A

Table 5. AC Mix for Different Cases in the Three Zones.

Different Pavement Cases	Zone 1	Zone 2	Zone 3
Case-1: Poor Subgrade – Low Traffic	PG 58-28	200-300A	200-300A
Case-2: Poor Subgrade – Medium Traffic	PG 58-28	PG 58-28	PG 58-28
Case-3: Poor Subgrade – High Traffic	120-150A	120-150A	PG 58-28
Case-4: Strong Subgrade – Low Traffic	PG 58-28	200-300A	200-300A
Case-5: Strong Subgrade – Medium Traffic	PG 58-28	PG 58-28	PG 58-28
Case-6: Strong Subgrade – High Traffic	120-150A	120-150A	PG 58-28

Table 6. Pavement Design Input Values Used in the MEPDG.

Parameter	Value
Pavement Design Life (Years)	20
Reliability (%)	85
Longitudinal Cracking (m/km)	379
Transverse Cracking (m/km)	189
Alligator Cracking (%)	25
IRI Limit Value (m/km)	2.3
Total Rutting Limit Value (mm)	19

Table 7. Statistical Summary of Pavement Performance Indicators for Different Pavement Cases Predicted Using the MEPDG.

Pavement Distresses	Case Number	20-Year MEPDG Predicted Performance Indicator			
		Min.	Max.	Mean	MEPDG Limit Value
IRI (m/km)	1	2.5	2.5	2.5	2.3
	2	2.6	2.6	2.6	
	3	2.6	2.9	2.7	
	4	2.4	2.8	2.5	
	5	2.5	2.5	2.5	
	6	2.5	2.6	2.5	
Total Rutting (mm)	1	19	21	20	19
	2	22	24	23	
	3	23	32	25	
	4	16	18	18	
	5	19	21	19	
	6	19	23	21	

Alberta. As part of the implementation plan, the threshold values for each performance indicator needs to be established for the province based on local field data and the AT tolerance level for each distress.

Pavement Design Using the MEPDG

A total of 162 simulations of the MEPDG were made. The 20-year pavement performance indicators including fatigue and transverse cracking together with total pavement rutting and IRI were analyzed. The analysis of the predicted fatigue and transverse cracking for all runs revealed that, the models, especially the transverse cracking model, are insensitive to the varying design inputs. Furthermore, three of all runs showed exceptionally high values for transverse cracking. These three stations belong to Case 4 and correspond to Lac La Biche 1 and 2 and Fort Chipewyan weathers stations. The weather stations are located northeast of Edmonton and correspond to Zone 3 in Fig. 2. The reason for the anomalous behavior for the three stations is not clear. Unstable trends in the predicted cracking for flexible pavements were also observed in other studies conducted in Canada and the United States [8, 9]. Based on these observations, the main focus of the study is steered toward the predicted total rutting and IRI.

The minimum, mean and maximum 20-year MEPDG-predicted IRI and total pavement rutting for all runs is presented in Table 7. In this table, the values predicted for mean total rutting, increase as the traffic level increases. This behavior is evident for both groups with poor and strong subgrade materials. It is also noticed that, the cases with poor subgrade show higher distresses compared to the cases with strong subgrade material and the same traffic level. Based on Table 7, minimum, maximum and mean IRI values for all cases are consistent, especially for cases with a strong subgrade material. A slight increase is seen in the mean predicted IRI for both groups as the traffic level increases.

ATPD Versus The MEPDG

In order to facilitate the comparisons between the design performed using the MEPDG and the ATPD method, the predicted reliability values was used. The desired limit reliability level is defined by the MEPDG user for each pavement performance indicator. This was remained as the default value of 85 percent for all the runs performed in this study. When performing the design using the MEPDG, reliability is predicted and reported for each predicted distress at the end of the design life, based on the limit value defined for each distress. Fig. 3 to Fig. 5 present the box plots of the MEPDG-predicted reliabilities for the three performance indicators of total rutting, AC rutting and IRI, respectively.

According to Fig. 3, the average reliability predicted for total rutting using the MEPDG is less than the MEPDG limit value of 85 percent for all cases except for Case 4. Case 4 represents pavement sections with strong subgrade materials and low traffic conditions. This observation implies that, although the sections in Case 4 meet the serviceability requirements by the ATPD method, do not meet the default criteria in the MEPDG. Furthermore, a trend is noticeable in the MEPDG-predicted mean reliability for total rutting within each subgrade group. It is noticed that, the mean reliability drops as the traffic level increases in each subgrade group. This trend was expected to be in the opposite direction, since the reliability considered in the ATPD method for the cases with a low level of traffic is 85 percent, while it is 95 percent for the cases with high traffic levels. One can conclude that, the pavement design thickness established using the ATPD procedure is underestimated, especially at higher levels of traffic.

On the other hand, when comparing the results between the two subgrade groups, it is noticed that the three cases with strong subgrade materials show higher reliabilities compared to the cases in the group with poor subgrade materials. Additionally, a drop of 53 percent is seen in the first group between Cases 1 and 2, while the drop in reliability in the second group is only 14 percent from Case 1 to Case 2. This is because the ATPD pavement thickness design is 27 cm thinner for Case 2 compared to Case 1 in the first group, while this difference is only 17.5 cm in the second group. These observations show that, the ATPD pavement design thickness is underestimated even more for the cases with poor subgrade materials.

The variability seen in Fig. 3 for each case represents the effect of change in climate across the province and also different binder types. It should be noted that, Cases 2 and 5 include only one binder type so the variability observed for these two cases is merely due to climatic changes. The most variability is seen for Cases 3 and 6, which represent high levels of traffic.

Fig. 4 shows the MEPDG-predicted reliability for AC rutting. In Fig. 4, the average reliability predicted for AC rutting is 100 percent

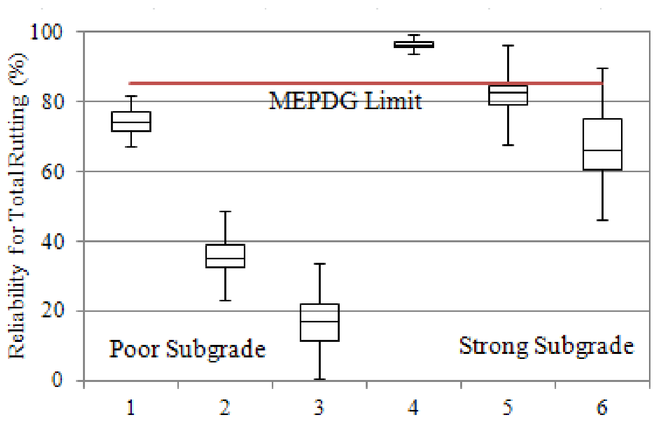

Fig. 3. MEPDG-predicted Reliability for all Runs Based on Total Rutting.

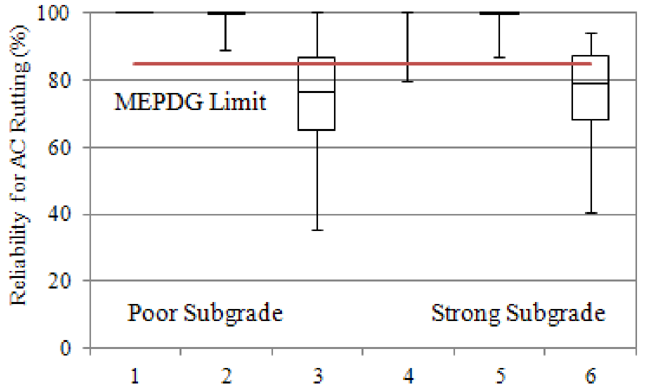

Fig. 4. MEPDG-predicted Reliability for all Runs Based on AC Rutting.

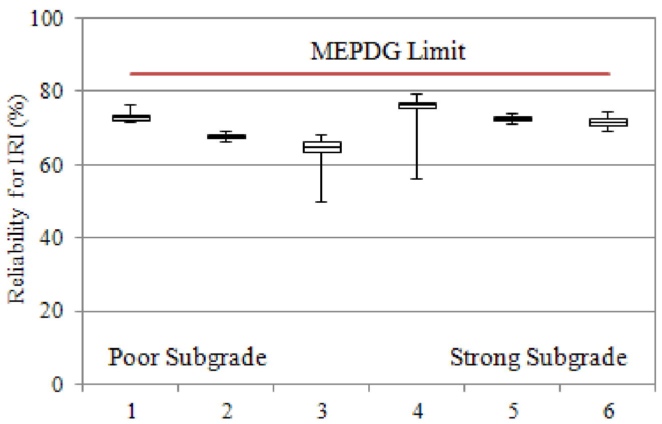

Fig. 5. MEPDG-predicted Reliability for all Runs Based on IRI.

for all cases except for Cases 3 and 6. Both these cases represent high traffic conditions. The average reliability for these two cases is lower than the MEPDG default value of 85 percent. Since the trial design used in the MEPDG is defined based on the AC thickness established using the ATPD method, it can be concluded that the AC thickness is overestimated, when using the ATPD for low and medium traffic conditions and underestimated for the pavement sections with high traffic conditions. Based on this conclusion and previous observations, one can conclude that, following the ATPD procedure results in the underestimation of both the AC and the unbound layer in cases with high traffic levels, regardless of the subgrade modulus.

Fig. 5 shows the reliability predicted for IRI using the MEPDG. It is observed in this figure that the minimum, mean and maximum reliability predicted for the IRI using the MEPDG is less than the limit value of 85 percent for all six cases in both groups. The same trend seen previously for total rutting is seen in Fig. 5 between the three cases in each group. This trend shows that the reliability drops as the traffic increase. Again, it is concluded that the pavement design thickness obtained using the ATPD method, especially at higher traffic levels, is underestimated in comparison to the MEPDG default criteria. Furthermore, overall, the cases in the strong subgrade group show a slightly higher reliability compared to the cases in the other subgrade group. This again shows that the ATPD pavement design thickness is compromised even more for pavements with poor subgrade.

It must also be noted that the unexpected high variability seen for Case 4 in Fig. 5, is caused by the three stations with anomalous transverse cracking values, as discussed previously.

Summary and Conclusions

This study is the first step toward the MEPDG implementation in Alberta. The study highlights the future efforts required for improving the MEPDG flexible pavement performance models. The climatic files recently collected for the MEPDG implementation in Alberta were also evaluated in this study.

- A systematic and critical comparison was made between the pavement design performed following the AASHTO-based ATPD method and using the MEPDG. Six different design scenarios including three different traffic levels and two different subgrade materials were included in the study. The comparison was made through the analysis of the MEPDG-predicted distress reliabilities at the end of the design period for the ATPD pavement design thicknesses. In doing so, the default values in the MEPDG were used for the distress and reliability criteria. The analysis revealed that, although a higher level of reliability is advised in the ATPD method for the sections with high traffic levels, the pavement design thickness does not meet the MEPDG default requirements. Additionally, following the ATPD procedure to design cases with poor subgrade materials results in higher MEPDG distresses in comparison to cases with strong subgrade material. The efforts presented in the present study needs to be continued toward further evaluation of the effectiveness of both pavement design guides for the province. In doing so, the performance of the existing pavement sections across the province, already designed using the ATPD, need to be fully evaluated in comparison to the design recommendations from the MEPDG.

References

1. AASHTO (1993). *Guide for Design of Pavement Structures.* American Association of State Highway and Transportation Officials, Washington, DC, USA.

2. Mulandi, J., Khanum, T., Hossain, M. and Schieber, G. (2006). Comparison of Pavement Design Using AASHTO 1993 and NCHRP Mechanistic–Empirical Pavement Design Guides. *ASCE Proceedings of Airfield and Highway Pavements Specialty Conference*, Atlanta, Georgia, USA, April 30-May 3.
3. El-Badawy, S., Bayomy, M.F., Santi, M., and Clawson, C.W. (2011). Comparison of Idaho Pavement Design Procedure with AASHTO 1993 and MEPDG Methods. *ASCE Proceedings of T & DI Congress,* Chicago, Illinois, USA, March 13-16.
4. Alberta Transportation & Utilities. (1997). *Pavement Design Manual*, Edmonton, Alberta, Canada. Online http://www.transportation.alberta.ca/Content/docType233/Production/pavedm2.pdf, Last Accessed June, 2012.
5. ARA Inc. ERES Consultants Division (2004). *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Final Report*. NCHRP Project 1-37A, Transportation Research Board of the National Academies, Washington, DC, USA.
6. Saha, J. and Bayat, A. (2010). Evaluation of the Canadian Climate Information & Its Effect on Pavement Performance through MEPDG Prediction. Paper presentation at the 90th Transportation Research Board Annual Meeting, Washington DC, USA.
7. Alberta Transportation & Utilities (2007). *Design Bulletin#13.* Edmonton, Alberta, Canada.
8. Schwartz, C.W. and Carvalho, R.L. (2007). *Implementation of the NCHRP 1-37A Design Guide Final Report Volume 2: Evaluation of Mechanistic-Empirical Design Procedure.* The University of Maryland, Prepared for Maryland State Highway Administration, Lutherville, Maryland, USA.
9. Ali, O. (2005). *Evaluation of the Mechanistic Empirical Pavement Design Guide NCHRP 1-37A.* Institute for Research in Construction, National Research Council, Ottawa, Ontario, Canada.