14th Quarterly Progress Report
Submitted to
FEDERAL HIGHWAY ADMINISTRATION
(FHWA)

THE IMPACT OF WIDE-BASE TIRES ON PAVEMENT DAMAGE
DTFH61-11-C-00025

July 1- September 30
2014

Submitted by
Illinois Center for Transportation
University of Illinois at Urbana-Champaign

FEDERAL HIGHWAY ADMINISTRATION
QUARTERLY PROGRESS REPORT

FHWA Project DTFH61-11-C-00025 FY: 2014 Quarter: 14 July-September
Research Agent Illinois Center for Transportation
Principal Investigator Imad L. Al-Qadi

PHASE	RESEARCH TASK	2011									2012												2013												2014												ESTIMATED % COMPLETION
		A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
1	1.1. Comprehensive literature review and synthesis on past and current research	20	60	90	100																																										100
	1.2. Experimental plan and modeling framework			50	60	80	100																																								100
	1.3. Implementation and marketing plan		10	50	70	80	100																																								100
	1.4. Phase I report			60	70	80	100																																								100
	1.5. Conference call with panel	0	50			100																																									100
	1.6. Presentations to relevant conferences and symposiums						50																																								100
2	2.1. Prepare experimental equipment, test structures, and instrumentation					0	0	0	0	0	10	30	40	45	50	60	70	85	90	95	100																										100
	2.2. Conduct experiments, including material characterization and accelerated loading						0	0	0	0	5	10	20	25	30	40	50	60	70	40	40	40	45	50	55	55	57	60	62	65	68	70	72	73	75	77	80	82	84	85	87	88	90				90
	2.3. Conduct modeling					0	0	0	0	0	1	2	5	6	8	10	20	25	30	30	35	35	40	45	50	50	53	55	56	57	59	60	61	62	65	68	70	85	90	95	96	97	97				97
	2.4. Development of analysis tool													0	0	0	0	5	5	10	15	15	20	25	35	40	42	45	46	48	49	51	52	52	55	58	60	62	65	70	75	77	80				80
	2.5. Delivery of draft Phase II report and analysis tool																												0	0	0	0	0	0	0	0	0	0	0	0	10	20	30				30
	2.6. Present to relevant conferences and symposiums																																														50
	2.7. Prepare article and technical papers																																														0
	Estimated Progress (%)	1	3	7	8	10	11	11	11	11	13	15	19	21	23	27	33	38	43	41	40	38	42	45	49	50	51	53	54	56	57	58	59	60	62	63	65	71	73	76	##	##	##				84
	Planned Progress (%)	1	3	7	10	13	17	21	25	29	33	36	40	44	47	51	55	59	61	63	64	66	68	70	71	73	75	77	81	85	89	93	97	100	100	100	100	100	100	100	100	100	100				100

QUARTERLY PROGRESS REPORT

QUARTER 14

The Impact of Wide-Base Tires on Pavement Damage – A National Study

1. Work Performed

The following tasks were accomplished during this quarter:

- Regression analysis was conducted to finalize Adjustment Factor 1 (AF1), which accounts for the effect of using wide-base tire.
- Preliminary analysis and development of Adjustment Factor 2 (AF2) has been completed. A total of 336 DTA cases were simulated using finite element analysis based on MEPDG procedure via ABAQUS, and 230,000 input files were run in JULEA.
- The online database user interface was updated per the comments given during the last teleconference meeting. Detailed responses for all comments are provided in Table 1 (Appendix B).

2. Work to Be Accomplished in the Next Quarter

- A distinct challenge in the development of AF2 is governed by the differences between the simulations conducted by the finite element analysis (ABAQUS) and the MEPDG procedure (JULEA), including the loading condition and material characterization. Therefore, further analysis will be performed to obtain a better statistical correlation between the results obtained from ABAQUS and JULEA to finalize the adjustment factor.
- Remaining comments for online database user interface will be addressed.
- Current simulations for numerical model validation will be completed.
- A full report will be finalized, including numerical, environmental and economic analyses and potential modes of implementation.

3. Current and Cumulative Expenditures

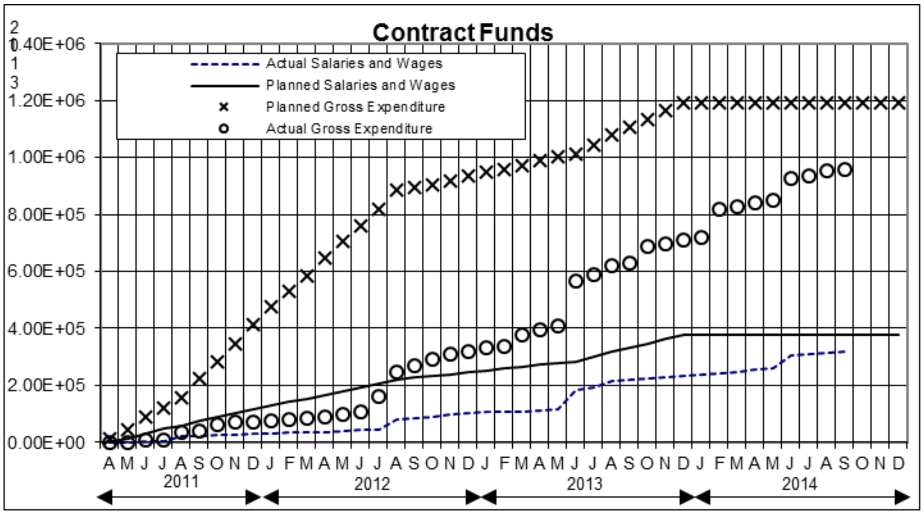

Figure 1. Project's expenditure.

4. Planned, Actual, and Cumulative Percentage of Effort

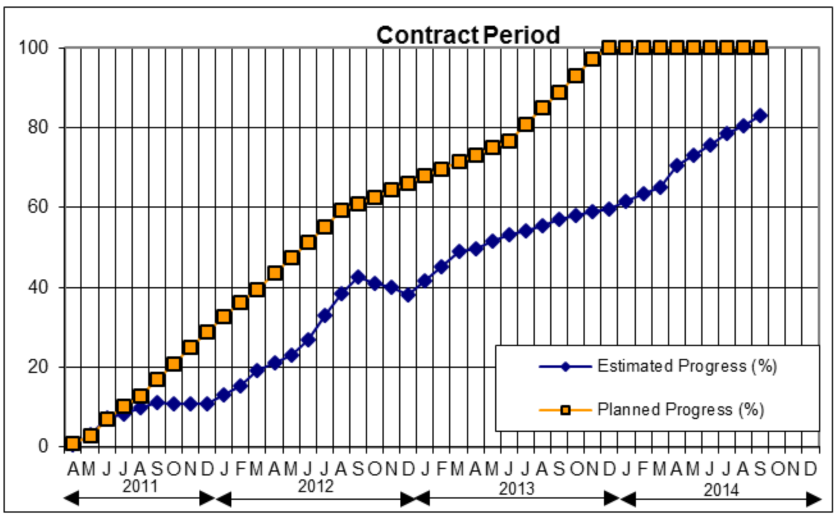

Figure 2. Project's progress.

APPENDIX A

ADJUSTMENT FACTOR FOR MECHANISTIC-EMPIRICAL PAVEMENT DESIGN GUIDE

Details of the theoretical approach and implementation of the adjustment factor were provided in the previous quarter report. The following figure illustrates the summary of the approach.

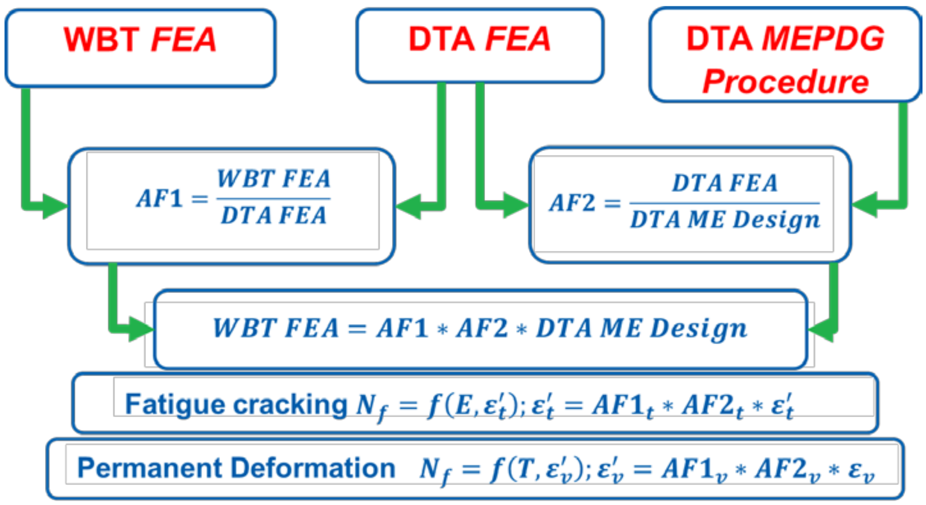

Figure 3. Adjustment factor approach.

AF1 – Conversion from Dual Tire Assembly to Wide-Base Tire

AF1 was developed using 480 FEM simulations (240 DTA and 240 WBT cases), which were run in ABAQUS considering the same material properties and pavement structures assumed in JULEA. However, differences between the inputs include the contact stresses and contact areas, measured under the same axle load for DTA and WBT cases. The presented results pertain to the critical response inputs for the empirical transfer functions. Each response corresponds to a linear regression function that represents the adjustment factor.

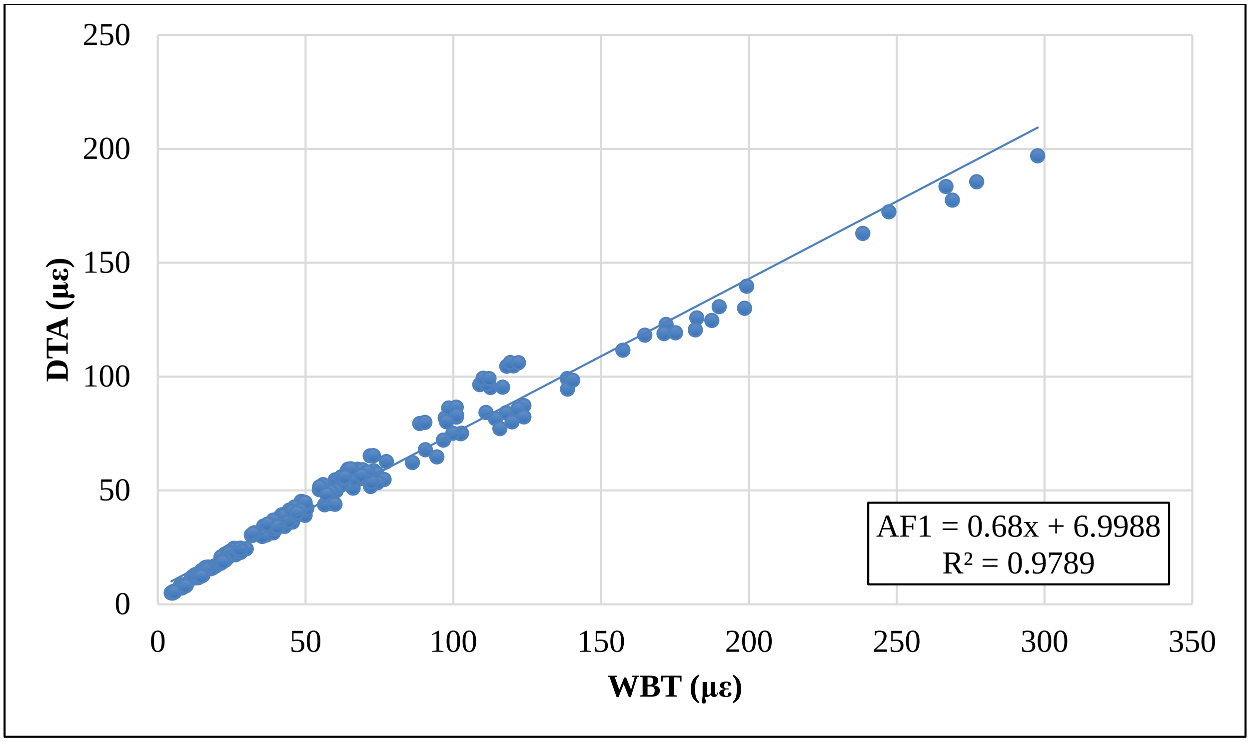

Figure 4. Maximum tensile strain at AC surface.

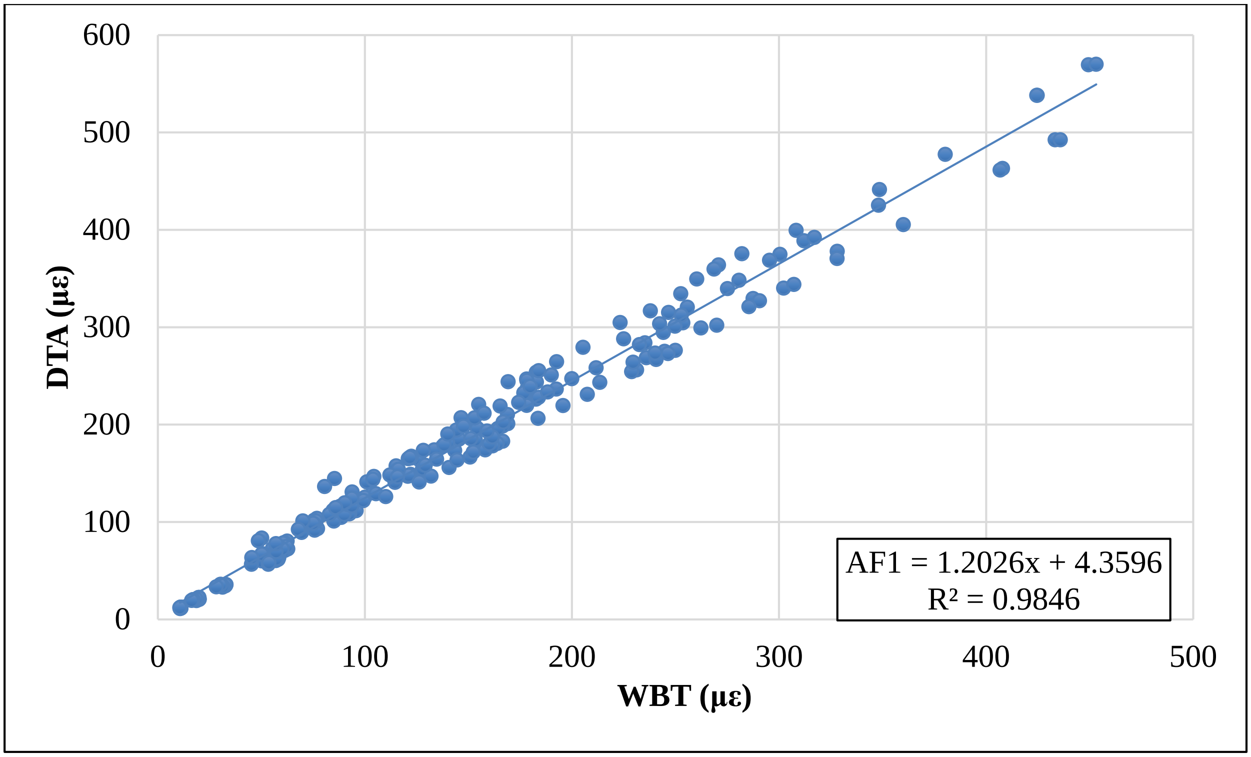

Figure 5. Maximum longitudinal tensile strain at bottom of AC.

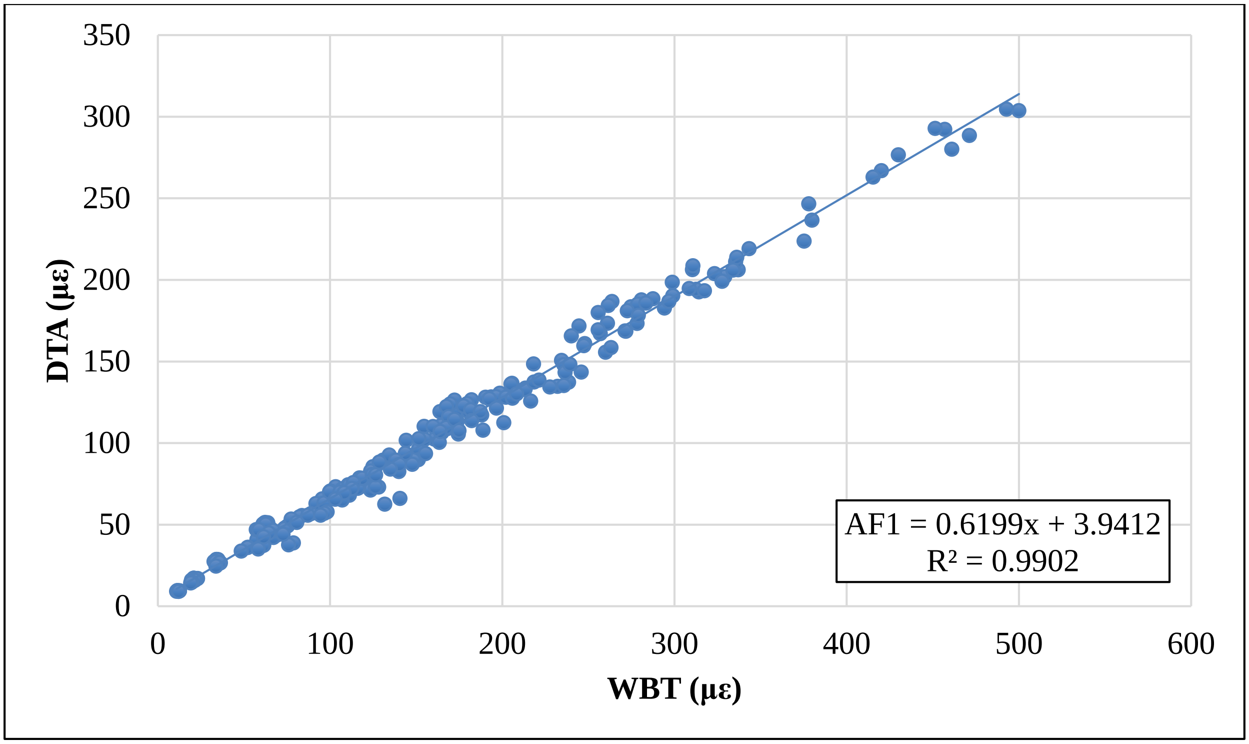

Figure 6. Maximum transverse tensile strain at bottom of AC.

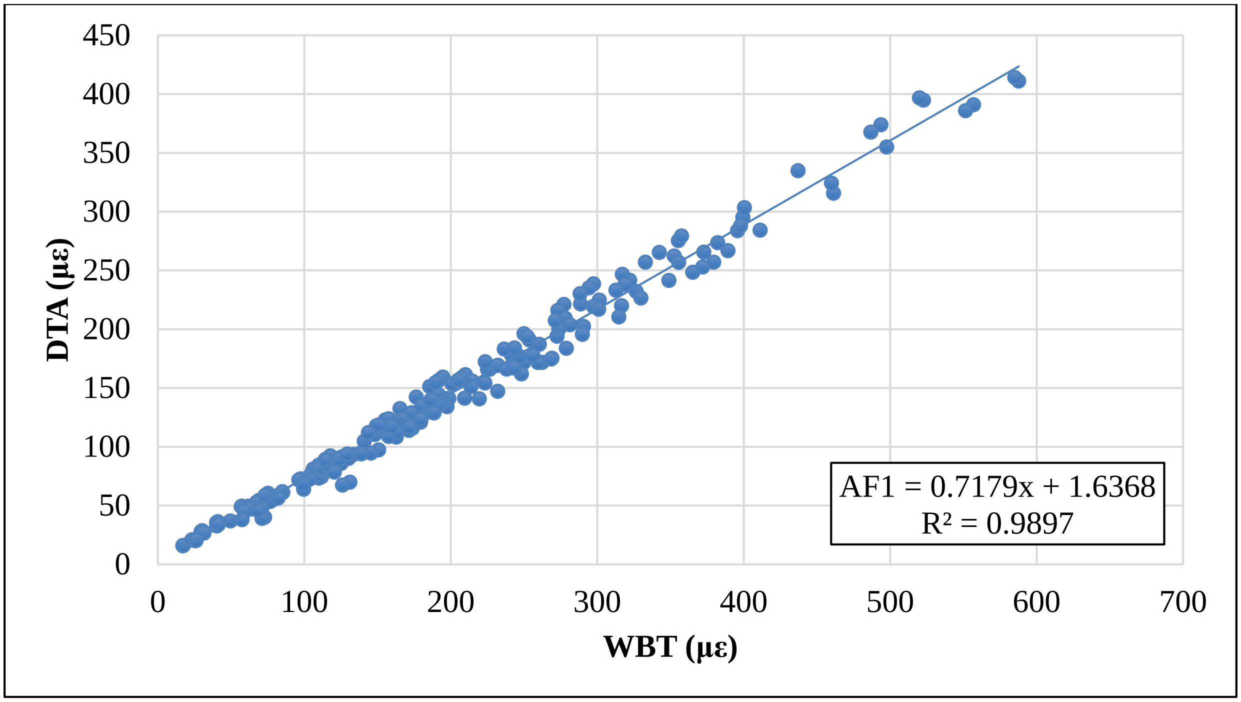

Figure 7. Maximum compressive strain within AC.

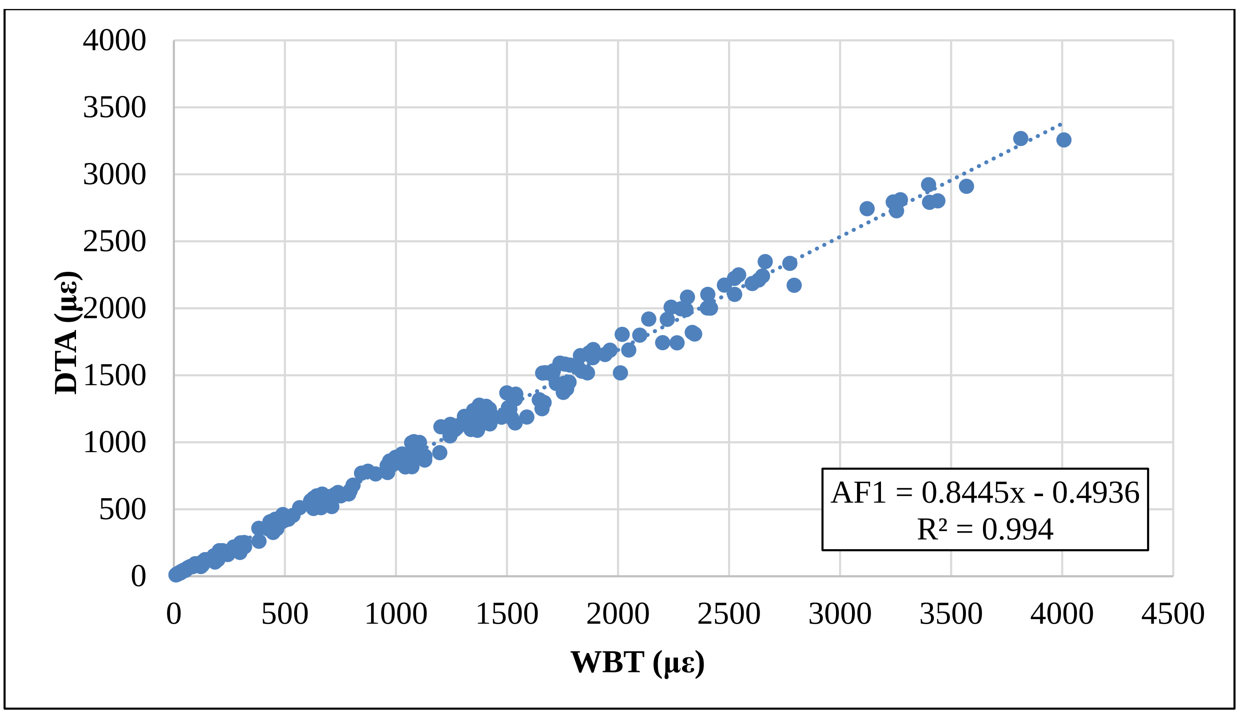

Figure 8. Maximum compressive strain within base.

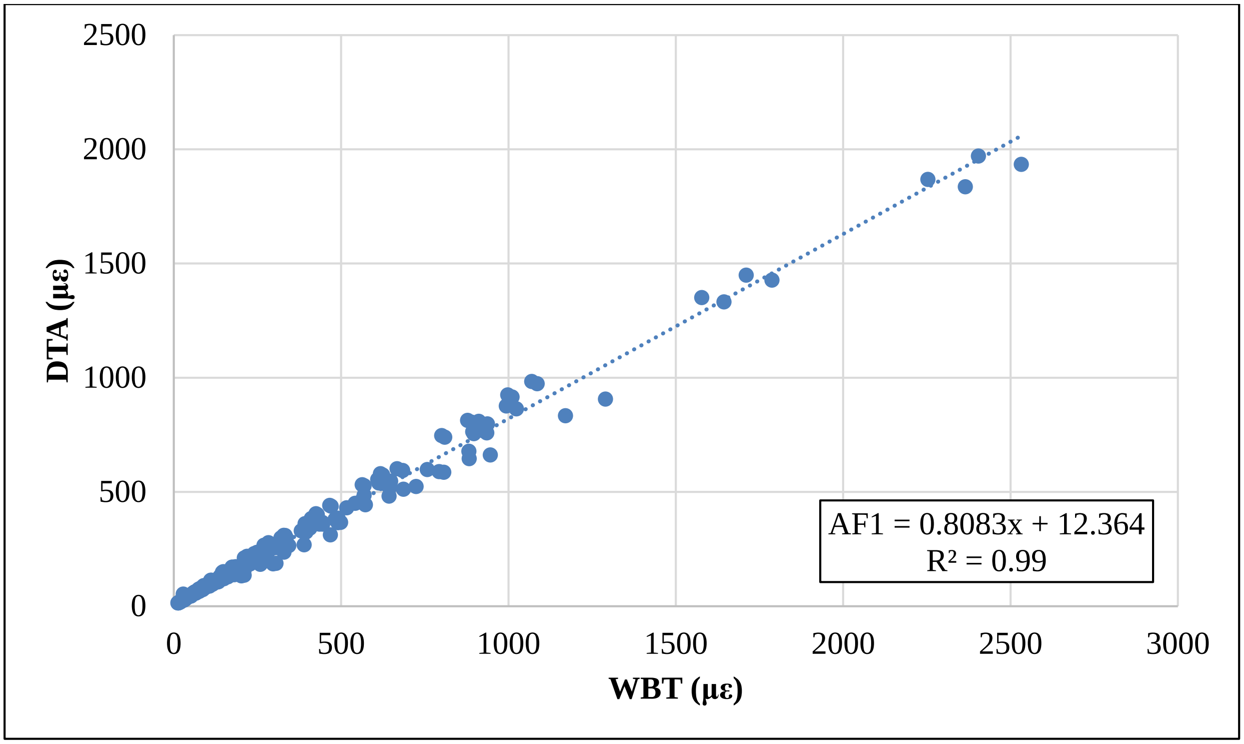

Figure 9. Maximum compressive strain within subgrade.

AF2: Adjustment Factor for Model Complexity (MEPDG to FEM)

In comparison with AF1, only DTA cases were considered for the second adjustment factor as MEPDG cannot simulate the WBT loading condition. AF2 development has not been completed yet as it is not as straightforward as developing AF1. Differences in the loading condition (three-dimensionality and non-uniformity of the contact stresses), material characterization, and layer interaction introduce serious challenges that complicates the development of AF2. Preliminary analysis from the thick pavement simulations are illustrated in the following figures.

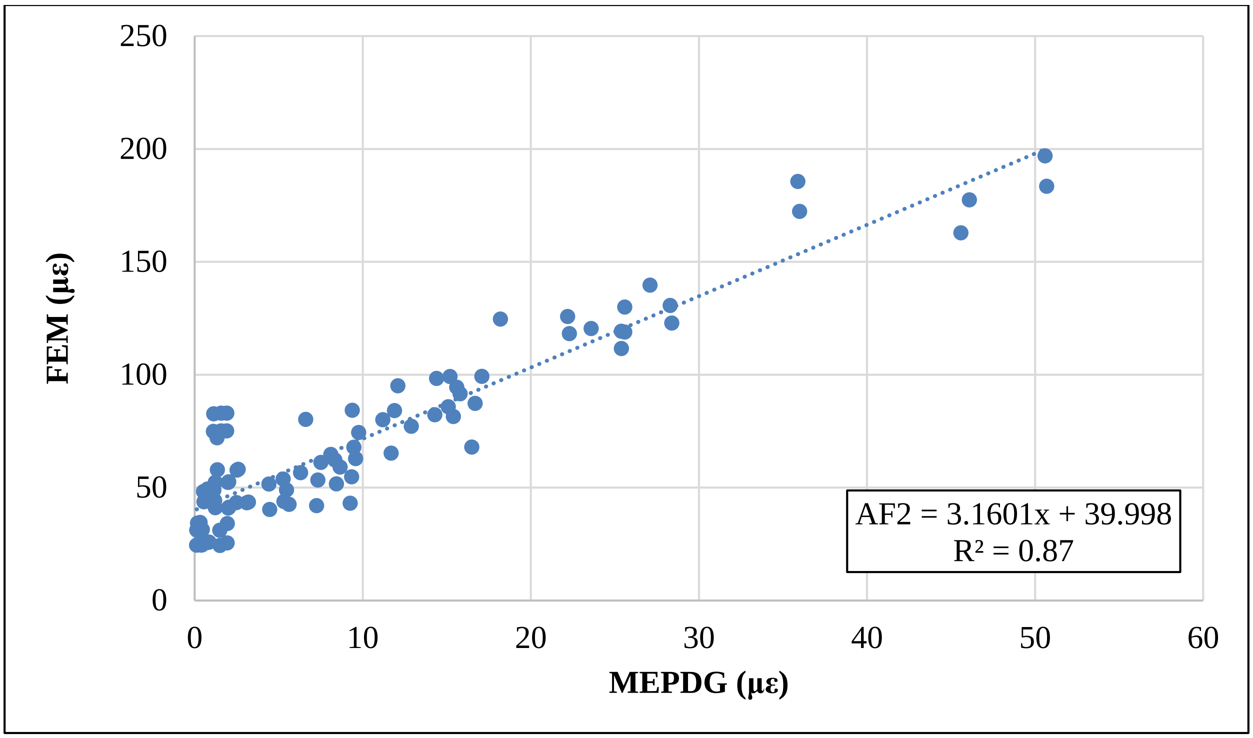

Figure 10. Maximum tensile strain at AC surface.

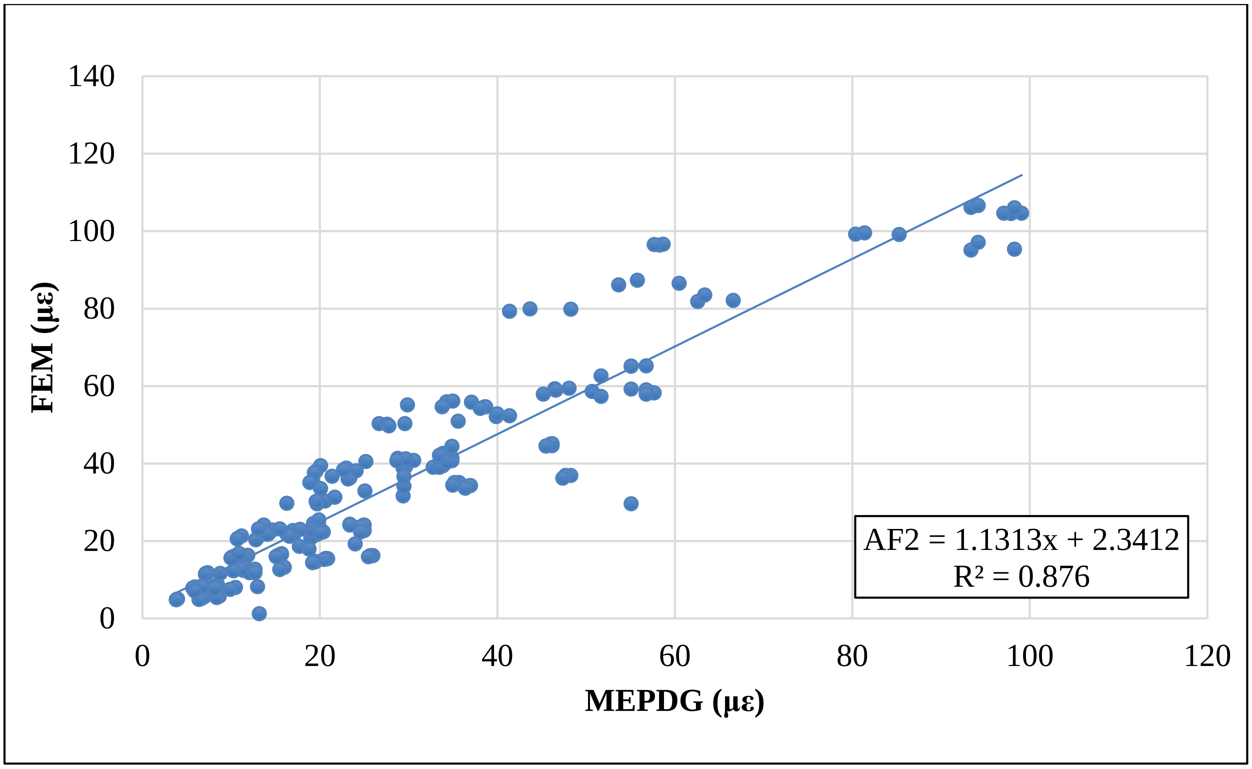

Figure 11. Maximum longitudinal tensile strain at the bottom of AC.

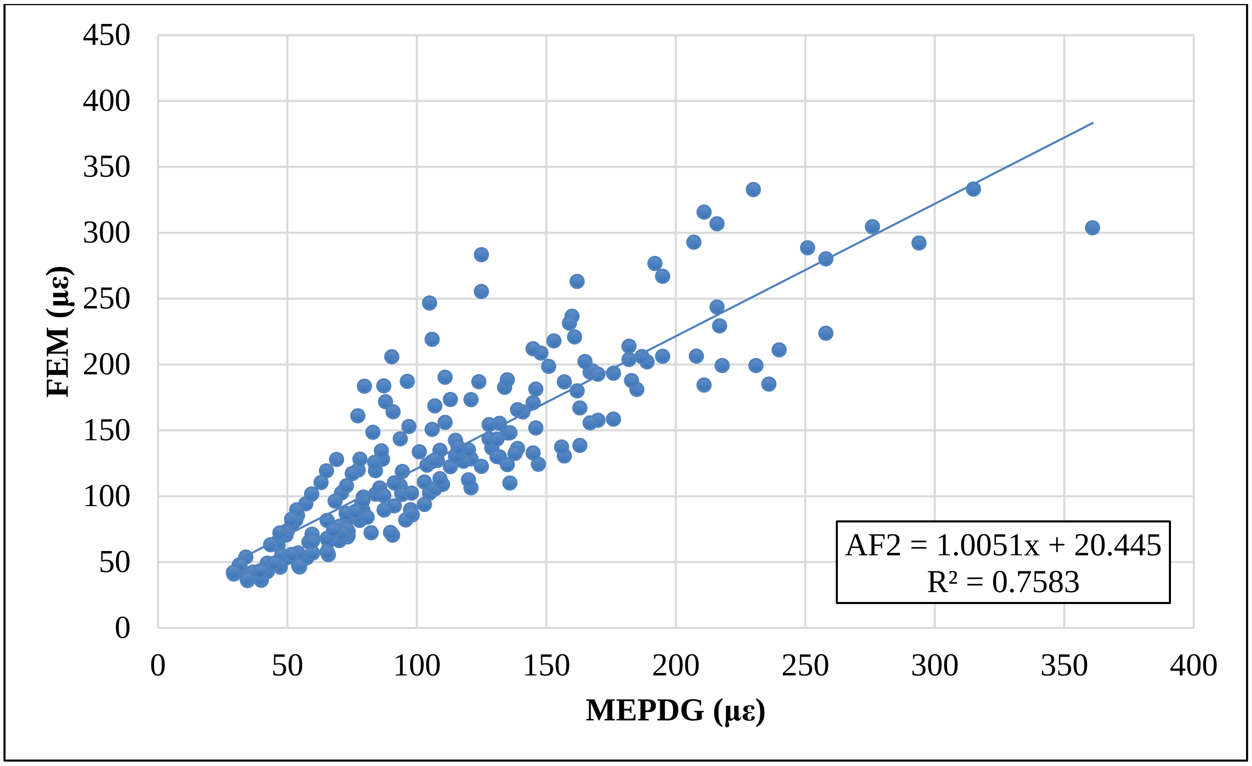

Figure 12. Maximum transverse tensile strain at the bottom of AC.

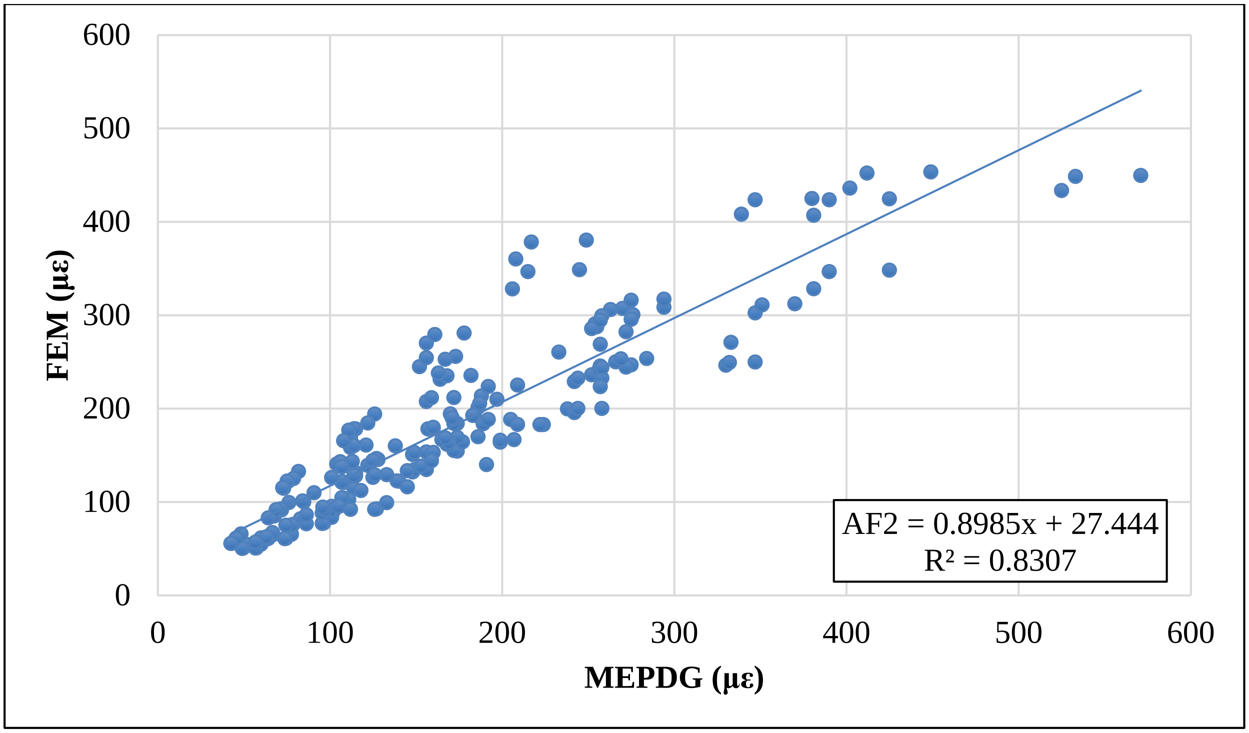

Figure 15: Maximum longitudinal tensile strain at the bottom of AC.

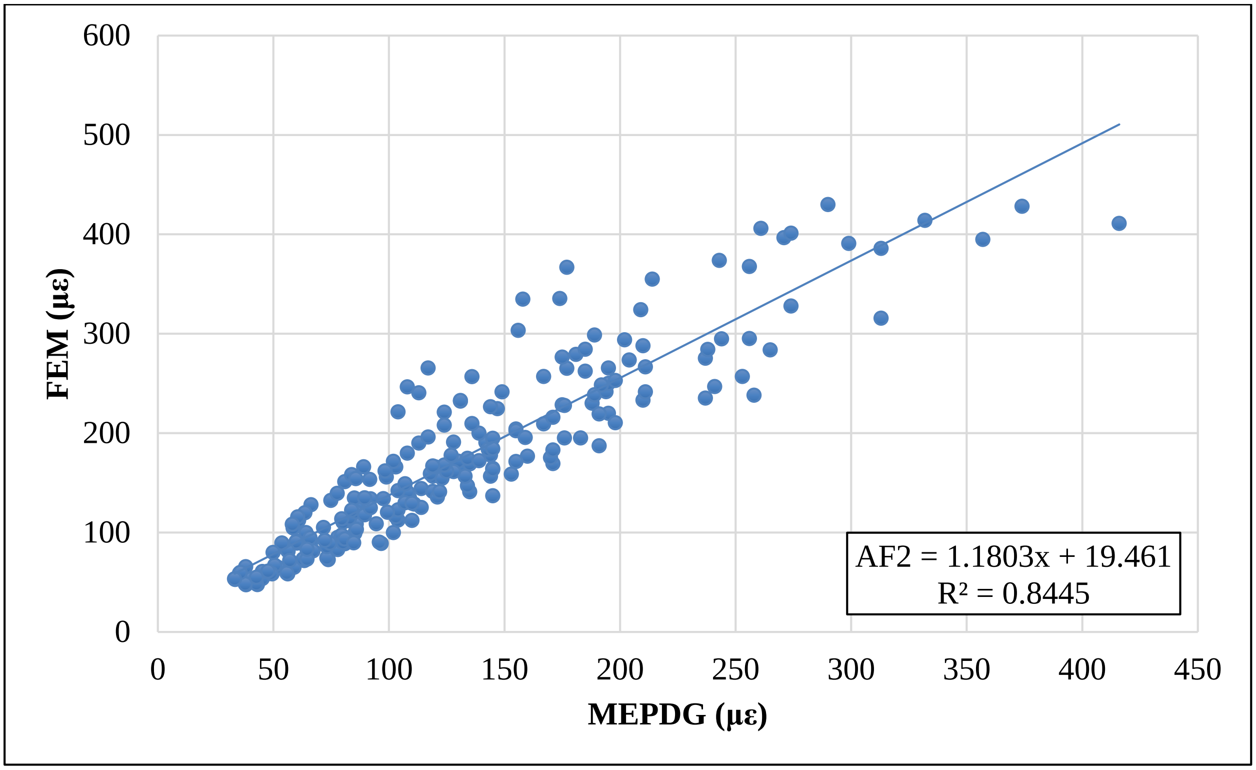

Figure 16: Maximum compressive strain within AC.

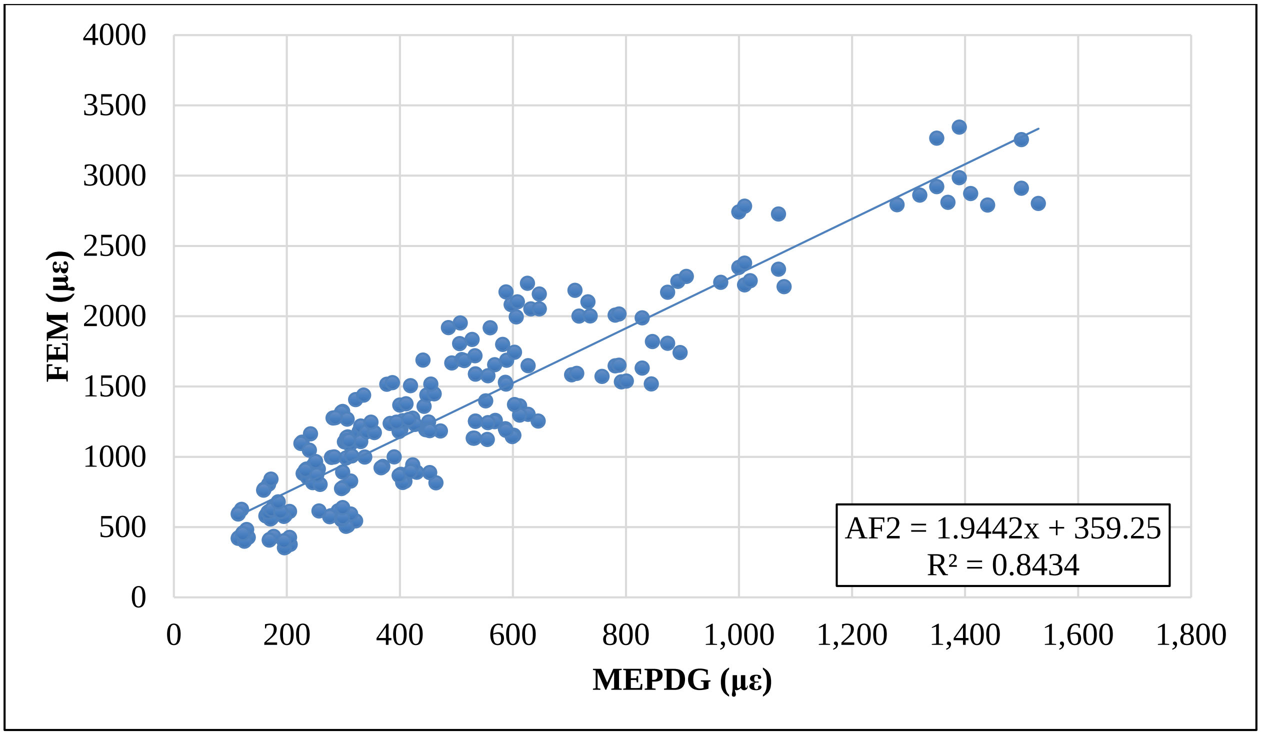

Figure 13. Maximum compressive strain within base.

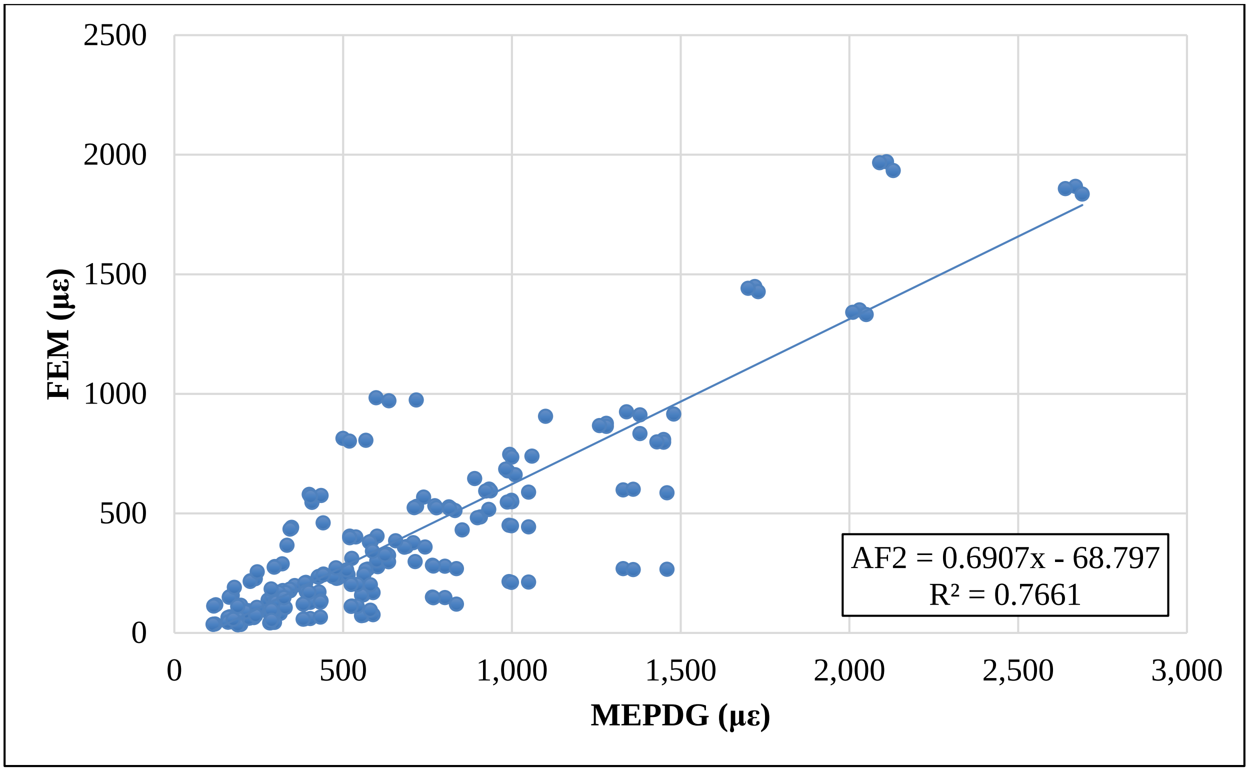

Figure 14. Maximum compressive strain within subgrade.

APPENDIX B

DEVELOPMENT OF THE ANN TOOL

The UIWide tool (University of Illinois Wide-base tire effect on pavements Artificial Neural Network tool) has been finalized. Figure 15 illustrates a snapshot of the tool.

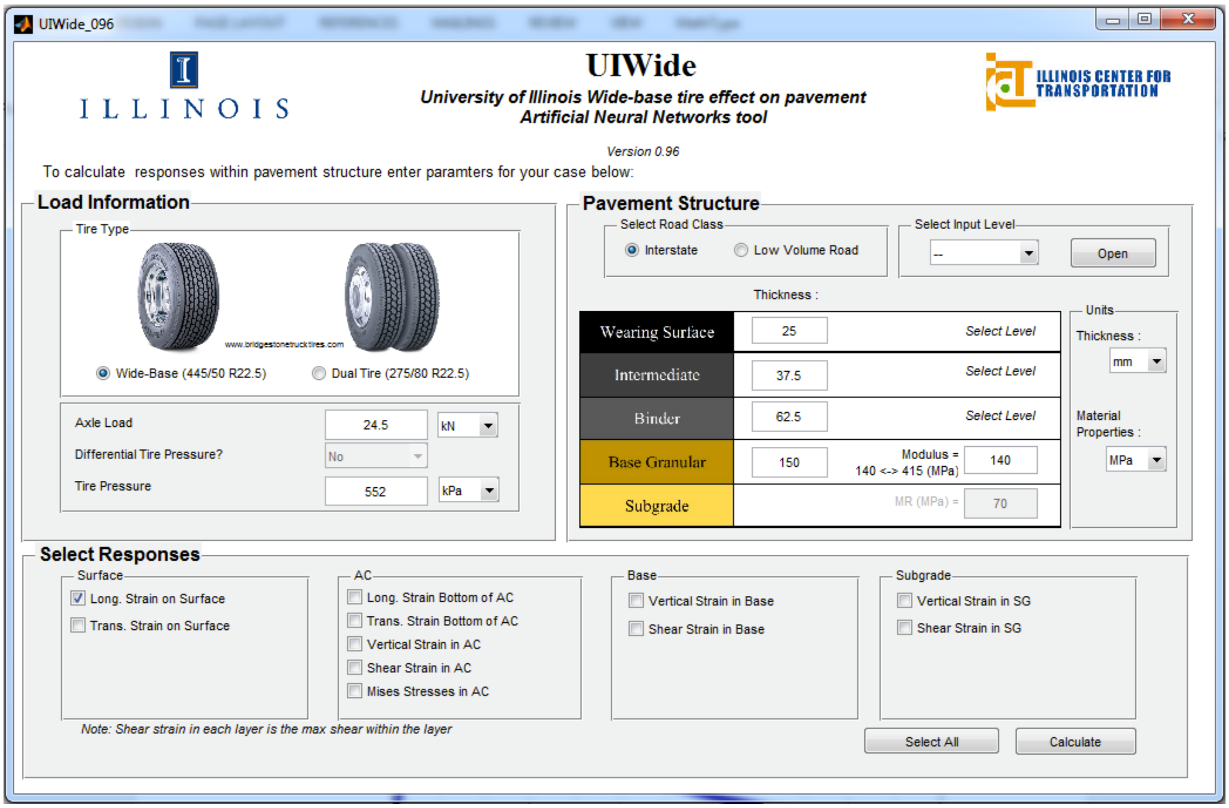

Figure 15. Snapshot of the UIWide ANN-based tool.

Based on the previous teleconference meeting, a summary of the comments provided by the technical panel is presented.

Table 1. Comments for the Artificial Neural Network Tool

Item #	Comment	How to Address	Status	Importance
1	Error: mail service not working	Mail server will be installed on the server and will be fixed in final version.	No	Important
2	Graph not plotting	There was a bug in the code and it has been fixed. Please report any future problems.	Yes	Important
3	Instrumentation plans not easily found	For each project, a separate instrumentation plan is included as a push button next to filters. This will be checked to ensure that it is working properly.	No	Good to have
4	Every file should be a PDF file	All documents will be converted to PDF in final version.	No	Good to have
5	Better header names in excel file for raw data	All the details are in the instrumentation plan. The excel files are raw data from each section without any modification.	Yes	Good to have
6	Two graphs side by side	It is a good-to-have this feature. This requires code changing and can lead to breaking of existing functionality.	Yes	Good to have
7	Admin username/ password change	There should be an admin account to help the developer debug issues. The password will be changed in the final release.	Yes	Important
8	Registration should send a confirmation link	Administrator has to give access to user. No need for this extra step as user will not access the database unless confirmed by admin.	Yes	Good to have

9	Captcha need to be placed	This will be available in next version.	No	Good to have
10	Domain name	When the final server to host the application is confirmed, domain name can be purchased.	Yes	Important
12	Legend unnecessary	This is a design decision. Although there is only one line in sensor, legend still highlights the selection of sensor.	No	Important
13	Automatic restart of services	During regular maintenance, server keeps on shutting down. Services never restart on its own.	Yes	Important
14	Download option for the graph	Download option was added to the charts.	Yes	Important
15	By default new users should be disabled	This is fixed. By default, any account created will be disabled. All admin will be notified by email whenever a new account is created. The admin then enables that account.	Yes	Important
16	More description of projects	Currently, every project has a concise description. For details, please refer to the reports published by corresponding agencies.	Yes	Good to have
17	Instrumentation plot better appear as in image	An instrumentation plan is provided in PDF by the agencies conducting the project (in case of old data). We prefer to adhere to that format.	Yes	Good to have
18	Good description of the test for all section and instrumentation	Same as comment #16	No	Important

19	No data coming for particular sensors	Option should be removed from the sensor list. This requires code change and will affect the latency with which the page opens.	Yes	Good to have
20	Ohio existing opens in the same tab	Refactor code to take care of the bug. This is fixed in the latest version.	Yes	Important
21	It is fun to change one parameter and see how that affects response	As long as the new parameter is within the filter range, it is possible to do so.	Yes	Good to have
22	In some cases no plot is available for a particular sensor	A warning is indicated in the user manual. This might be caused by the absence of data for that specific sensor and filter.	Yes	Good to have
23	Units in downloaded data excel	This will be addressed in final version.	No	Good to have

APPENDIX B

DISK-SHAPED COMPACT TENSTION TEST RESULTS

The DCT tests performed on all sections of Florida, Davis, and Ohio are completed and analyzed. Figure 16 shows a sample of the CMOD curve from the DCR test.

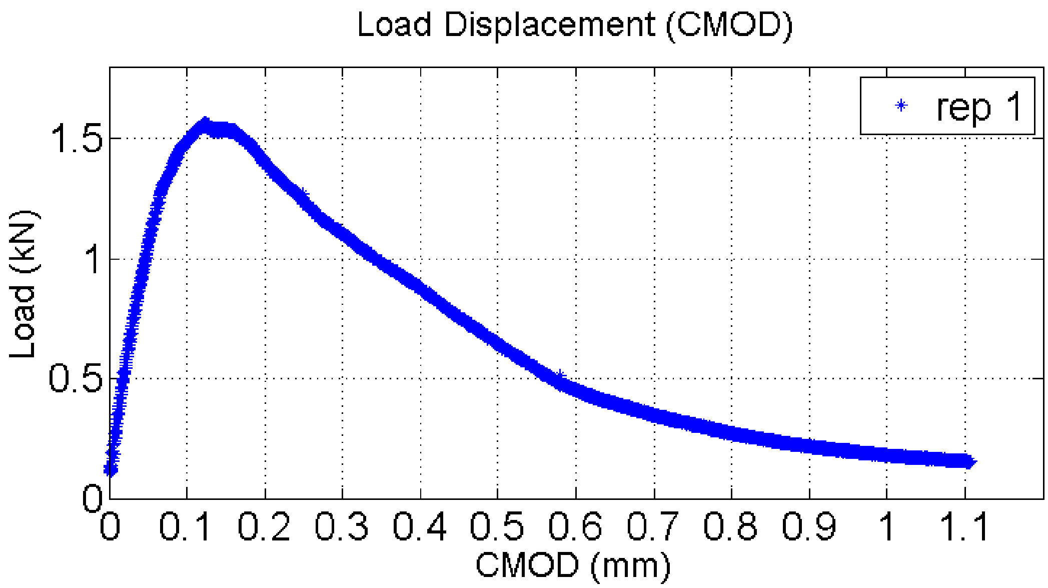

Figure 16. Sample SCB CMOD curve.

The fracture energies were calculated for specimens obtain3ed from all the test sections and corrected for thickness using the following equation [1]:

$$G_{f\_cor} = \frac{G_{f\_test}}{\left(0.313\ln\left(\frac{t}{50}\right)\right)+1.03}$$

where,

G_{f_cor} = thickness-corrected fracture energy

G_{f_test} = fracture energy without correction

t = thickness.

Table 2. Fracture Energy for Florida Specimens from DCT Test

Lift	Test Temp (C)	Average Ligament Length (mm)	Average Thickness (mm)	Average Corrected Fracture Area (N/m)
1in 4.75mm (PG 76-22)	-12	81.6	24.6	467.9
1.5 in SP12.5 (PG 76-22)	-12	81.6	36.4	705.8
1.5 in SP12.5 (PG 76-22)	-12	81.6	45.7	515.9

As indicated in Table 2, the resulting fracture energies of the bottom layers are higher than those of the surface layer, suggesting greater fracture resistance. The average difference in fracture energies between the top and bottom layers is 9.3%. Visual inspection of the specimens after testing showed that cracks propagated through large aggregates and traversed around smaller aggregates.

Table 3. Fracture Energy for UC-Davis Specimens from DCT Test

Lift	Test Temp (C)	Average Ligament Length (mm)	Average Thickness (mm)	Average Corrected Fracture Area (N/m)
60 mm HMA, 15% RAP	-6	81.7	51.5	566.3

Testing of the specimens obtained from UC-Davis produced good repeatability with a standard deviation of 7.4. The UC-Davis sections has 15% RAB. The addition of RAB did not adversely affect the mix fracture energy.

Table 4. Fracture Energy for Ohio Specimens from DCT Test

Lift	Test Temp (C)	Average Ligament Length (mm)	Average Thickness (mm)	Average Corrected Fracture Energy (N/m)
1in 4.75mm Surface (PG 76-22)	-12	86.3	50.9	409.2
2in 19mm INT (PG 64-28)	-18	81.3	51.2	281.9
6in 37.5mm ATB (PG 64-22)	-12	81.0	50.9	135.0 (2 out of 4 failed)
4in 37.5mm FRL(PG 64-22)	-12	81.3	51.3	270.5

Compared to the surface layer of the Ohio test section, the intermediate (INT) layer and Fatigue Resistant Layer (FRL) have relatively low fracture energies, which can be alluded to poor mix design. In addition, two out of four specimens from the Asphalt Treated Base (ATB) layer failed during testing. Visual inspection of the ATB specimens indicated that the failure is possibly caused by the presence of large aggregate size (37.5mm). In general, cracks propagated around the large aggregates, which means that mixes have low interfacial strength between aggregates and binder, whereas for the Florida and UC-Davis specimens, cracks usually penetrated through the aggregates.

REFERENCES

[1] Kim, M., Buttlar, W.G., Baek, J, and Al-Qadi, I.L. "Field and Laboratory Evaluation of Fracture Resistance of Illinois Hot-Mix Asphalt Overlay Mixtures." *Transportation Research Record: Journal of the Transportation Research Board*, No. 2127, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 146-154.