Sensitivity Study of Design Input Parameters for Two Flexible Pavement Systems Using the Mechanistic-Empirical Pavement Design Guide

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ABSTRACT

Many agencies use the *AASHTO Guide for Design of Pavement Structures* to design their pavement systems. The limitation inherent in this method is the empirical nature of the decision process, which was derived from a road test conducted almost 45 years ago in Ottawa, Illinois. The newly released Mechanistic-Empirical Pavement Design Guide (MEPDG), based on NCHRP Study 1-37A, has adopted a mechanistic-empirical pavement design procedure, in which pavement distresses are calculated through calibrated distress prediction models based on material properties laboratory test results and local climatic conditions. The calibrated distress prediction models are based on the critical pavement responses mechanistically calculated by a structural model and coefficients determined through national calibration efforts using the Long-Term Pavement Performance (LTPP) database. The MEPDG requires many parameters to map the calibrated distress prediction models with traffic, environment, and material properties. The present study was conducted to evaluate the relative sensitivity of MEPDG input parameters to asphalt cement concrete (ACC) properties, traffic, and climatic conditions based on field data from two existing Iowa flexible pavement systems. The sensitivities of five MEPDG performance measures (longitudinal cracking, alligator cracking, thermal cracking, rutting, fatigue cracking, and smoothness) were studied by either varying a single input parameter or by varying two input parameters at a time. The findings of this study, presented in this paper, will provide pavement designers a better understanding of those design parameters that affect certain pavement distresses the most and need careful consideration during the design process.

Keywords: flexible pavements—mechanistic-empirical pavement design guide—pavement analysis and design—sensitivity study

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INTRODUCTION

The newly released Mechanistic-Empirical Pavement Design Guide (MEPDG) (based on NCHRP Study 1-37A) predicts pavement distresses using calibrated distress prediction models, based on critical pavement responses computed by a structural model (like JULEA for flexible pavements) and coefficients determined through national calibration efforts using the Long-Term Pavement Performance (LTPP) database. A mechanistic-empirical pavement design procedure requires many input parameters related to traffic, climate, and material conditions and presents the predicted pavement distresses with time series. In such situations, the pavement designers should consider the traffic and climatic conditions in the pavement construction area and decide the thickness of each layer and the material properties that satisfy the distress criteria in the pavement design life by running the program several times with varying input parameters.

Recent studies (Mohamed and Witczak 2005a; Mohamed and Witczak 2005b) reported the sensitivities of some of key input parameters for the permanent deformation model and the fatigue model in conventional flexible pavement. In these studies, design input parameters were grouped into three different levels based on the severity (low, medium and high), and the magnitude of the input parameter in question was changed in the medium stage. Though these studies provided general information on input parameter sensitivities in the MEPDG, they focused only on conventional three-layer flexible pavement structures (an HMA surface, granular base, and subgrade), which are not currently used for interstate and state roads in Iowa.

This paper presents the results of a study conducted on the relative sensitivity of MEPDG input parameters to the properties of asphalt cement concrete (ACC), traffic, and climate using field data from two existing Iowa flexible pavements (US-020 in Buchanan County and I-80 in Cedar County). The sensitivities of five MEPDG performance measures were studied either by varying a single input parameter or by varying two input parameters at a time for these pavements.

MECHANISTIC-EMPIRICAL FLEXIBLE PAVEMENT DESIGN

A major limitation of the current AASHTO pavement design procedure is the empirical nature of the thickness decision process, which is derived from a road test conducted almost 45 years ago at a single location in Ottawa, Illinois. This empirical approach cannot be applied to current pavements systems with increased traffic volumes, different climate conditions, different pavement construction areas, etc. In recognition of the limitation of current AASHTO guide, the AASHTO Joint Task Force on Pavements initiated an effort to develop an improved pavement design guide based on mechanistic-empirical principles (NCHRP 1-37A 2004). The product of this effort is the newly released MEPDG, based on NCHRP Study 1-37A.

The major components of the MEPDG are the input system, mechanistic pavement analysis model, transfer functions, and an output system that consists of predicted pavement distresses. A new feature in the MEPDG, absent from the current AASHTO design guide, is the availability of hierarchical input levels. Users have the option to choose to any one of them for design. Depending on the accuracy of the input parameter, three levels of input are provided, from level 1 to level 3. However, it should be recognized that irrespective of the input design level, the computational algorithm for the design procedure is the same. In addition, a mix of levels can be used for a given design project. To decide on a suitable input level, a designer should recognize which input parameter would be important for the results.

The mechanistic pavement analysis model used in the MEPDG for flexible pavements is the multilayer elastic program JULEA. In JULEA, the critical stress, strain, and displacement due to traffic and material parameters are generated for the designer's selected pavement structure. These critical responses generated in JULEA are used to calculate the incremental damage accumulations on a monthly basis over the entire design life. The incremental damage accumulations are adjusted through the transfer function coefficients, developed through national calibration efforts using the LTPP database to provide the predicted pavement distress in time series as output. In this procedure, it should be noted that even though the pavement responses are generated with a mechanistic approach, an empirical approach (calibrated transfer function coefficient) is still used to provide the predicted distress measures. The LTPP database used to develop the calibrated transfer functions did not include the Iowa locations.

Compared to the current AASHTO guide, another important feature of the MEPDG for flexible pavement is that the new guide does not yield a design thickness as output. The MEPDG predicts performance measures as output for selecting layer thickness and material properties. These predicted performance measures can be assessed to established performance criteria. Thus, the designer must continue to adjust thickness and material input parameters until the predicted performance measures satisfy the established performance criteria.

OBJECTIVE

The primary objective of this study was to evaluate the input parameters related to ACC material properties, traffic, and climate that significantly or insignificantly influence the predicted MEPDG performance model for Iowa's flexible pavement systems. To achieve this objective, the sensitivities of five MEPDG performance measures (longitudinal cracking, alligator cracking, thermal cracking, rutting, fatigue cracking, and smoothness) were conducted by either varying the magnitudes of a single input parameter or by varying the magnitudes of two input parameters in a representative pavement structure. The findings of this study can provide pavement designers a better understanding of the design parameters that should be defined more carefully in the design process and those that most affect certain pavement distresses.

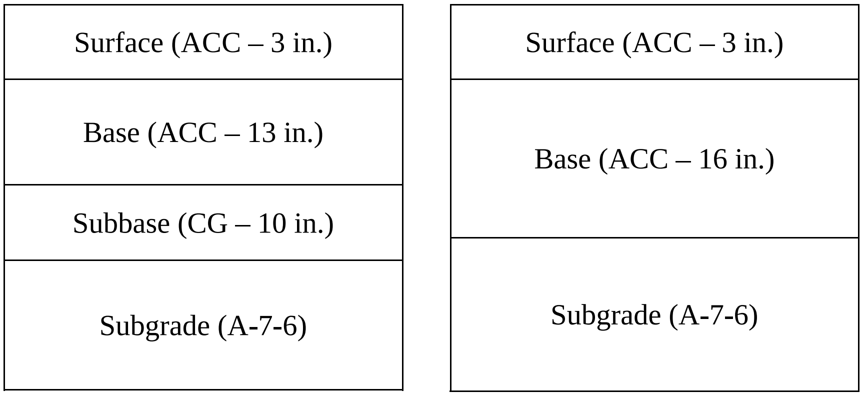
FLEXIBLE PAVEMENT STRUCTURE

Two flexible pavement structures were considered in this study. Though these pavements are ACC overlays of ACC pavements, the pavement structures could be represented as thick ACC-layer pavement structures normally used on interstate and state roads in Iowa. Table 1 summarizes the information for these existing pavements.

Table 1. Summary for two existing flexible pavements

County		Buchanan	Cedar
Route		US 020	I 80
Mile post		266.7–269.24	257.66–265.76
Construction years		Construction: 1971 1st resurfacing: 1989	Construction: 1962 1st resurfacing: 1976 2nd resurfacing: 1990
Surface	**Type**	ACC	ACC
	Thickness	Construction: 3 in. 1st resurfacing: 2 in. (mill: 1.5 in.)	Construction: 4.5 in. 1st resurfacing: 3 in. 2nd resurfacing: 4 in. (mill: 1.5 in.)
Base	**Type**	ACC	ACC
	Thickness	13 in.	16 in.
Subbase	**Type**	Crushed gravel (CG)	N/A
	Thickness	10 in.	N/A
Subgrade	**Type**	A-7-6	A-7-6

Based on the information summarized in Table 1, the two standard flexible structures used in this study were diagrammed, shown in Figure 1.



(a) US-020 in Buchanan County **(b) I-80 in Cedar County**

Figure 1. Standard flexible pavement structures

INPUT DESIGN PARAMETERS FOR FLEXIBLE PAVEMENTS

To investigate the effect of a particular pavement input parameter, the other input parameters are held constant. The design input parameters were divided into two groups: fixed input parameters and varied input parameters. While one design parameter was being examined, a standard value was assigned for the other design parameters. The ranges of magnitude for the varied input parameters were selected based on the recommendations of MEPDG and engineering judgment. Twenty-three key input parameters were selected as varied input parameters for the flexible pavement structure. Table 2 lists the fixed input parameters and standard values for the two flexible pavement structures used in this study.

Table 2. Fixed project input parameters

Fixed input parameter	Standard value
General information	
Design life (years)	20
Base/subgrade construction month	Sept. 2004
Pavement construction month	Sept. 2004
Traffic open month	Oct. 2004
Type of design	Flexible pavement
Site/project identification	
Location	Buchanan/Cedar
Analysis parameter	
Initial IRI (in./mi)	40
Terminal IRI (in./mi)	172 (maximum criteria)
ACC surface down cracking (ft/mi)	1000 (maximum criteria)
ACC bottom up cracking (%)	25 (maximum criteria)
ACC thermal fracture (ft/mi)	1000 (maximum criteria)
Permanent deformation—total pavement (in.)	0.75 (maximum criteria)
Permanent deformation—ACC only (in.)	0.25 (maximum criteria)

Traffic

The traffic input parameters required in the MEPDG are truck traffic volume, truck traffic movement information (speed, lateral wander, and axle load distribution), and truck traffic load character related to tire, axle, and wheel. This is more traffic information than what is required by the current AASHTO guide.

Traffic input parameters were expected to reflect real traffic condition in two locations (US-020 in Buchanan County and I-80 in Cedar County) so that the monthly adjustment factors (non-varied input parameters) in Table 3 and the vehicle class distribution (varied input parameters) in Table 4 could be obtained from the Iowa DOT database (Iowa DOT 2004; 2003). Five cases of vehicle class distribution were investigated for sensitivity analysis of vehicle class distribution. Each vehicle class distribution has a different shape of distribution. Tables 5 and 6 show the fixed traffic input parameters and varied traffic input parameters.

Table 3. The monthly traffic adjustment factors (fixed input parameter)

Month	MAF for Buchanan	MAF for Cedar
Jan.	0.82	0.78
Feb.	0.86	0.79
Mar.	0.90	0.90
Apr.	0.96	0.93
May	1.04	1.03
Jun.	1.06	1.13
Jul.	1.08	1.17
Aug.	1.11	1.23
Sep.	1.07	1.05
Oct.	1.08	1.05
Nov.	1.04	1.00
Dec.	0.99	0.92

Table 4. Vehicle class distributions (varied input parameters)

Veh.	Buchanan					Cedar				
Class	Case1[a]	Case2[b]	Case3[c]	Case4[d]	Case5[e]	Case1[a]	Case2[b]	Case3[c]	Case4[d]	Case5[e]
4	1.5	0.5	5.3	5.2	0.1	1.2	0.5	5.3	5.2	0.1
5	12	3.2	8.5	38.9	0.6	4.1	3.2	8.5	38.9	0.6
6	5.7	2	6.5	35.8	0.8	2.2	2	6.5	35.8	0.8
7	1.1	0.2	4.8	10.2	0.6	0.4	0.2	4.8	10.2	0.6
8	19.7	45	15.6	5.6	6.8	27.5	45	15.6	5.6	6.8
9	53.9	49	38.9	3.5	9.2	57.9	49	38.9	3.5	9.2
10	3.9	0.1	7	0.2	25.8	1.8	0.1	7	0.2	25.8
11	0.8	0	4.5	0.3	36.4	1.7	0	4.5	0.3	36.4
12	0.7	0	4.5	0.2	16.5	1.6	0	4.5	0.2	16.5
13	0.7	0	4.4	0.1	3.2	1.6	0	4.4	0.1	3.2

a: real vehicle distribution; b: high-medium class concentrated vehicle distribution; c: low-medium class concentrated vehicle distribution; d: low class concentrated vehicle distribution; e: high class concentrated vehicle distribution

Table 5.Fixed traffic input parameters

Fixed input parameter	Standard value
Traffic general	
Number of lanes in design direction	2
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	90
Traffic volume adjustment factors	
Hourly truck distribution	Default
Traffic growth factor	4 – composite
Axle load distribution factors	Default
General Traffic inputs	
Mean wheel location (in.)	18
Design lane width (ft)	12
Axle configuration	
Average axle width (ft)	8.5
Dual tire spacing (in)	12
Axle spacing—Tandem, Tridem, Quad axle	51.6 , 49.2 , 49.2
Wheel base	
Average axle spacing (ft)	12 , 15 , 18
Percent of trucks	33 , 33 ,34

Table 6.Varied traffic input parameters

Varied input parameter	Standard value	Investigated value
Traffic General		
Initial two-way AADTT	1168 for Buchanan/ 10928 for Cedar	100,1000,5000,10000,25000
Operational speed (mph)	60	3,25,45
General traffic input		
Traffic wander standard deviation (in.)	10	7,13
Axle configuration		
Tire pressure—single and dual tire(psi)	120/120	90/90,110/110,130/130,150/150

Climate

Climate input parameters for pavement design locations can be generated by choosing climate data from a specific weather station or by interpolating climatic data for a given location. Two new climate files, Buchanan County and Cedar County, were generated to determine standard input values. To investigate the effect of climate, Burlington in southern Iowa and Estherville in northern Iowa were chosen as investigated input values. The climate may influence the asphalt binder property more than the aggregate property, so the study should investigate the interacted sensitivity for different climates and different binder grades. Two types of PG grade binder, PG 58-28 and PG 64 -22, were assigned in different climate areas, summarized in Table 7.

Table 7. Varied climate input parameter

Varied input parameter	Standard value	Investigated value
Climate		
Climate data file	Buchanan file/Cedar file	Burlington (relatively warm area in Iowa) Estherville (relatively cold area in Iowa)
Asphalt material property		
Asphalt binder grade	PG 58 – 28	PG 64 – 22

Material properties

The materials used in this study can be divided into three major groups: ACC material, unbounded material (aggregate), and subgrade material. Most properties of ACC required in the MEPDG were investigated. However, for unbounded material and subgrade material, strength-based properties were investigated with the Integrated Climate Model input analysis. The standard material property values were used to reflect actual field pavement properties in Buchanan and Cedar County. Table 8 shows the varied material input parameters used in this study. Table 9 shows the unbound and subgrade material properties used.

SENSITIVITY RESULTS

The results of the MEPDG software runs for the evaluated input parameters provided numerous charts and tables. Therefore, due to space limitations, it is difficult to discuss each evaluated input parameter and provided distress in this paper. The results of the MEPDG software runs are summarized. The sensitivities of five MEPDG performance measures were conducted by either varying a single input parameter or by varying two input parameters at a time. Each performance measure was graded at three levels (very sensitive, sensitive, insensitive). The trends in performance measure magnitude changes (increasing or decreasing) with respect to input parameter magnitude changes are presented in Table 10. The relative sensitivity of input parameters can be changed with the scale used in analysis, so that the scale in the examined chart should be fixed according to Table 11. Examples of different performance measures are illustrated in Figure 2. A large difference among output trends with respect to input parameter changes indicates an increased sensitivity, while little or no difference indicates insensitivity. It is also noted that the relative sensitivity of one input parameter could be influenced by the other input parameter when varying two parameters at a time.

Table 8. Varied material input parameters used in sensitivity analysis

Varied input parameter	Standard value	Investigated value
Asphalt layer		
Asphalt surface thickness (in.)	3	4,5,6,7,8
Asphalt base thickness (in.)	13 (Buchanan)/16 (Cedar)	5,10
Type of asphalt base material	ACC	CG, A-1-a, A-2-4, A-2-7
Surface ACC aggregate gradation	NMS ¾ in. gradation	NMS ½”
	- Cuml.% retain. ¾ in.: 0	- Cuml.% retain. ¾ in.: 0
	- Cuml.% retain.3/8 in.: 22	- Cuml.% retain.3/8 in.: 15
	- Cuml.% retain.#4: 48	- Cuml.% retain.#4: 41
	- % passing #200: 3	- % passing #200: 4
Base ACC aggregate gradation	NMS ¾ ” gradation	NMS ½”
	- Cuml.% retain. ¾ in.: 0	- Cuml.% retain. ¾ in.: 0
	- Cuml.% retain.3/8 in.: 25	- Cuml.% retain.3/8 in.: 13
	- Cuml.% retain.#4: 56	- Cuml.% retain.#4: 42
	- % passing #200: 3	- % passing #200: 4
Asphalt binder	PG 58 – 28	PG52-22,PG52-28,PG52-34 PG58-22,PG58-34 PG64-22,PG64-28,PG64-34
Initial volumetric properties (Vbe/ Va/ VMA, %)	11/7/18	12/8/20,13/7/20,11/6/17 12/5/17,12/4/16,11/3.5/14
Poisson’s ratio	0.25	0.35,0.45
Thermal conductivity asphalt (BTU/hr-ft –F”)	0.67	0.5, 0.7,1
Heat capacity asphalt (BTU/lb-F”)	0.23	0.1,0.3,0.5
Unbound layer (ν =0.35, K_O = 0.5)		
Subbase thickness (in.)	10	3,6,9,12
Type of subbase material	CG	A-1-a, A-2-4, A-2-7
Subgrade layer (ν =0.35, K_O = 0.5)		
Type of subgrade material	A-7-6	A-1-a,A-2-4,A-5
Thermal cracking		
Aggregate coefficient of thermal extraction (/ºF)	2.8 x 10^-6	10^-7,10^-4

Table 9. Unbound and subgrade materials (varied input parameter)

Classification	CG	A-1-a	A-2-4	A-2-7	A-5	A-7-6
Modulus (Ksi)	42	40	32	24	20	8
PI (%)	1	1	2	15	1	40
% Passing #4	30	20	80	90	90	99
% Passing #200	10	3	20	20	80	90
D60 (mm)	2	8	0.1	0.1	0.05	0.01

Table 10. Notation used in sensitivity study

Notation	Meaning
↑↑ / ↓↓	Very sensitive (↑↑ = more increasing / ↓↓ = more decreasing output trend) on varying two input parameters
↑ / ↓	Sensitive (↑= increasing / ↓= decreasing output trend) on varying two input parameters
	Sensitive (↑= increasing / ↓= decreasing output trend) on varying one input parameter
↔ (↑) / ↔ (↓)	Insensitive (↔ (↑) = increasing / ↔ (↓) = decreasing output trend) on varying input parameter
↔	Insensitive on varying input parameter

Table 11. Scales in different distress charts for sensitivity study of two flexible pavements

Distress	Minimum	Maximum	Unit	Recommended distress target
L.C (ft/mi)	0	10000	1000	1000
F.C (%)	0	26	2	25
T.C (ft/mi)	0	2000	200	1000
A.C rutting (in.)	0	1	0.2	0.25
T. rutting (in.)	0	1.6	0.2	0.75
I.R.I (in./mi)	0	220	20	172

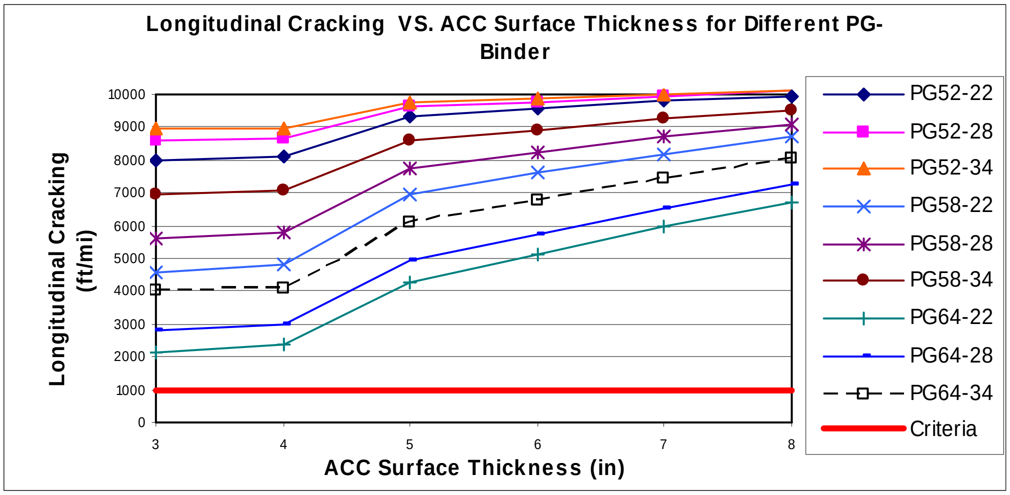


Figure 2. (a) Sensitive and different magnitude output trends for evaluating two input parameters (PG ↑ ➢ Long. crk.↓↓ for thin surface ACC layer and PG ↑➢ Long. crk. ↓for thick surface ACC layer)

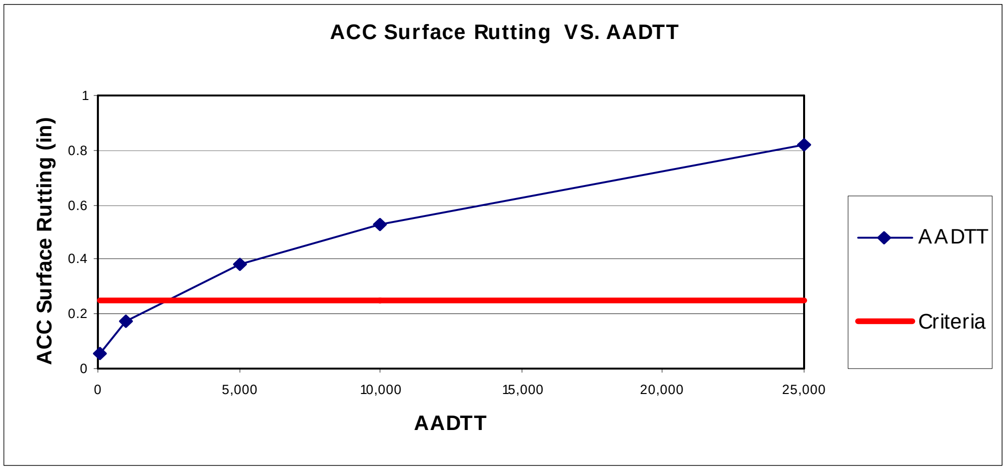


Figure 2. (b) Sensitive and different magnitude output trends for evaluating one input parameter (AADTT ↑ ➢ ACC surface rutting ↑)

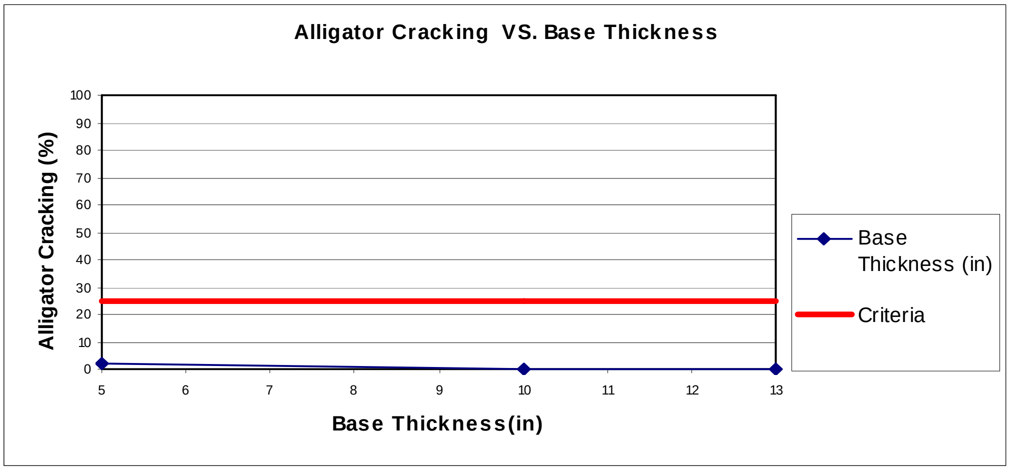


Figure 2. (c) Insensitive and different magnitude output trends for evaluating input parameter (base thickness ↑ ➢ allig. crk. ↔ (↓))

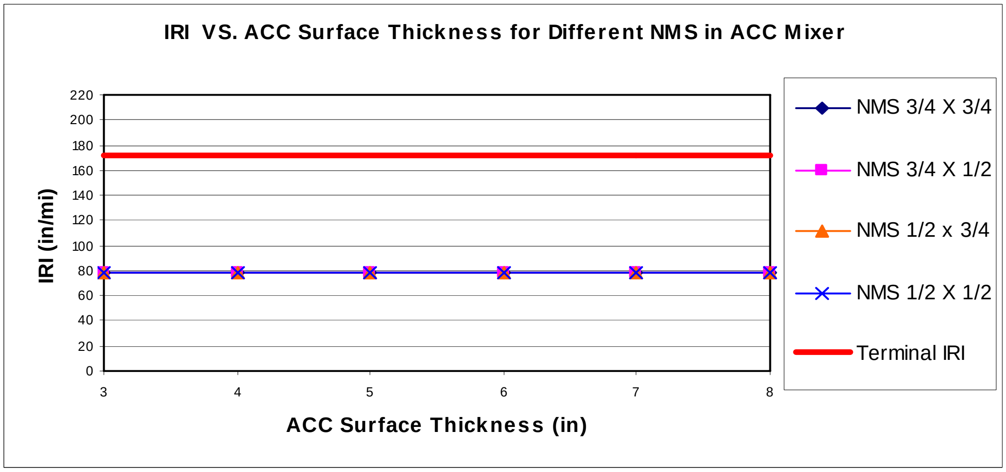


Figure 2. (d) Insensitive and no difference magnitude output trends for evaluating input parameter in legend (ACC surface thickness ↑➢ IRI ↔)

Figure 2. Examples of different sensitive output trends

Twenty-three input parameters were investigated in this study. Table 12 summarizes the results. Interestingly, there is no input parameter that is sensitive to all of the MEPDG performance measures in this study. This indicates that it would be quite difficult to obtain the optimum pavement structure that would be able to resist all distresses.

Most investigated input parameters were sensitive to longitudinal cracking, while most were insensitive to alligator cracking (19 of 23 input parameters were listed as “relatively sensitive” for longitudinal cracking, while 3 of 23 input parameters were listed as “relatively sensitive” for alligator cracking). The reason for this might be related to the relatively thick ACC layer pavement structure evaluated in this study. This is verified in that changing the base type and thickness results in relative sensitivity to alligator cracking. Considering that flexible pavement structures in Iowa have relatively thick ACC layer pavements, a pavement designer in Iowa should be more concerned about longitudinal cracking than alligator cracking. Transverse cracking was more influenced by 5 of 23 input parameters related to material properties and climate. Thus, there is reasonable agreement that transverse cracking might be due to material properties and not to structure. Rutting was found to be a more sensitive distress by most input parameters (14 of 23 input parameters were listed as being quite sensitive for rutting). It is also interesting that the ACC surface rutting was found to be more sensitive to the variance of input parameters. Though 6 of 20 input parameters were listed as sensitive for international roughness index (IRI), IRI was not very sensitive for most input parameters. It may be due to the nature of the IRI model that alligator cracking and transverse cracking contribute more to the IRI value.

The interaction between two parameters, 7 of 23 input parameters, was investigated. Among them, four of seven input parameters were listed as interactive for longitudinal cracking while most input parameters were listed as non-interactive for other performance measures. These results indicate that a pavement designer using the MEPDG for flexible pavement design should recognize the interactive effects among input parameters to obtain the predicted performance measures for satisfying the design criteria.

The differences in trends of performance measures between the two flexible pavements were also investigated. Five of twenty-three input parameters show differences for projected longitudinal cracking measurements. Only 1 of 23 input parameters shows differences in the projected alligator cracking and projected rutting measurements. These differences might be attributed to the differences in AADTT and the component materials in the structures of the two investigated flexible pavements.

Table 12. Summary of sensitivity analysis results for two flexible pavements

Flexible Pavement Input Parameters			Predicted Performance measures								
						Rutting					
			Long. Crk. (Top down)	Allig. Crk. (Bottom up)	Therm.Crk. (Transverse)	ACC Surface	ACC Base	Subbase	Subgrade	Total	IRI
Traffic		**AADTT ↑**	↑	↔(↑)	↔	↑	↑	↔	↑	↑	↔
		Traffic Speed ↑	↓	↔	↔(↓)	↓	↔(↓)	↔	↔(↓)	↓	↔
		Traffic Distribution ↑at thin ACC surface in thick ACC layer	↑/↑↑*	↔	↔	↔(↑)/↑*	↔	↔	↔	↔(↑)/↑*	↔
		Traffic Distribution ↑at thick ACC thick. in thick ACC layer	↑	↔	↔	↔(↑)/↑*	↔	↔	↔	↔(↑)/↑*	↔
		Traffic Wander ↑	↓	↔	↔	↔(↓)	↔	↔	↔	↔(↓)	↔
		Tire Pressure ↑at thin ACC in thick ACC layer	↑/↑↑*	↔	↔	↑	↔	↔	↔	↑	↔
		Tire Pressure ↑at thick ACC in thick ACC layer	↑	↔	↔	↑	↔	↔	↔	↑	↔
Climate		**MAAT ↑ (North → south)**	↑	↔	↓	↑	↔	↔	↔	↑	↓
		ACC E* ↑ (PG ↑) at low MAAT (North)	↓	↔	↑	↓	↔	↔	↔	↓	↑
		ACC E* ↑ (PG ↑) at high MAAT (South)	↓	↔	↑	↓	↔	↔	↔	↓	↑
Material	**A.C Mix. Property**	**NMS ↓ (E*↑) at thin ACC surface in thick A.C layer**	↓	↔	↔	↔(↓)	↔	↔	↔	↔(↓)	↔
		NMS ↓ (E*↑) at thick ACC surface in thick A.C layer	↓↓/↓*	↔	↔	↔(↓)	↔	↔	↔	↔(↓)	↔
		PG ↑ (E*↑) at thin ACC surface in thick A.C layer	↓/↓↓*	↔	↑	↓	↔	↔	↔	↓	↑
		PG ↑ (E*↑) at thick ACC surface in thick ACC layer	↓↓/↓*	↔	↑	↓	↔	↔	↔	↓	↑
		Volumetric (Va ↓ → E*↑)	↓	↔(↓)	↔	↓	↔	↔	↔	↓	↔
		Volumetric (Vbe ↓ → E*↑)	↑	↔(↑)	↓	↓	↔	↔	↔	↓	↓
		Unit Weight ↑	↔(↓)/↓*	↔	↔(↓)	↔(↓)	↔	↔	↔	↔(↓)	↔
		Poisson Ratio ↑	↓	↔	↔	↓	↔	↔	↔	↓	↔

Table 12. Continued

Flexible Pavement Input Parameters			Predicted Performance measures								
			Long. Crk. (Top down)	Allig. Crk. (Bottom up)	Therm.Crk. (Transverse)	Rutting					IRI
						ACC Surface	ACC Base	Subbase	Subgrade	Total	
Material	**A.C Thermal Property**	**Thermal Conductive↑ at thin ACC surface in thick ACC layer**	↔(↑)	↔	↔(↓)	↔(↑)	↔	↔	↔	↔(↑)	↔
		Thermal Conductive↑ at thick ACC surface in thick ACC layer	↔(↑)	↔	↔(↓)	↔(↑)	↔	↔	↔	↔(↑)	↔
		Heat Capacity ↑ at thin ACC surface in thick ACC layer	↓	↔	↔(↓)	↓	↔	↔	↔	↓	↔ (↓)
		Heat Capacity ↑ at thick ACC surface in thick A.C layer	↓	↔	↔(↓)	↓	↔	↔	↔	↓	↔ (↓)
	Base	**Mr ↑ (Type of Base)**	↔(↓)	↓	↔	↔	↓	↔	↔(↓)	↔(↓)	↓
		Mr → E* (Unbound → Bound)	↑	↓	↓	↓	↓	↔(↓)	↔(↓)	↓	↓
	Subbase	**Mr ↑ (Type of Subbase)**	↔(↑)	↔	↔	↔	↔	↔	↔	↔	↔
	Subgrade	**Mr ↑ (Type of Subgrade)**	↑	↔(↓)	↔	↔	↔	↔	↓	↓	↔
Layer Thick.	**ACC Surface**	**Thickness ↑**	↑	↔(↓)	↔	↔(↑)	↔(↓)	↔(↓)	↔(↓)	↔(↓)	↔
	ACC Base	**Thickness ↑**	**H<10** ↓ **H>10** ↑	↔(↓)/↓*	↔	↓	↔(↓)	↔	↔(↓)	↓	↔
	Subbase	**Thickness ↑**	↑	↔(↓)	↔	↔	↔	↔(↑)	↔(↓)	↔(↓)	↔
Others	**Aggr.**	**Aggregate Thermal Coefficient ↑**	↔	↔	↔	↔	↔	↔	↔	↔	↔

* US 20 in Buchanan County/I 20 in Cedar County

CONCLUSIONS AND RECOMMENDATIONS

The relative sensitivity of MEPDG input parameters related to the properties of ACC, traffic, and climate were investigated in two existing Iowa flexible pavement structures. Most of the input parameter variations could be represented in Iowa conditions. Based on the observations of this study, the following conclusions were drawn:

- The MEPDG requires many more input parameters than the current AASHTO guide. These input parameters are connected to each other inside the software and provide predicted performance measures. Thus, increasing layer thickness, which is the general design approach in the current AASHTO guide to reduce the distress, is not the only solution in the MEPDG.
- Few input parameters used in this study affect all the predicted performance measures. However, binder PG grade, volumetric properties, climate, AADTT, and type of base generally influenced most of the predicted performance measures.
- The predicted longitudinal cracking performance measure was influenced by most input parameters. A reasonable design concept to reduce longitudinal cracking should be considered in relatively thick pavement designs.
- Alligator cracking was not a critical distress in the relatively thick pavement structures used in this study.
- The input parameters related to material properties and climate were especially sensitive to the predicted transverse cracking performance measures.
- ACC surface rutting dominated total rutting in the relatively thick pavement structures used in this study.
- IRI was not sensitive for most input parameters. This might be due to the nature of the IRI model. Alligator cracking and thermal cracking are the primary contributors to the IRI value.

To supplement the conclusions made in this sensitivity study, remaining research efforts related to the MEPDG include the following:

- The predicted pavement measures were not validated through the MEPDG against the recorded measurements in the DOT PMIS database in this study. This research approach is strongly recommended for local calibration.
- The input parameters in the MEPDG are interconnected and provide different severities for each performance measure. The optimizing input parameters (especially layer thickness and material parameters), which can be satisfied with the criteria for all of the predicted performance measures, will be useful to pavement designers. This research will provide a valuable guideline to pavement designers using the MEDPG for flexible pavement design.

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