MEPDG Implementation: Manitoba Experience

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Abstract

The AASHTO pavement design method was developed based on road tests conducted in the 1950's with a limited variation in test conditions including the traffic. Extrapolation was required for conditions outside the experiment boundary. This may involve uncertainty in design and may lead to an over or under designed structure. In fact, over the last several decades, highway agencies experienced a reduction in pavement life for large increase truck traffic. Highway agencies were eager to improve the way the pavement is currently being designed. The new Mechanistic Empirical Pavement Design Guide (MEPDG) has been developed based on fundamental properties of materials and the physical observations of performance. It can be used for all truck volume and axle load scenarios. However, for a more reliable design, local material properties, climate data, truck volume and distributions, and axle load spectra (ALS) are critical.

This paper presents the experience of Manitoba Infrastructure and Transportation (MIT) with the MEPDG in using the local truck traffic data with an example of a flexible pavement design. The sensitivity of the program for changes in truck volume, ALS and truck distributions are presented. Analysis/experience showed that MEPDG produces designs with similar or thinner pavement structures for low truck volume but it overestimates the pavement structures for moderate to high truck volumes compared to the AASHTO 1993 and surface deflection methods. A significant variation in required structure was also noted for a within province variation in the truck class distribution. This emphasizes the importance of calibrating the performance models to local conditions. The issues and challenges in calibrating the MEPDG performance models are also discussed.

Introduction

Like many other highway agencies, Manitoba Infrastructure and Transportation (MIT) has been using the AASHTO 1993 guide (1) or its earlier version(s) for the design of new and/or rehabilitated pavement structures. The AASHTO pavement design guide evolved based on road tests conducted in the 1950's at sites near Ottawa, Illinois. Empirical equations were developed from the results of this accelerated testing with a limited variation in design governing factors including the traffic loading (truck size, number of axles and axle loads). The original empirical equations were modified and adjustment factors were developed over time based on observation of the field performance under different weather conditions as well as laboratory testing and correlations of materials properties. However, extrapolation of the empirical equations outside the experiment boundary, specifically for different traffic loadings, involves uncertainty in design due to the variation in material responses under different loading and climatic conditions. This may result in over or under designed structures leading to under utilization or premature failure, both causing an economic loss. In fact, the increased traffic volume in terms of the number of trucks and axle loads, and the evolution of large trucks with different axle distributions over the last several decades has resulted in a reduction in pavement life and/or increase in maintenance activities. Highway agencies were eager to improve the method with which the pavement is currently being designed, especially for routes that experience a high truck loading.

The new Mechanistic Empirical Pavement Design Guide (MEPDG) has been developed under NCHRP Project 1-37A (2) based on the fundamental properties of pavement and supporting subgrade materials as well as long term physical observation of the behaviours under various traffic loading and climatic scenarios. The MEPDG program has two modules- mechanistic and empirical. The mechanistic module in the MEPDG program determines the stresses and strains at critical locations in a pavement structure for various loads, materials and environmental inputs. In the empirical module, the predicted stresses and strains are related to the observed field performance of the pavements in terms of physical distresses such as roughness, rutting, cracking and faulting. The MEPDG distress models were calibrated using the data from the long term pavement performance program (LTPP) project sites that lasted over 20 years.

The MEPDG can be used for the design of pavements for all traffic loading including different traffic and axle load distributions. Pavement design using the MEPDG can be grouped into three categories depending on the quality of input data (Levels 1-3). For the most reliable (Level 1) design, inputs of local material properties, climate data, truck traffic class distribution and patterns, and axle load spectra are critical requirements. Most agencies are facing challenges to obtain all this input information, especially in the wake of the current AASHTO DARWin sunset schedule. MIT has been running the MEPDG program since 2007 for most major projects parallel to the existing (AASHTO 1993 and surface deflection) methods that are in use for new construction and rehabilitation designs. Some mechanistic properties of subgrade, base and asphalt mixes have been determined. Local climate data, truck traffic distributions and truck axle load spectra have also been developed. This paper discusses the experience of MIT with the MEPDG using a flexible pavement design example for a local project. The discussion presented in this paper and the subsequent discussion in the TAC conference are expected to be beneficial for all participating agencies in their effort to adopt the MEPDG.

Experiences of Different Agencies

MEPDG is a sophisticated tool. Implementation of this program requires high technical skills and significant financial resources. Several North American highway agencies have taken initiatives to adopt this new design guide. Some agencies are waiting for the release of the DARWin-ME version or they are attempting to gain knowledge from the experiences of other users. The interested agencies are primarily struggling to obtain the input information. A few agencies have stepped forward to calibrate the MEPDG distress prediction models. Baus and Stires (3) summarized the status of the MEPDG implementation in the United States. In Canada, several provincial and municipal agencies are evaluating this guide and working to develop the required inputs.

Florida performed some sensitivity analyses with different materials inputs and noted that AC dynamic modulus, layer thickness, base modulus, subgrade modulus, portland cement concrete (PCC) coefficient of thermal expansion, joint spacing, dowel bar diameter, and PCC compressive strength are the most sensitive to predicted distresses. Maryland found that the longitudinal cracking model is not reliable and the IRI prediction is insensitive to structural distresses. An increase in base thickness resulted in a slight decrease in fatigue cracking and a negligible change in rutting while an increase in asphalt thickness resulted in a decrease in both fatigue cracking and rutting. Minnesota also observed that the longitudinal cracking prediction is questionable. Montana found significant differences in predicted distresses with limited difference in traffic and material inputs between them and adjacent states. They suggested that the MEPDG improves the load related longitudinal cracking and rutting performance prediction models. New Jersey found that the rutting prediction is highly sensitive to the monthly traffic adjustment factor while the alligator cracking is sensitive to the hourly traffic distribution. Longitudinal cracking was shown to be sensitive to both the hourly distribution and the monthly adjustment factor. The IRI prediction was found to be insensitive to measured traffic inputs compared to the MEPDG defaults. For the flexible pavements, North Carolina found the IRI to be insensitive to traffic and material inputs. Washington found negligible variations in predicted alligator cracking, longitudinal cracking and rutting for a variation in the ALS from light to heavy. (3-10).

Iowa observed that alligator cracking, transverse cracking, rutting and IRI are not sensitive to a change in asphalt layer thickness. The MEPDG prediction of AC longitudinal cracking, alligator cracking and rutting, and subgrade rutting were shown to be sensitive to changes in truck volume but the predicted subbase rutting and IRI were insensitive. Longitudinal cracking was found to be sensitive to truck distribution whereas IRI and alligator cracking were insensitive (11). A Canadian study found that predicted rutting is sensitive to changes in AC layer thickness and modulus while changes in the base layer thickness and stiffness showed little or no effect on predicted permanent deformation (12).

The examples of the study results presented above show mixed experiences with the MEPDG predicted distresses. Therefore, stringent evaluations of the MEPDG software and calibration of the prediction models are important before using it as a day to day pavement design tool.

Objectives

The main objectives of this paper are: i) present an example of a flexible pavement design using local traffic, climate and materials data, ii) examine the sensitivity of the MEPDG program to increase in truck volume from low to high traffic, iii) examine the sensitivity of the MEPDG program to the variation in truck traffic distributions and axle load spectra, and iv) discuss the calibration aspect of the MEPDG distress models.

Project Description

The project used as an example in this paper is Provincial Trunk Highway (PTH) 29 located at the Emerson port of entry (Figure 1). The design lane is a southbound truck only lane. PTH 29 serves long-distance trips carrying a broad mix of commodities to and from U.S. destinations. It is functionally classified as a divided expressway with a depressed median. It is also a core route in Manitoba under the National Highway System (NHS). Current annual average daily traffic (AADT) on this section is 2,940 (two-way) with 40.5% trucks (two-way 1,200 trucks per day). The loading classification is RTAC with an average truck load equivalent factor (LEF) of 3.25 which is used to determine the equivalent single axle load. Manitoba currently uses 2% growth rate for the future traffic volume estimate. The design life is 20 years for both flexible and rigid pavements. The directional distribution of traffic is assumed to be 50%. It is assumed that 100% trucks in one direction will use this proposed truck only lane leading to the border crossing.

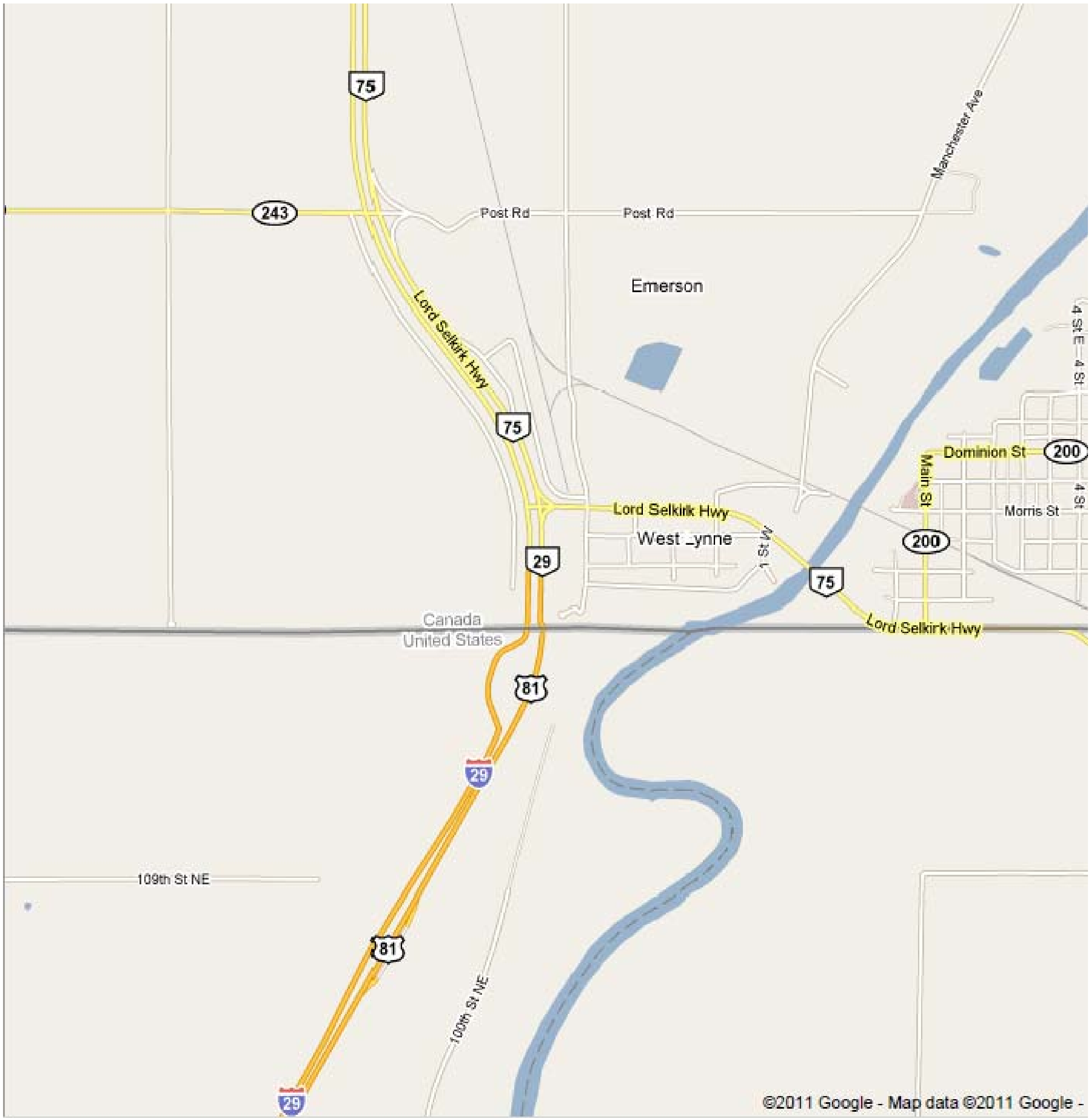

Figure 1: Location of Project Site (Source: 2011 Google Map Data)

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Truck Traffic Data for the MEPDG

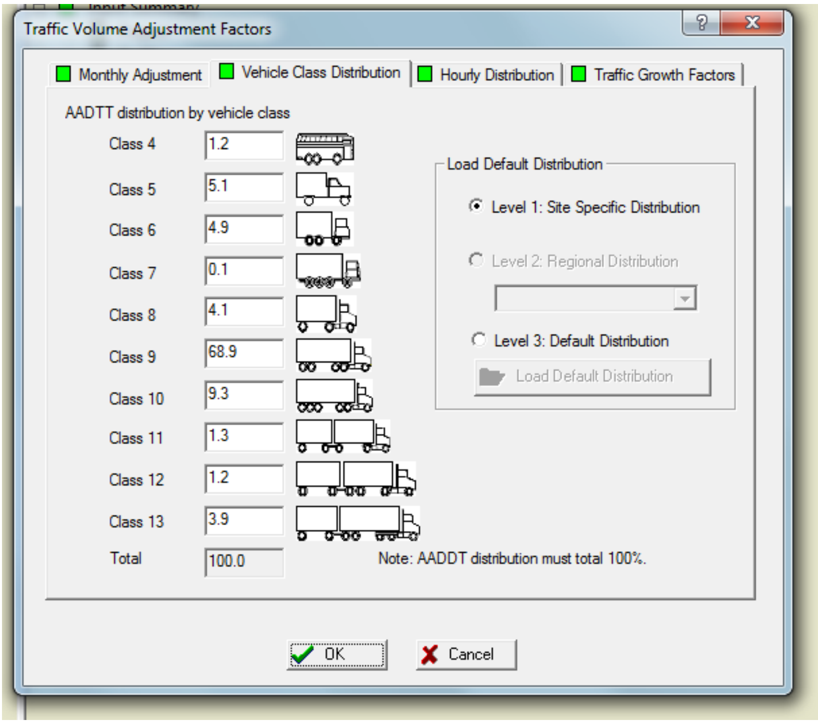
The University of Manitoba Transport Information Group was engaged to develop the Manitoba specific (Level 1) truck traffic input files for the MEPDG program. The major traffic inputs for the MEPDG program are truck count, traffic growth rate, truck class distribution (classes 4 to 13), truck traffic temporal variations (monthly and hourly), and axle load spectra (ALS). Manitoba highways were classified into road groups based on the level of accuracy and availability of the truck traffic data.

Currently, Manitoba has 49 permanent counters that include 42 automatic vehicle classifiers (AVCs) and seven weigh-in-motion (WIM) stations. Five WIM stations have AVC as well. Short term (14-hour) Titan counts are available for 506 locations across the province. Site specific truck traffic classification and temporal distribution files were developed for 47 permanent AVC count stations. For the rest of the sections in the highway network, six truck traffic classification and five temporal variation groups were developed using the data from the AVC and Titan count stations. These classifications are based on similarity in truck traffic distributions. Site specific ALS was also developed for five WIM stations. Three ALS groups were developed for the rest of the network based on the similarity in truck traffic. A province wide default ALS was developed for roads with no traffic data.

For the project (a major single-trailer route) presented in this paper, the traffic distributions (Manitoba truck classification Group 6 and temporal variation Group 2) and ALS (truck weight or ALS Group 2) that best represent the section were used as the inputs to the MEPDG. A sensitivity analysis for varying truck volume (300, 600, 1,200 and 2,000 trucks/day) was performed keeping the above mentioned input files unchanged. The sensitivity to variation in truck distribution was performed at design truck counts but changing the classification and hourly distributions. Figure 2 shows the truck traffic classification (Group 6) distribution while Figure 3 shows the temporal (Group 2) distribution.

Climate Data for the MEPDG

Climate data in the MEPDG format are available for 14 Manitoba locations. Winnipeg is the nearest location to the project site for the MEPDG purpose. Therefore, Winnipeg climate data was used in all the analysis presented in this paper. It should be noted that this paper focuses on the effect of truck loadings in the pavement structure requirements and predicted performance. Therefore, sensitivity of the MEPDG program to the variation in climate inputs is not included in this paper.



AADTT distribution by vehicle class

Class 4	1.2
Class 5	5.1
Class 6	4.9
Class 7	0.1
Class 8	4.1
Class 9	68.9
Class 10	9.3
Class 11	1.3
Class 12	1.2
Class 13	3.9
Total	100.0

Load Default Distribution

● Level 1: Site Specific Distribution

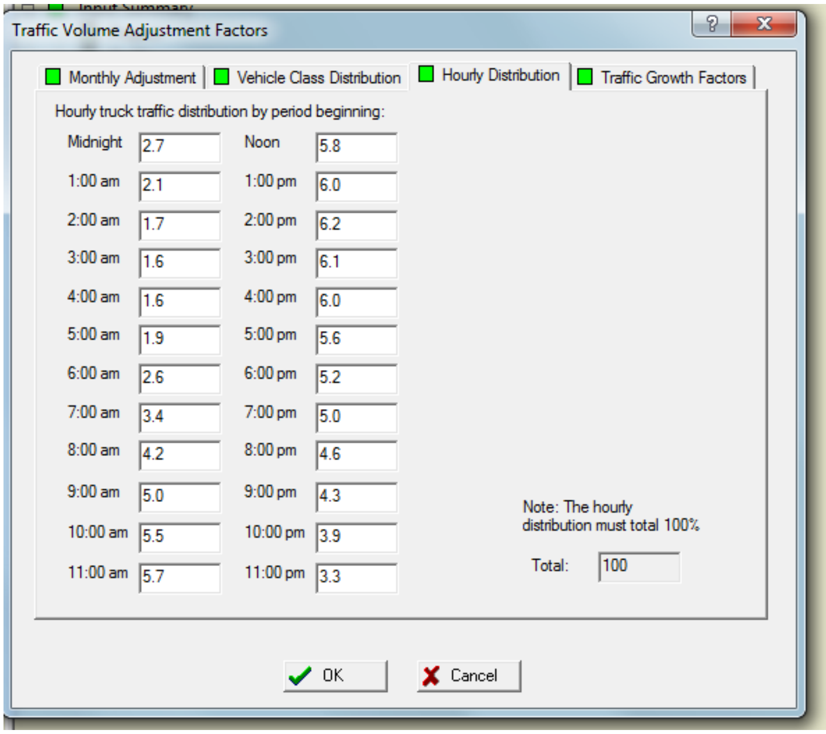
○ Level 2: Regional Distribution

○ Level 3: Default Distribution

Load Default Distribution

Note: AADDT distribution must total 100%.

Figure 2: Manitoba Truck Traffic Distribution (Group 6)



Hourly truck traffic distribution by period beginning:

Midnight	2.7	Noon	5.8
1:00 am	2.1	1:00 pm	6.0
2:00 am	1.7	2:00 pm	6.2
3:00 am	1.6	3:00 pm	6.1
4:00 am	1.6	4:00 pm	6.0
5:00 am	1.9	5:00 pm	5.6
6:00 am	2.6	6:00 pm	5.2
7:00 am	3.4	7:00 pm	5.0
8:00 am	4.2	8:00 pm	4.6
9:00 am	5.0	9:00 pm	4.3
10:00 am	5.5	10:00 pm	3.9
11:00 am	5.7	11:00 pm	3.3

Note: The hourly
distribution must total 100%

Total: 100

Figure 3: Manitoba Truck Traffic Hourly Adjustment Factors (Group 2)

Materials Properties Data

The University of Manitoba pavement research laboratory has been engaged for advanced testing of Manitoba asphalt mixes, granular base, subbase and subgrade materials. Asphalt mix dynamic modulus, creep compliance and other properties as required by the MEPDG have been tested for several samples. Testing is also in progress for the binder for Level 1 input for the MEPDG. The modulii of unbound (subgrade, base and subbase) materials have also been determined for several samples. These results are being evaluated. For this project, Level 3 materials data were used. The materials data remained the same in all the analysis presented as the sensitivity of the MEPDG program to materials inputs is not covered in this paper. Table 1 summarizes the materials properties used in the design and analysis presented. Table 1 also presents the layer coefficients typically used by MIT for pavement design using the AASHTO 1993 guide (1).

Table 1: Summary of Material Properties for the AASHTO 1993 and MEPDG Designs

Properties	Asphalt Mix and Binder	Granular A	Granular C	Subgrade
Materials type	Bituminous mix type B with PG 58-34 asphalt binder (19 mm maximum size, 5% air voids, 14.9 % VMA)	Crushed lime stone (19 mm maximum size)	Crushed lime stone (25 mm maximum size)	High plastic clay. AASHTO Classification A-7-6.
Modulus and other properties	MEPDG calculated from mix properties	207 MPa (30, 000 Psi)	172 MPa (25,000 Psi)	34.5 MPa (5,000 Psi) (MEPDG recommend minimum).
AASHTO layer coefficients	0.42	0.14	0.12	

AASHTO 1993 Design Inputs

The inputs for the design of pavements using the AASHTO 1993 (1) guide are: the calculated accumulated ESALs for the 20-year design period (varies with truck volumes), initial serviceability = 4.5, terminal serviceability = 2.5, reliability = 90% (also for the design using the MEPDG), overall standard deviation = 0.49, drainage factor = 1.0 and roadbed soil resilient modulus = 34.5 MPa (5,000 Psi).

Pavement Structures Based on AASHTO 1993

Table 2 summarizes the pavement structure requirements for different truck traffic volumes including the actual design truck count of 1,200 per day. Table 2 shows that when truck volume is doubled, say from 600 trucks per day to 1,200 trucks per day, an additional 100 mm C base is required. The difference is the same for a truck volume increase from 300 trucks per day to 600 trucks per day. This linear increase indicates that the AASHTO 1993 design equations do not account for the variation in materials stiffness due to changes in the applied load or stress (increased stiffness for increased stress and vice versa). This is one the several limitations of the AASHTO 1993 design method.

Table 2: Summary of Pavement Structures using AASHTO 1993 (DARWin) Program

Traffic Volume (trucks/day)	Design (20-year) ESALs x 10^6	Bituminous Layer Thickness (mm)	*Granular A Base thickness (mm)	*Granular C Base Thickness (mm)
300	4.3	150	200	325
600	8.6	150	200	425
1,200	17.3	150	200	525
2,000	28.8	150	200	600

*Note: *Typical distribution between base (Granular A) and subbase (Granular C).*

Comparison of AASHTO and MEPDG Designs and Sensitivity to Traffic Loading

The MEPDG program was run for different truck traffic counts including the design number of trucks as shown in Table 2. The structural layer thicknesses determined using the AASHTO 1993 design method were entered for running the MEPDG at different traffic counts keeping all other inputs unchanged. Additionally, the MEPDG was used for the design truck volume (1,200 trucks per day) with increased thicknesses of all layers. The initial roughness was assumed to be 63 in/mile for every run of the MEPDG. The design reliability was taken to be 90% for all distresses.

Figure 4 shows the roughness and Figure 5 shows the rutting progressions over time for the design truck traffic with the required structure (layer thicknesses are 150 mm AC, 200 mm granular A base and 525 mm granular C base).) according to the AASHTO 1993. Table 3 presents the summary of the MEPDG program predicted distresses, reliabilities for predicted distresses and expected service life at design (90%) reliability based on different distresses. Figure 5 and Table 3 show that for the selected design reliability, MEPDG predicted pavement life is 11 years based on the total permanent deformation (rutting) criterion for the design traffic (1,200 trucks per day) and selected pavement structure based on the AASHTO 1993 procedure. In this case, MEPDG predicted pavement life is nine years less than the design life based on the AASHTO 1993 design criteria. Based on the roughness criterion as shown in Table 3, MEPDG predicted life is three years less than the design (20 years) life. The design met the rutting criterion with a pavement structure that consisted of 200 mm AC, 300 mm granular A base and 600 mm granular C base but still failed (expected life is 19 years) in roughness criteria. Further trials with the MEPDG by increasing the granular C base thickness to 800 mm showed that the predicted reliability for roughness is 88.57% with an expected life of 19.25 years i.e., additional 200 mm granular C base layer expected to increase the pavement life by less than ¼ of a year, a negligible change. The structural layer thicknesses determined by using the MEPDG program are substantially higher than that determined using the AASHTO 1993 program. This indicates that a closer evaluation of the MEPDG program and calibration of the distress models to local conditions are necessary before accepting the MEPDG as the only pavement design tool.

It should also be noted that the MEPDG roughness prediction is a function of several factors that include pavement age after construction, site factor (function of rainfall, annual freezing index, base materials percentage passing 0.075 mm as well as 0.02 mm sieves and the plasticity index), sealed longitudinal cracking and the MEPDG predicted rutting, transverse cracking, fatigue cracking and block cracking. Combining predicted values from several prediction models to a new prediction model may result in a reduced accuracy of the later prediction because of the accumulation of errors associated with different prediction models. For example, say model for the site factor showed a R^2 value of 0.70. Then the unaccounted variability (error) in the prediction of site factor is 30%. Also say the rutting prediction model showed a similar R^2 value of 0.70 i.e., 30% error for rutting prediction as well. If the roughness is now predicted from these two previously predicted variables (predicted site factor and rutting), then the accumulated error in the roughness prediction is likely to be greater than 30%. Therefore, agencies need to be cautious in using the roughness as the design governing factor. Further study is required in this area including the causes of pavement roughness.

Table 3 shows that the MEPDG program predicted life at the design (90%) reliability is 19 years, 18 years, 17 years and 16 years for a daily truck volume of 300, 600, 1,200 and 2,000, respectively, based on the roughness criteria. The predicted life at the design reliability is 20 years, 17 years, 11 years and 8 years, respectively, based on the rutting criterion. The MEPDG design for 2,000 trucks per day was also shown to fail based on the longitudinal cracking criterion with an expected life of 14 years at the design reliability. These show that the difference between the design life (based on the AASHTO 1993) and the predicted life based on the MEPDG increases as the traffic loading (truck volume) increases. Is this expected? Does the MEPDG program account for the change in materials stiffness with changes in applied stress? The above comparison shows that the MEPDG program overestimates the pavement structure compared to that dictated by the AASHTO 1993 program for the traffic loading examined in this paper although the design was close for low traffic volume. The general experience of MIT is that compared to the AASHTO 1993 and surface deflection methods, the MEPDG program underestimates or resembles the structures for low traffic volume but overestimates the structures for moderate to high truck volumes depending on the subgrade materials and types of design (new versus rehabilitation) and types of pavement (flexible versus rigid).

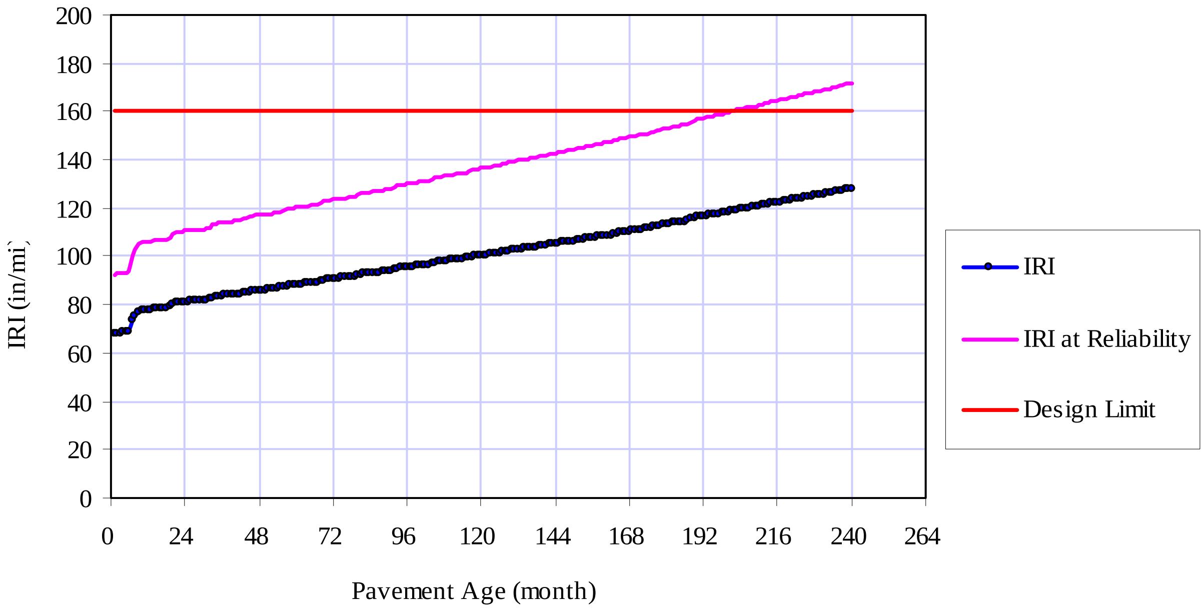


Figure 4: Predicted Roughness for 1,200 trucks per day

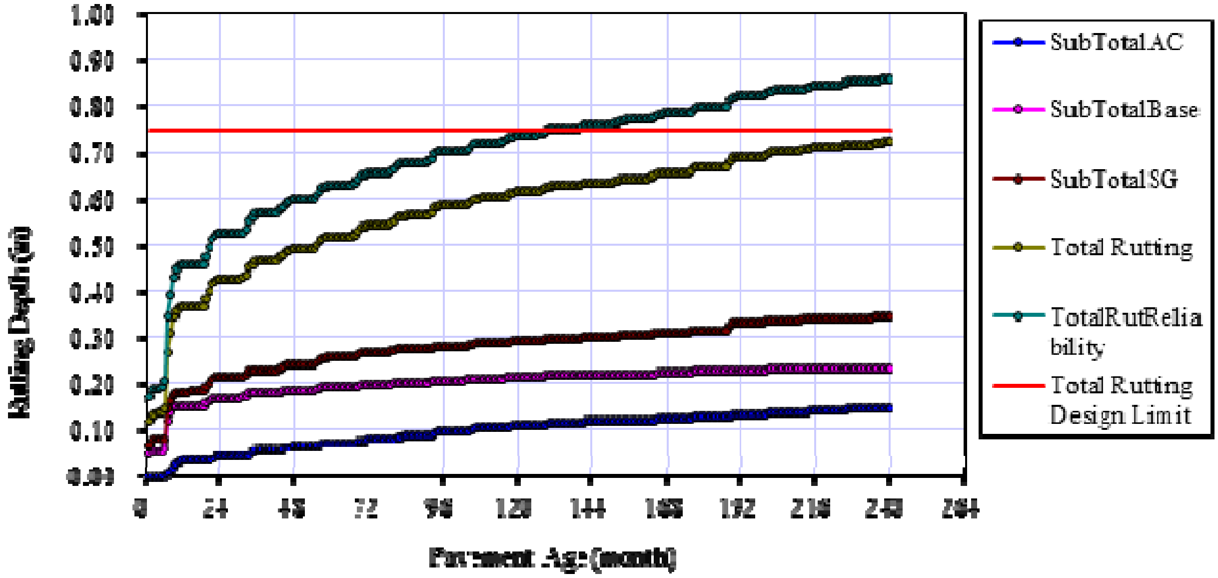


Figure 5: Permanent deformation (rutting) for 1,200 trucks per day

Table 3: Summary of MEPDG Outputs with Different Truck Volumes

Truck volume (Trucks/day)		**300**	**600**	**1,200**	**1,200**	**2,000**
Layer thicknesses (mm) AC/A Base/C Base		**150/175/350**	**150/200/425**	**150/200/525**	**200/300/600**	**150/200/600**
Terminal IRI	Target (in/mile)	160	160	160	160	160
	Predicted (in/mile)	121.8	124.7	128.2	121.2	131.2
	Reliability Predicted (%)	87.69	85.4	82.44	88.18	79.61
	Acceptance	Fail	Fail	Fail	Fail	Fail
	Predicted life (years)*	19	18	17	19	16
AC Surface Down Cracking (Long. Cracking)	Target (ft/mile)	2000	2000	2000	2000	2000
	Predicted (ft/mile)	3.5	12.9	55.8	3.9	157
	Reliability Predicted (%)	99.98	98.89	92.34	99.97	85.81
	Acceptance	Pass	Pass	Pass	Pass	Fail
	Predicted life (years)*	>20	>20	>20	>20	14
AC Bottom Up Cracking (Alligator Cracking)	Target (%)	25	25	25	25	25
	Predicted (%)	0.3	0.5	1.1	0.2	1.8
	Reliability Predicted (%)	99.999	99.999	99.999	99.999	99.99
	Acceptance	Pass	Pass	Pass	Pass	Pass
	Predicted life (years)*	>20	>20	>20	>20	>20
AC Thermal Fracture (Transverse Cracking)	Target (ft/mi)	1000	1000	1000	1000	1000
	Predicted (ft/mi)	1.0	1.0	1.0	1.0	1.0
	Reliability Predicted (%)	99.999	99.999	99.999	99.999	99.999
	Acceptance	Pass	Pass	Pass	Pass	Pass
	Predicted life (years)*	>20	>20	>20	>20	>20
Permanent Deformation (AC Rutting Only)	Target (in.)	0.47	0.47	0.47	0.47	0.47
	Predicted (in.)	0.07	0.1	0.15	0.13	0.19
	Reliability Predicted (%)	99.999	99.999	99.999	99.999	99.999
	Acceptance	Pass	Pass	Pass	Pass	Pass
	Predicted life (years)*	>20	>20	>20	>20	>20
Permanent Deformation (Total Pavement Rutting)	Target (in.)	0.75	0.75	0.75	0.75	0.75
	Predicted (in.)	0.58	0.65	0.72	0.56	0.79
	Reliability Predicted (%)	97.15	85.83	59.91	97.88	36.98
	Acceptance	Pass	Fail	Fail	Pass	Fail
	Predicted life (years)*	>20	17	11	>20	8

*Note: *Predicted life at 90% reliability level.*

Sensitivity of MEPDG to Varying ALS and Truck Distribution

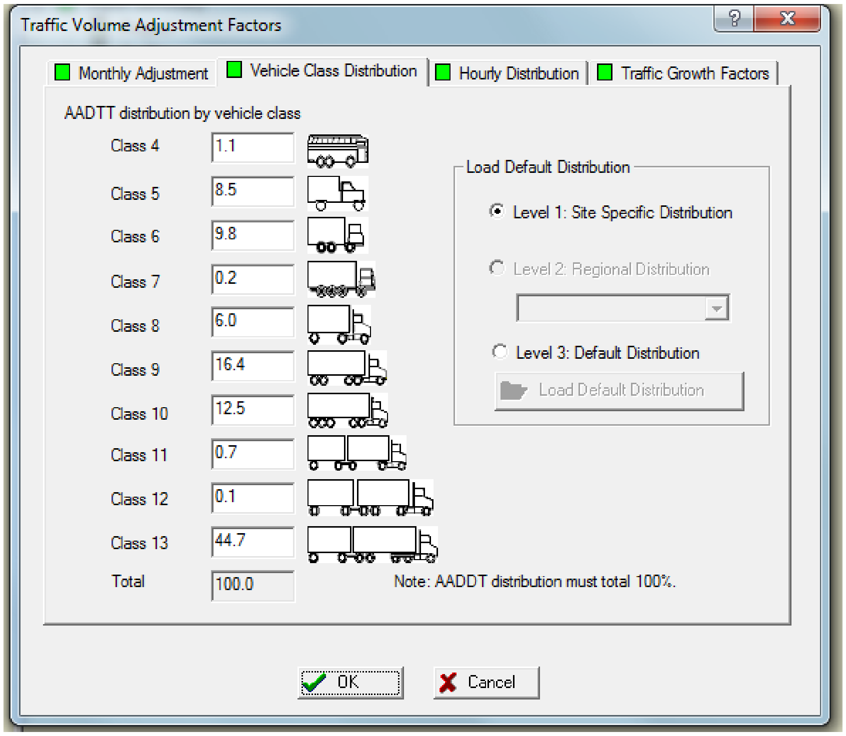
To determine the sensitivity to different axle load spectra, the MEPDG program was run for the design truck count (1,200 trucks per day) with thicknesses (150 mm AC, 200 mm granular A base and 525 mm granular C base) determined from the AASHTO 1993 program and with the design truck class distribution (Manitoba Group 6) and temporal variation (Group 2) but varying the ALS. Table 4 compares the predicted distresses and expected life for a given design reliability (90%) between Manitoba Group 3 ALS and the MEPDG default ALS. The predicted roughness, AC thermal cracking and total rutting were shown to be higher with the U.S. default ALS as compared to the Manitoba Group 3 ALS. The longitudinal cracking and AC layer rutting were slightly lower with the U.S. default ALS where as the predicted fatigue and transverse cracking were the same for both ALS. Although the difference in predicted total rutting was quantitatively small, the expected life was shown to be two years less with the MEPDG default ALS as compared to Manitoba ALS Group 3. These emphasize the importance of using local ALS and calibration of distress models to local conditions for a more reliable design.

Table 4: Summary of MEPDG Outputs with Different ALS and Truck Classification Distribution

Axle Load Spectra		**Manitoba Group 3**	**U.S. Default (Level 3)**	**Manitoba Group 3**
Truck Class Distribution		**Manitoba Group 6**	**Manitoba Group 6**	**Manitoba Group 4**
Terminal IRI	Target (in/mile)	160	160	160
	Predicted (in/mile)	128.2	128.8	132.8
	Reliability Predicted (%)	82.44	81.89	78.20
	Acceptance	Fail	Fail	Fail
	Predicted life (years)*	17	17	15
AC Surface Down Cracking (Long. Cracking)	Target (ft/mile)	2000	2000	2000
	Predicted (ft/mile)	55.8	55.1	184.0
	Reliability Predicted (%)	92.34	99.999	84.76
	Acceptance	Pass	Pass	Fail
	Predicted life (years)*	>20	>20	12
AC Bottom Up Cracking (Alligator Cracking)	Target (%)	25	25	25
	Predicted (%)	1.1	1.1	1.4
	Reliability Predicted (%)	99.999	99.999	99.999
	Acceptance	Pass	Pass	Pass
	Predicted life (years)*	>20	>20	>20
AC Thermal Fracture (Transverse Cracking)	Target (ft/mi)	1000	1000	1000
	Predicted (ft/mi)	1.0	1.0	1.0
	Reliability Predicted (%)	99.999	99.999	99.999
	Acceptance	Pass	Pass	Pass
	Predicted life (years)*	>20	>20	>20
Permanent Deformation (AC Rutting Only)	Target (in.)	0.47	0.47	0.47
	Predicted (in.)	0.15	0.14	0.16
	Reliability Predicted (%)	99.999	99.999	99.999
	Acceptance	Pass	Pass	Pass
	Predicted life (years)*	>20	>20	>20
Permanent Deformation (Total Pavement Rutting)	Target (in.)	0.75	0.75	0.75
	Predicted (in.)	0.72	0.74	0.83
	Reliability Predicted (%)	59.91	54.34	23.81
	Acceptance	Fail	Fail	Fail
	Predicted life (years)*	11	9	6

*Note: *Predicted life at 90% reliability level.*

Table 4 also presents the comparison of performance with varying truck class distributions (Manitoba Class Distribution Group 6 versus Group 4) for the same structural layer thicknesses, truck count and ALS, truck temporal variations and materials properties. The truck class distribution for Group 4 is shown in Figure 6 and that for Group 6 is shown in Figure 2. Group 6 consists of major single-trailer truck routes that serve long-distance trips to U.S. destinations (high percentage of Class 9 trucks). Group 4 consists of major multiple-trailer truck routes that serve trips related to the forest industry (high percentage of Class 13 trucks). The predicted distresses were shown to be higher for Group 4 as compared to that for Group 6. The predicted life was shown to reduce significantly in terms of longitudinal cracking (> eight years) and rutting (five years) for a route that serves mainly multiple-trailer trucks as opposed to major single-trailer trucks. The MEPDG program seems to be promising to respond to the effect of truck types. However, the justification of this high difference in predicted pavement life needs to be more closely examined.



AADTT distribution by vehicle class

Class 4	1.1
Class 5	8.5
Class 6	9.8
Class 7	0.2
Class 8	6.0
Class 9	16.4
Class 10	12.5
Class 11	0.7
Class 12	0.1
Class 13	44.7
Total	100.0

Load Default Distribution
● Level 1: Site Specific Distribution
○ Level 2: Regional Distribution
○ Level 3: Default Distribution

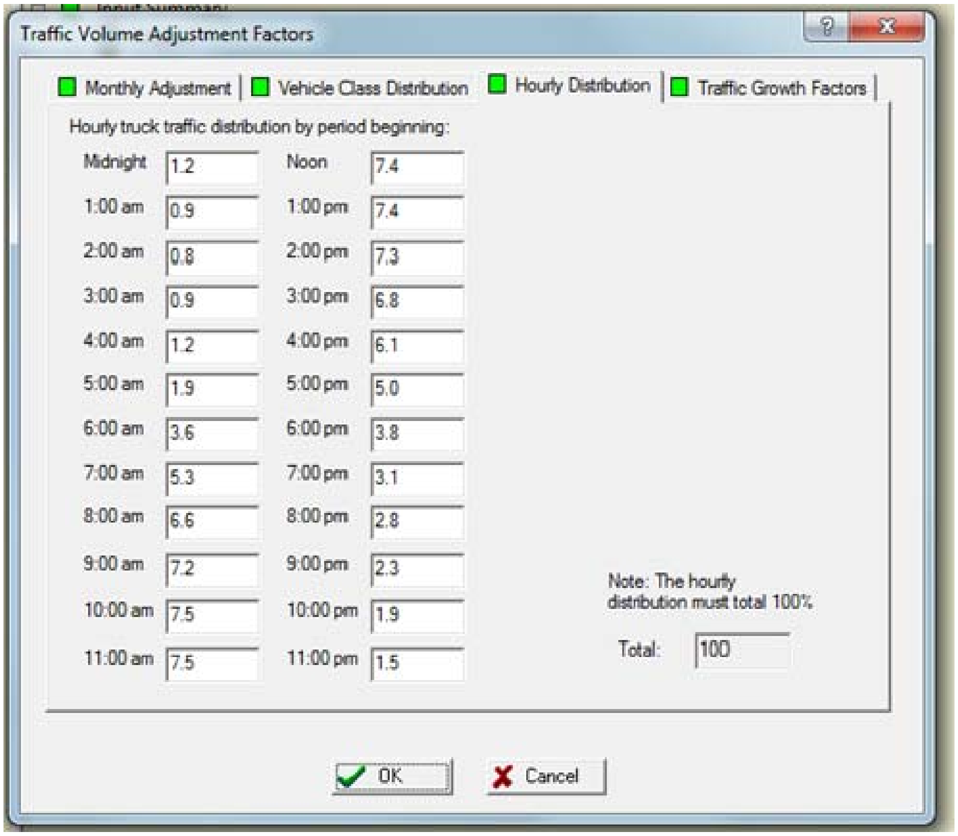
Note: AADDT distribution must total 100%.

Figure 6: Manitoba Truck Traffic Distribution (Group 4)

Sensitivity of MEPDG to Truck Traffic Temporal Variation

The sensitivity of the MEPDG program to the varying truck traffic temporal distribution was examined by running the program for two different temporal distribution groups- Groups 1 and 2. The truck count (1,200 trucks per day), layer thicknesses (150 mm AC, 200 mm granular A base and 525 mm granular C base), truck class distribution (Manitoba Group 6) and the ALS (Group 3) remained unchanged. The Truck Traffic Pattern Group 1 (TTPG 1) consists of routes that serve a mix of urban delivery trips and long distance trips to transport a broad mix of commodities. These are routes located near the City of Winnipeg. This group is characterized by: 1) single unit trucks that exhibit low seasonal variation, low weekend traffic and heavier daytime than night time traffic with moderate a.m. and p.m. peak hours, 2) single-trailer trucks that exhibit low seasonal variation, low weekend traffic and somewhat heavier daytime than night time traffic with no evident peak hours, and 3) multiple-trailer trucks that exhibit low seasonal variation, low weekend traffic, and somewhat heavier daytime than night time traffic with no evident peak hours. Figure 7 shows the hourly adjustment or distribution factors for TTPG 1.

The hourly adjustment factors for Group 2 are shown Figure 3. The Truck Traffic Pattern Group 2 consists of routes that serve long-distance trips to transport a broad mix of commodities and are major highways (the National Highway System). The temporal truck traffic variations are characterized by: 1) single unit trucks that exhibit low seasonal variation, moderate weekend traffic, and slightly heavier daytime than night time traffic with no evident peak hours, 2) single-trailer trucks that exhibit low seasonal variation, moderate weekend traffic, and slightly heavier daytime than night time traffic with no evident peak hours and 3) multiple-trailer trucks that exhibit low seasonal variation, moderate weekend traffic, and slightly heavier daytime than night time traffic with no evident peak hours.



Hourly truck traffic distribution by period beginning:

Midnight	1.2	Noon	7.4
1:00 am	0.9	1:00 pm	7.4
2:00 am	0.8	2:00 pm	7.3
3:00 am	0.9	3:00 pm	6.8
4:00 am	1.2	4:00 pm	6.1
5:00 am	1.9	5:00 pm	5.0
6:00 am	3.6	6:00 pm	3.8
7:00 am	5.3	7:00 pm	3.1
8:00 am	6.6	8:00 pm	2.8
9:00 am	7.2	9:00 pm	2.3
10:00 am	7.5	10:00 pm	1.9
11:00 am	7.5	11:00 pm	1.5

Note: The hourly distribution must total 100%

Total: 100

Figure 7: Manitoba Truck Traffic Hourly Adjustment Factors (Group 1)

Table 5 summarizes the MEPDG predicted distresses and expected life at the design reliability for two hourly distribution patterns. Table 5 shows that a variation in hourly truck traffic distribution has no effect on pavement distresses as predicted by the MEPDG program.

Table 5: Summary of MEPDG Outputs with Different Temporal Variations

Truck Traffic Temporal Distributions		**Manitoba Pattern Group 1**	**Manitoba Pattern Group 2**
Terminal IRI	Target (in/mile)	160	160
	Predicted (in/mile)	128.2	128.2
	Reliability Predicted (%)	82.44	82.44
	Acceptance	Fail	Fail
	Predicted life (years)*	17	17
AC Surface Down Cracking (Long. Cracking)	Target (ft/mile)	2000	2000
	Predicted (ft/mile)	55.8	55.8
	Reliability Predicted (%)	92.34	92.34
	Acceptance	Pass	Pass
	Predicted life (years)*	>20	>20
AC Bottom Up Cracking (Alligator Cracking)	Target (%)	25	25
	Predicted (%)	1.1	1.1
	Reliability Predicted (%)	99.999	99.999
	Acceptance	Pass	Pass
	Predicted life (years)*	>20	>20
AC Thermal Fracture (Transverse Cracking)	Target (ft/mi)	1000	1000
	Predicted (ft/mi)	1.0	1.0
	Reliability Predicted (%)	99.999	99.999
	Acceptance	Pass	Pass
	Predicted life (years)*	>20	>20
Permanent Deformation (AC Rutting Only)	Target (in.)	0.47	0.47
	Predicted (in.)	0.15	0.15
	Reliability Predicted (%)	99.999	99.999
	Acceptance	Pass	Pass
	Predicted life (years)*	>20	>20
Permanent Deformation (Total Pavement Rutting)	Target (in.)	0.75	0.75
	Predicted (in.)	0.72	0.72
	Reliability Predicted (%)	59.91	59.91
	Acceptance	Fail	Fail
	Predicted life (years)*	11	11

*Note: *Predicted life at 90% reliability level.*

Calibration of MEPDG Distress Prediction Models

As mentioned earlier, the AASHTO 1993 design equations were developed based on the road tests conducted in the 1950's. However, the original empirical equations were modified and adjustment factors were developed by AASHTO based on the observation of performance of different projects. Many agencies also determined the layer coefficients, resilient modulus, California Bearing Ratio (CBR), etc. for local materials and developed load equivalent factors (LEFs) for different truck configurations or mix of trucks for typical roads/highways. Although different agencies attempted to adjust the AASHTO structural number or design thicknesses based upon local experience of the field performance with previously used designs, no effort has been made to modify the AASHTO empirical equations or to develop adjustment factors for local traffic loading and climate. Also, there was no attempt to modify the AASHTO empirical equations based on the materials properties determined under dynamic loading conditions to eliminate the limitation of the AASHTO 1993 that uses materials properties determined under static loads. However, pavement design/analysis engineers and researchers expressed some concerns about the application of the AASHTO empirical equations and adjustment factors to different conditions, especially for the higher traffic volume than that experienced in the AASHTO road tests.

The new MEPDG program is expected to accommodate the variation in material properties, climate, traffic loadings and actual field performance through the mechanistic and empirical modules. The MEPDG distress models have been calibrated using the performance data available in the U.S. national databases, mainly the long term pavement performance program data. However, as discussed earlier in the paper with examples of outputs from the MEPDG program, the variation in predicted distresses and corresponding expected life need to be further examined. This requires a closer look into the program, especially the mechanistic module. Manitoba obtained inconsistent results with the mechanistic models. An example is the backcalculation of layer modulus, stress and strain from the falling weight deflectometer (FWD) deflection data. Inconsistent variation was noted with changes in input values such as increasing the AC seed modulus by 100 MPa resulted in a 2,000 MPa or more change in backcalculated AC modulus. Calibration of the MEPDG distress models to local conditions (materials, traffic, climate and performance) is another key requirement for a reliable design.

The calibration of the MEPDG distress models is a challenge for almost all agencies including Canadian provinces, regions, cities and municipalities. Lack of resources including appropriate data as required by the MEPDG are the key issues. The AASHTO has developed a calibration guide for MEPDG distress models (13). It provides a general guidance for local calibration. Highway agencies need to go more in depth into this process which is probably beyond the capability of the agencies with current resources, especially in Canada. The tremendous efforts devoted by several U.S. States including North Carolina, Minnesota and Washington give some indication of the extent of effort required in the calibration process.

An important requirement for the calibration is the good quality data obtained following the LTPP protocol. Many highway agencies including MIT collect and maintain pavement structure, materials, traffic, and performance data for pavement and/or asset management purposes. Most of these data are collected following the agency specific protocol. The appropriateness and adequacy of these data for calibration of the MEPDG distress models need to be examined.

Also the calibration process requires substantial effort, commitment and resources. As mentioned earlier, this may be beyond the capability of individual Canadian agencies. This is particularly true in the time of budget shortfalls, lack of expertise or experience with the MEPDG program. A national initiative through the Transportation Association of Canada (TAC) with the contribution from different agencies across Canada will be beneficial for each agency willing to implement the MEPDG program.

It should be noted that the latest version of the MEPDG program called the DARWin-ME was released in May 2011. It has options for inputs and outputs in metric units and has incorporated Canadian climate data. It also provides a log of errors in the input data. Therefore, it is advisable that Canadian agencies evaluate the DARWin-ME and compare the results from the DARWin-

ME with that of the traditional design methods and performances before any calibration initiative.

Summary

A number of highway agencies are working towards the implementation of the M- E PDG and are experiencing some issues/inconsistencies, especially in the predicted distresses. This paper presents traffic and structure related observations by Manitoba Infrastructure and Transportation in using this new software. The general findings are summarized below:

1. An increase in the granular subbase thickness of 200 mm in the MEPDG resulted in an increase in the pavement life by ¼ year (a negligible change) whereas in the AASHTO 1993 guide, such as a change means doubling the service life.
2. The difference between the design life based on the AASHTO 1993 and the predicted life based on the MEPDG predicted distresses increases as the traffic loading (truck volume) increases. This indicates MEPDG require a substantially thicker structure for higher traffic volume.
3. The difference between predicted distresses using local (Manitoba specific) ALS and the MEPDG default ALS were shown to be inconsistent (some distresses are similar, some are higher and some are lower). This emphasizes the need for local calibration.
4. The difference between predicted distresses using two Manitoba truck class distributions was significant. Agencies need to aware of the impact of using the default values.
5. A variation in hourly truck traffic distribution showed no effect on predicted pavement distresses or expected life.

Closing Remarks

The MEPDG program is a sophisticated pavement design and analysis tool. The use and calibration of this program requires a high level of technical/expertise knowledge and experience with the fundamental properties of the materials under different loading and climatic conditions. A thorough understanding of the required inputs, the accuracy of the input data and the accuracy or reasonableness of the resulting outputs is important. Information of the previously recommended pavement structures using the historic design tools for different materials, climates, traffic loads, local construction practices and the corresponding field performance will be useful in modifying the design using the MEPDG and calibrating the performance models. Highway agencies and/or their engineering service providers should also examine the sensitivity of the mechanistic module used in the MEPDG program. A comprehensive sensitivity analysis of the MEPDG outputs with varying materials, traffic and climate inputs will develop more confidence in adopting the MEPDG program for routine pavement design practices.

References

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

2. NCHRP, 2002 Design Guide: Design of New and Rehabilitated Pavement Structures, NCHRP Study Report 1-37A, National Cooperative Highway Research Program (NCHRP), Washington D.C., July 2004.
3. Baus, R. L. and Stires, N. R., Mechanistic-Empirical Pavement Design Guide Implementation, Department of Civil and Environmental Engineering, University of South Carolina, Report No. GT06-10, July 2010.
4. Fernando, F. G., Oh, J., and Ryu, D., Phase I of MEPDG Program Implementation in Florida, Report D04491/PR15281-1, Texas Transportation Institute, College Station, TX, 2007.
5. Schwartz, C., Implementation of the NCHRP 1-37A Design Guide, Report No. SP0077B41, Maryland State Highway Administration, Lutherville, MD, 2007.
6. Velasquez, R., Hoegh, K., Yut, I., Funk, N., Cochran, G., Marasteanu, M., and Khazanovich, L., Implementation of the MEPDG for New and Rehabilitated Pavement Structures for Design of Concrete and Asphalt Pavements in Minnesota, Report MN/RC 2009-06, Minnesota Department of Transportation, St. Paul, MN, 2009.
7. Montana Department of Transportation, Performance Prediction Models, http://mdt.mt.gov/research/docs/research_proj/pave_model/final_presentation.pdf, 2007.
8. Pavement Resource Program Quarterly Progress Report, Center for Advanced Infrastructure & Transportation, Rutgers, the State University of New Jersey. http://www.state.nj.us/transportation/refdata/research/pdf/caitqrep/cait_06_q1_pavement_resourse.pdf, 2006.
9. Kim, R. and Muthadi, N., Implementation Plan for the New Mechanistic- Empirical Pavement Design Guide, NCDOT Project 2005-28, North Carolina State University, Raleigh, NC, 2007.
10. Pierce, L., New Pavement Design Guide. Washington State Department of Transportation, Olympia, WA, http://nwpma-online.org/resources/07Fall_NewPavemtDesignGuide.pdf, 2007.
11. Ceylan1, H., Coree, B., and Gopalakrishnan, K., Evaluation of the Mechanistic - Empirical Pavement Design Guide for Implementation in Iowa, The Baltic Journal of Road and Bridge Engineering, Vol. 4(1):12, 2009.
12. Ali, O, Evaluation of the Mechanistic Empirical Pavement Design Guide (NCHRP 1-37A), Report No. RR- 216, National Research Council (NRC), Ottawa, ON, Sept. 2005.
13. AASHTO, Guide for the Local Calibration of the Mechanistic-Empirical Pavement Design Guide, American Association of State Highway and Transportation Officials (AASHTO), Washington D.C., April 2010.