CAIT-UTC-NC21

Optimization of Pavement Surface Properties

FINAL REPORT
August 2015

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In cooperation with

Rutgers, The State University of New Jersey
And
Virginia Department of Transportation
And
U.S. Department of Transportation
Federal Highway Administration

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1. Report No. CAIT-UTC-NC21	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Optimization of Pavement Surface Properties**		5. Report Date August 2015
		6. Performing Organization Code Virginia Tech/ CAIT
TECHNICAL REPORT STANDARD TITLE PAGE 7. Author(s) Daniel E. Mogrovejo, Gerardo W. Flintsch, Samer W. Katicha, Edgar D. de León Izeppi, Kevin K. McGhee		8. Performing Organization Report No. CAIT-UTC-NC21
9. Performing Organization Name and Address Center for Sustainable Transportation Infrastructure 3500 Transportation Research Plaza Blacksburg, VA 24061		10. Work Unit No.
		11. Contract or Grant No. DTRT13-G-UTC28
12. Sponsoring Agency Name and Address Center for Advanced Infrastructure and Transportation Rutgers, The State University of New Jersey 100 Brett Road Piscataway, NJ 08854		13. Type of Report and Period Covered Final Report 06/01/14 - 08/31/15
		14. Sponsoring Agency Code

15. Supplementary Notes
U.S. Department of Transportation/OST-R
1200 New Jersey Avenue, SE
Washington, DC 20590-0001

16. Abstract
Adequate macrotexture characterization is an essential objective for transportation practitioners since primary pavement surface characteristics like friction, tire/pavement noise, splash and spray, and rolling resistance are significantly influenced by pavement macrotexture.

This study proposes an enhanced macrotexture characterization index based on the effective area for water evacuation (EAWE) that (a) better estimates the potential of the pavement to drain water, and (b) provides improved correlations with two pavement surface properties that are predominantly affected by macrotexture: friction and noise.

A three-step methodology is proposed to compute the index: (1) a procedure to remove the spikes from texture profile readings; (2) an enveloping profile calculation, which delimits the area between the tire and the pavement when contact occurs; and (3) a definition of the EAWE, which will be the index to characterize macrotexture.

Comparisons of current (MPD) and proposed (EAWE) macrotexture indices using 32 pavement sections confirmed that MPD overestimates the effective area for water evacuation between a tire and pavement surface. Results show that the proposed EAWE correlates better with tire-pavement friction and noise than the MPD does.

17. Key Words Macrotexture, Friction, Noise, Optimization, Surface properties		18. Distribution Statement	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 23	22. Price

Form DOT F 1700.7 (8-69)

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DESCRIPTION OF THE PROBLEM

Background

According to the International Organization for Standardization (ISO) 13473-5:2009, pavement texture is the "deviation of a pavement surface from a true planar surface with a texture wavelength λ less than 0.5 m. Surface deviations of wavelengths greater than 0.5 m are known as unevenness or roughness" (1). The World Road Association (PIARC) has established standard categories of texture (Microtexture, Macrotexture, Megatexture) and roughness (Unevenness), as well as their effects on pavement surface properties (2, 3). This categorization states that macrotexture is defined in the range of 0.5 mm < λ< 50 mm, and is likely the most influential category for most fundamental tire-pavement interactions (e.g., friction, tire/pavement noise, splash and spray, and rolling resistance).

The mean profile depth (MPD) index, calculated from Circular Track Meter (or Circular Texture Meter, CTMeter) measurements, has become widely accepted among practitioners for characterizing macrotexture. However, the CTMeter is a static device that is not suitable for network level measurements, and the MPD is an outdated method to characterize texture and can be improved.

More recently, new dynamic texture measurement methods (e.g. using High Frequency Laser Equipment [HFLE]) have developed with the objective of gathering more complete texture data and overcoming the limitations of the static test methods (time consuming, highly localized results, requires traffic control, etc.) (4-6). These devices achieve high resolution at highway speeds; however, two problems remain to be solved: a) most of the methods still report MPD, and b) standard procedures for dynamic methods are still not yet available.

MPD is a very crude approximation of the void area (or volume) between the tire and the pavement (texture). More realistic approaches to characterize macrotexture that take into account the interaction between the tire and the pavement, have been proposed. This interaction results in enveloping profiles (representing the actual profile of the tire when it rolls over the pavement surface) that have been shown to better take into account the effect pavement macrotexture on other pavement surface characteristics such as tire-pavement noise and rolling resistance (7-9).

The Virginia Tech Transportation Institute (VTTI) considered several of these models with the goal of applying the enveloping profile to macrotexture characterization rather than to texture–noise and texture–rolling resistance modeling. Three models were revised and evaluated: the Clapp's envelopment procedure based on a physical model that consists of evaluating the contact between a rigid body and a semi-infinite elastic body (8); the INRETS model based on calculation of vertical displacement of the border of an elastic medium under the influence of a vertical force (8, 10); and the von Meier model based on a mathematical-mechanistic approach based on the mathematical limitation of the second-order derivative of the discretized texture sample (8, 9, 11). This last model was selected for macrotexture characterization due to its versatility and customizable settings (as detailed in the methodology section of this paper).

PROBLEM STATEMENT

The CTMeter and other static methods for characterizing texture (e.g., the volumetric test method – ASTM E965) do not lend themselves for comprehensive or network level testing (12). There is a need for a better method to characterize pavement macrotexture, such as the VTTI method (4). By definition, MPD is calculated using the peaks in a high resolution profile, and thus the resulting index may not represent the actual potential of the pavement to drain water, which may be the most desired safety feature of the pavement. The use of an improved index is proposed in this study and detailed following.

OBJECTIVE

The objective of this study is to propose a better macrotexture characterization index based on the Effective Area for Water Evacuation (EAWE) that provides stronger correlations with pavement surface properties affected by macrotexture (tire-pavement friction and noise).

APPROACH

Sites

Thirty-two road sections were selected for this study, covering most of the asphalt types used in Virginia, including dense-, gap-, and open-graded mixes, as well as combinations of different aggregate sizes, binders, and rubber modification.

Twelve of the thirty-two sections were selected from the Virginia Smart Road, a 2.2-mile, controlled-access test track, located at the Virginia Smart Road in Blacksburg, Virginia *(13)*. Figure 1 shows an aerial view of the Virginia Smart Road, with pictures of the chosen sections and their details. The remaining 20 sections were chosen from three demonstration projects of the Virginia Quiet Pavement Implementation Program (VQPIP). These projects are located on State Route 199 west of Williamsburg, State Route 286 in Fairfax, and on State Route 288 near Chester (*14*). Figure 2 shows the locations and surface characteristics of these sections.

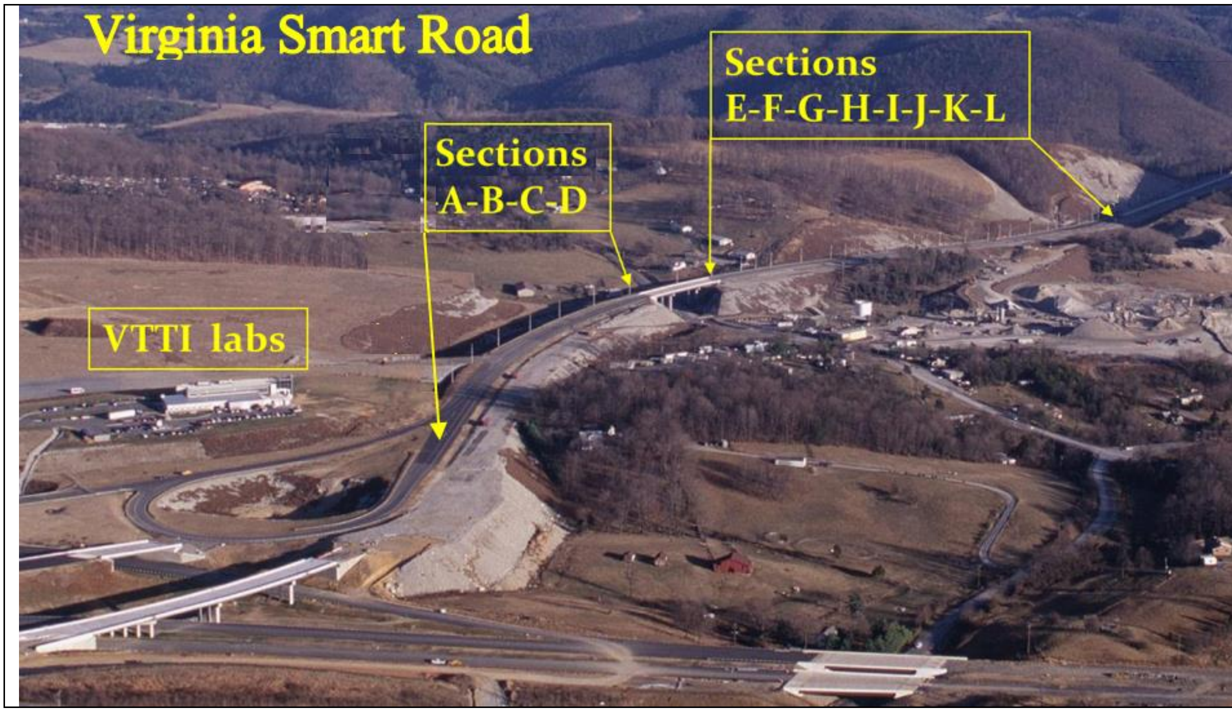
Equipment

Measurements for macrotexture, friction, and noise were performed to determine the effect of macrotexture on the other two properties.

For texture measurements, two different sets of data were collected: (a) static measurements using the CTMeter, and (b) dynamic measurements using a high-speed laser device (HSLD) that provided the data to be used for deriving both MPD and the proposed index based on the EAWE.

Two CTMeter devices (Figure 3a) were used for the Smart Road measurement to evaluate the repeatability. The measurements and analysis were made according to ASTM E2157 *(15)*. Before performing the measurements, the proper functioning of the two devices was checked with a manufacturer provided calibration plate. For the VQPIP sections, one CTMeter was used.

One HSLD (Figure 3b) capable of collecting measurements at different speeds (between 25 and 65 mph [40 and 105 km/h]) was used to gather the dynamic measurements on all sites (Smart Road and VQPIP sections). This HSLD uses a laser spot with a diameter of 0.2 mm and a sampling frequency of 64 kHz *(4, 5)*; more information about this device can be found in the Selcom Optocator User's Manual *(16)*.



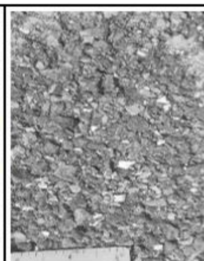
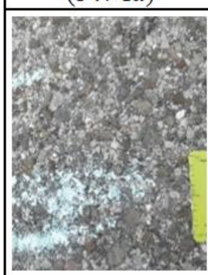
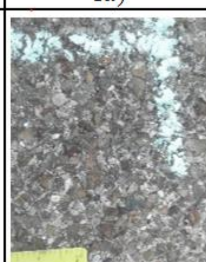
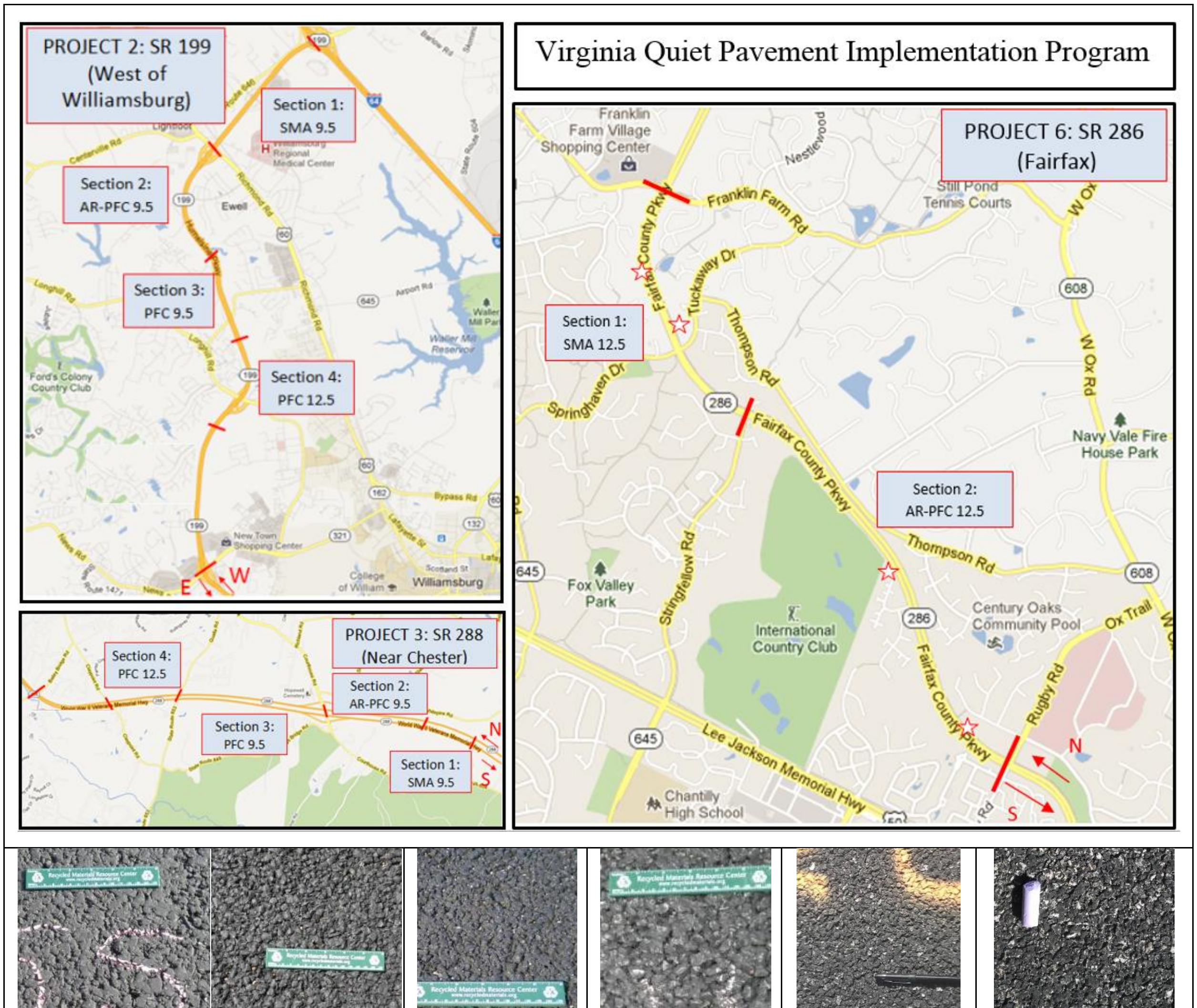
					
A–SMA-12.5D PG 70-22 Section length: 106 m (347 ft.)	B–SM-9.5D PG 70-22 Section length: 88 m (289 ft.)	C–SM-9.5E PG 76-22 Section length: 89 m (292 ft.)	D–SM-9.5A PG 64-22 Section length: 124 m (407 ft.)	E–SM-9.5D PG 70-22 Section length: 82 m (268 ft.)	F–SM-9.5D PG 70-22 Section length: 92 m (302 ft.)
					
G-SM-9.5D PG 70-22 Section length: 93 m (304 ft.)	H-SM-9.5D PG 70-22 Section length: 89 m (292 ft.)	I–SM-9.5A PG 64-22 Section length: 103 m (338 ft.)	J–SM-9.5D PG 70-22 Section length: 85 m (280 ft.)	K–OGFC PG 76-22 Section length: 92 m (302 ft.)	L–SMA-12.5D PG 70-22 Section length: 99 m (326 ft.)

FIGURE 1 Smart Road test sections.



SMA 9.5 Stone matrix asphalt pavement, PG: 76-22, 1.5" thick, maximum aggregate size: 9.5 mm, 165 lbs./sy	AR-PFC 9.5 Asphalt rubber – porous friction course, 1" thick, maximum aggregate size: 9.5 mm, 90 lbs./sy	PFC 9.5 Porous friction course, PG: 70-28, 1" thick, maximum aggregate size: 9.5 mm, 90 lbs./sy	PFC 12.5 Porous friction course, PG: 70-28, 1.5" thick, maximum aggregate size: 12.5 mm 180 lbs./sy in SR-199, 135 lbs./sy in SR-288	SMA 12.5 Stone matrix asphalt pavement, PG: 76-22, maximum aggregate size: 12.5 mm	AR-PFC 12.5 Asphalt rubber – porous friction course, maximum aggregate size: 12.5 mm
Section names:					
SR-199 SMA 9.5 – E SR-199 SMA 9.5 – W SR-288 SMA 9.5 – N SR-288 SMA 9.5 – S	SR-199 AR-PFC 9.5 – E SR-199 AR-PFC 9.5 – W SR-288 AR-PFC 9.5 – N SR-288 AR-PFC 9.5 – S	SR-199 PFC 9.5 – E SR-199 PFC 9.5 – W SR-288 PFC 9.5 – N SR-288 PFC 9.5 – S	SR-199 PFC 12.5 – E SR-199 PFC 12.5 – W SR-288 PFC 12.5 – N SR-288 PFC 12.5 – S	SR-286 SMA 12.5 – N SR-286 SMA 12.5 – S	SR-286 AR-PFC 12.5 – N SR-286 AR-PFC 12.5 – S

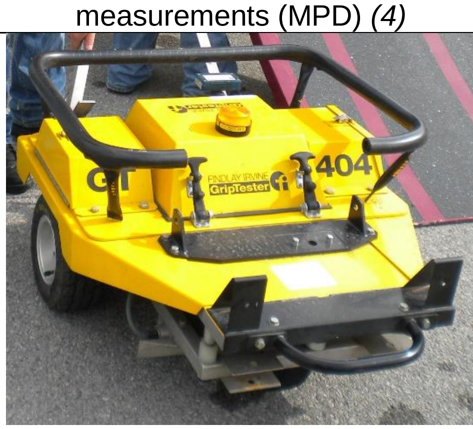
FIGURE 2 VQPIP test sections.

A GripTester device was used for friction measurements (Figure 3c). The GripTester, which conforms to ASTM Standard E2340, operates at a constant slip of 16%.

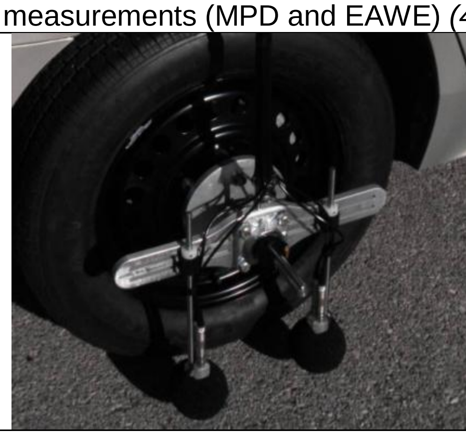
Tire/pavement noise was measured following the American Association of State Highway and Transportation Officials (AASHTO) standard TP 76-12, “Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method” *(17)*. VTTI’s OBSI equipment (shown in Figure 3d) was used for all sites *(18)*.

(a) CTMeter devices for static macrotexture measurements (MPD) *(4)*

(b) HSLD for dynamic macrotexture measurements (MPD and EAWE) *(4)*



(c) GripTester device for slip friction measurements



(d) OBSI for tire/pavement noise measurements *(18)*

FIGURE 3 Equipment used for the analysis.

Field Data Collection

The following measurements were made using the CTMeter, HSLD, GripTester, and OBSI:

- ✓ **CTMeter –** At least 10 measurements with each CTMeter were performed for each section on the Smart Road. For the VQPIP sections, at least five measurements for each section (e.g., SMA 9.5), in each direction (e.g., northbound/southbound), and for each location (e.g., SR-199), were performed. A lower number of measurements was collected on the VQPIP sections to minimize traffic disruption (these sections are open to traffic unlike the Smart Road Sections which are on a closed facility).

- ✓ **HSLD –** Ten runs at 50 mph (80.5 km/h) were performed on the Smart Road sections and three runs (at the same speed) on the VQPIP sections (giving a total of 180 runs to analyze). Although the data were collected at a frequency of 64 kHz the analysis used measurements at 0.5 mm intervals. A de-spiking procedure was performed prior to calculating the MPD and determining the enveloping profile used to calculate the EAWE–based index.
- ✓ **GripTester** –12 repeat GripTester runs were made on the Smart Road sections and three were performed on each VQPIP project. Testing was performed at 40 mph and data collected every 3 feet along the section.
- ✓ **OBSI –** Tire/pavement measurements on the Virginia Smart Road were performed as follows: 2 valid runs for Section K (minimum number of valid runs according to AASHTO standard TP 76-12), 3 valid runs over Sections L and A, 5 valid runs over Section B, and 7 valid runs over Sections E, F, G, and H. In the case of the VQPIP sections, at least 3 valid runs were performed for each section. A run was considered valid if it met all four criteria stated in the standard for coherence, pressure-intensity (PI) index, direction of the sound intensity vector, and standard deviation. Detailed information about this validation can be found in Mogrovejo et al. (14).

Calculating the Proposed Index Based on EAWE

An improved pavement surface texture index, the EAWE index (in mm^2) is proposed in this study. The index is computed following these three steps:
1) Remove the spikes from the raw HSLD data;
2) Calculate the enveloping profile, which is the profile that the tire creates when in contact with the surface of the pavement, and
3) Calculate the effective depth for water evacuation (EDWE) from which the EAWE index is derived.

Step 1. Spike Removal from HSLD Measurements

It is widely known that all HSLD measurements have "noise" in the data in the form of spikes that *must* be removed before any further analysis *(4, 5, 19)*. A spike-removal method developed by the authors and published elsewhere *(4),* was applied to the gathered raw data.

The spike-removal method basically consists of a two-step algorithm. First, the algorithm determines the distribution of texture measurements (after high-pass filtering of the raw data for slope removal) by using the family of Generalized Gaussian Distributions (GGDs), which allows for the tail of the distribution to be heavier or thinner than the normal distribution. Second, the algorithm uses the False Discovery Rate (FDR) method to adaptively determine a threshold used to identify the spikes. The FDR controls the average proportion of wrongly identified spikes among all identified spikes.

Step 2. Enveloping Profile Calculation

The enveloping procedure developed by von Meier, van Blokland, and Descornet was chosen because the mathematical–empirical model takes into account the tire stiffness (a required feature for comparison of the EAWE and MPD as explained and depicted in the results that follow). This procedure limits (or reduces) the second-order derivative of the profile to a given limit value, *d**, which is a measure for the elasticity of the tire rubber expressed in mm/mm^2 (or mm^{-1}). Von Meier et al. determined empirical values for d* from measurements of the deformation of a tire pressed onto various idealized profiles made of steel rods with different diameters and spacing; in their work, enveloping profiles with *d** values of 0.1, 0.054, 0.027 are presented *(20)*.

A revised version of the von Meier et al. model (including “form” corrections made by Goubert *(7)* and restructured by VTTI to fit MATLAB codification) was used in this study. The corrected and restructured model is diagrammed in Figure 4.

Step 3. Effective Area and Effective Depth for Water (and/or Air) Evacuation

The proposed index EAWE (in mm^2), represents the area between the resulting tire enveloping profile and the actual pavement texture profile when tire/pavement contact occurs.
EAWE (in mm^2) can be reported in three different ways:

1. As a vector of values $\widehat{EAWE}$, which means one value for every data point in the profile. This vector is arranged as follows:

$$\widehat{EAWE} = [EAWE_1\,, EAWE_2, \dots, EAWE_i, \dots, EAWE_n] \qquad \text{Eq. 1}$$

Where:

n is the number of data points in the texture profile, and

$$EAWE_i = \left(\frac{b_i + b_{i+1}}{2} * h\right) \qquad \text{Eq. 2}$$

Where:

b_i is the difference of the *i*th data point in the enveloping profile minus the *i*th data point in the original pavement profile,

h = 0.5 mm, which is the spacing between data points in the profiles.

2. As a vector of accumulated values with base length 100 mm ($\widehat{EAWE}_{100}$), which means one value for every 100 mm (every 200 data points) in the profile. The 100 mm base length was chosen to be consisted with MPD base length when analyzed with the HSLD, and thus allow point-by-point comparison of the 2 indices. This vector is arranged as follows

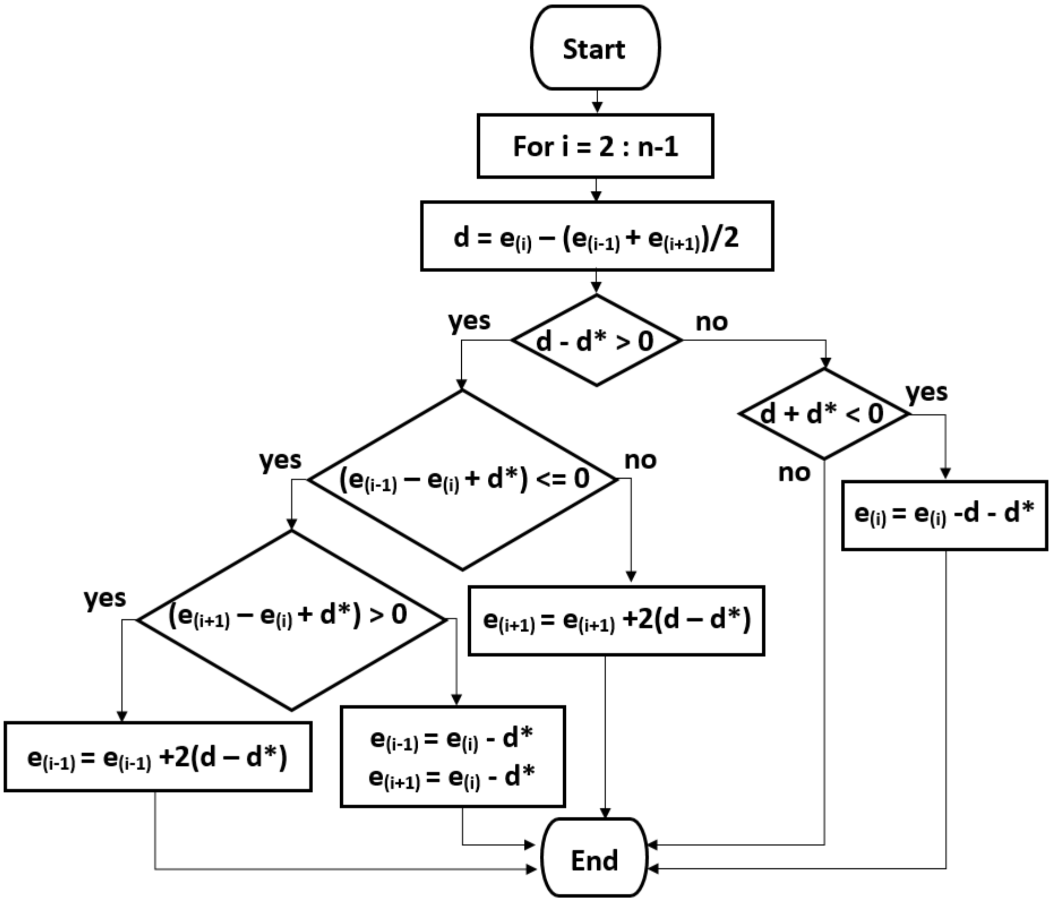
$$\widehat{EAWE}_{100} = \left[EAWE_{100_1}, EAWE_{100_2}, \dots, EAWE_{100_m}\right] \qquad \text{Eq. 3}$$

Where:

$$EAWE_{100_1} = \sum_{j=1}^{200} EAWE_j\,, EAWE_{100_2} = \sum_{j=201}^{400} EAWE_j\,, \dots, EAWE_{100_m} = \sum_{j=n-199}^{n} EAWE_j \qquad \text{Eq. 4}$$

3. As a scalar value (EAWE), which means a single average value with a 100-mm baseline that represents the whole section, calculated as follows:

$$EAWE = \frac{\sum_{j=1}^{m} EAWE_{100_j}}{m} \qquad \text{Eq. 5}$$



Where:

n = number of data points from the original pavement texture profile obtained with the HSLD
*d** = given maximum value (e.g. d* = 0.054 mm/mm^2) representing the elasticity of the tire rubber
d = changing aid variable
e = resulting enveloping profile (vector)

FIGURE 4 Diagram for enveloping profile calculation.

Finally, the correspondent Effective Depth for Water Evacuation (EDWE, in mm) is defined and can be reported as a scalar value (*EDWE*), which means a single average value with a 100-mm baseline that represents the whole section, calculated as follows:

$$EDWE = \frac{EAWE}{100} \qquad \text{Eq. 6}$$

The vector representations of EAWE allow every single location in the section to be analyzed (for example, to find significant variation of texture, section changes, critical spots [relatively low EAWE], etc.).

Results

Step 1. Spike Removal

A snapshot of the beginning of a randomly-selected section is presented in Figure 5 showing the original measurements and the measurements after spike removal.

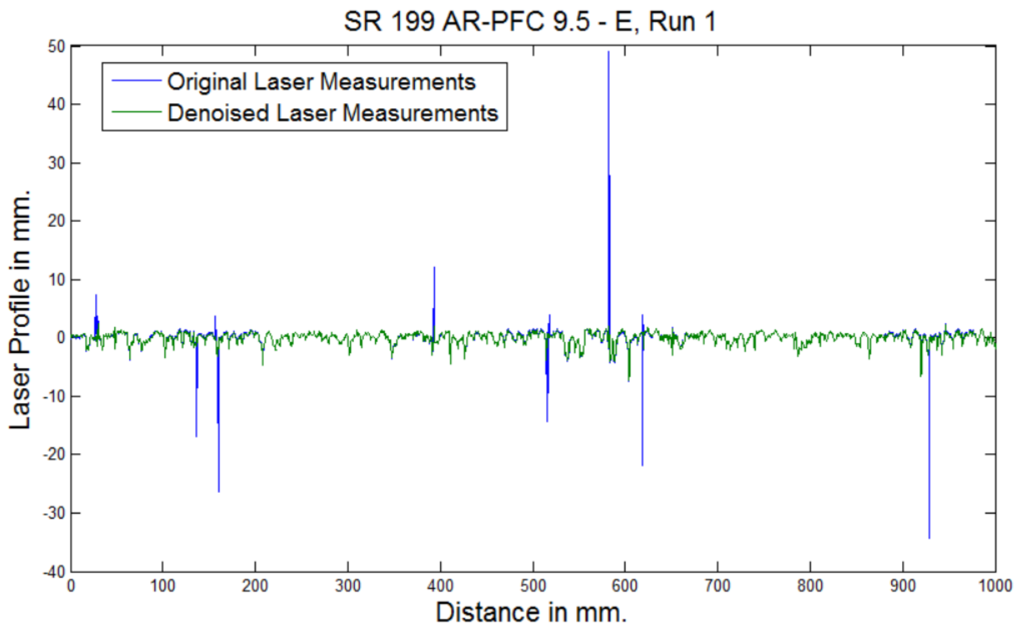


FIGURE 5 HSLD Measurements, with and without spikes (1st meter of Section B-SM-9.5D).

Step 2. Enveloping Profile Calculation

The enveloping profile analysis was performed for all 180 denoised profiles using four different *d** values; 0.054, 0.027, 0.01, 0.001), which can be related to medium soft, medium hard, stiff, and very stiff tires, respectively. Since we are interested in the pavement macrotexture, rather than the geometric properties of the tire, a smooth tire is assumed in this study. Examples of the resulting enveloping profiles, for different tire stiffnesses, are presented in Figure 6 and Figure 7. As expected, the higher the tire stiffness (e.g. smaller the *d** values), the higher the EAWE.

Step 3. EAWE and EDWE Calculation

Since the MPD is calculated as the average of the peak levels on each half of the baseline profile minus the average level (which means using the peaks by definition), then MPD is believed to overestimate the EAWE that the pavement may have.

To that point Figure 8 illustrates how Mean Profile Depth (MPD) overestimates the ability of the pavement to evacuate water, since these mean depths (function of the peaks) are higher in magnitude than the average effective depth of the resulting area between the tire and the pavement as represented by EDWE.

A sensitivity analysis (varying tire stiffness) confirms that the MPD models the area similarly to EAWE only when relatively little tire rubber deformation is allowed, which is not what really happens. That is, the EDWE index tends to compare with MPD in magnitude only when a relatively small *d** value of 0.001 is used (theoretically representing a significantly stiff tire).

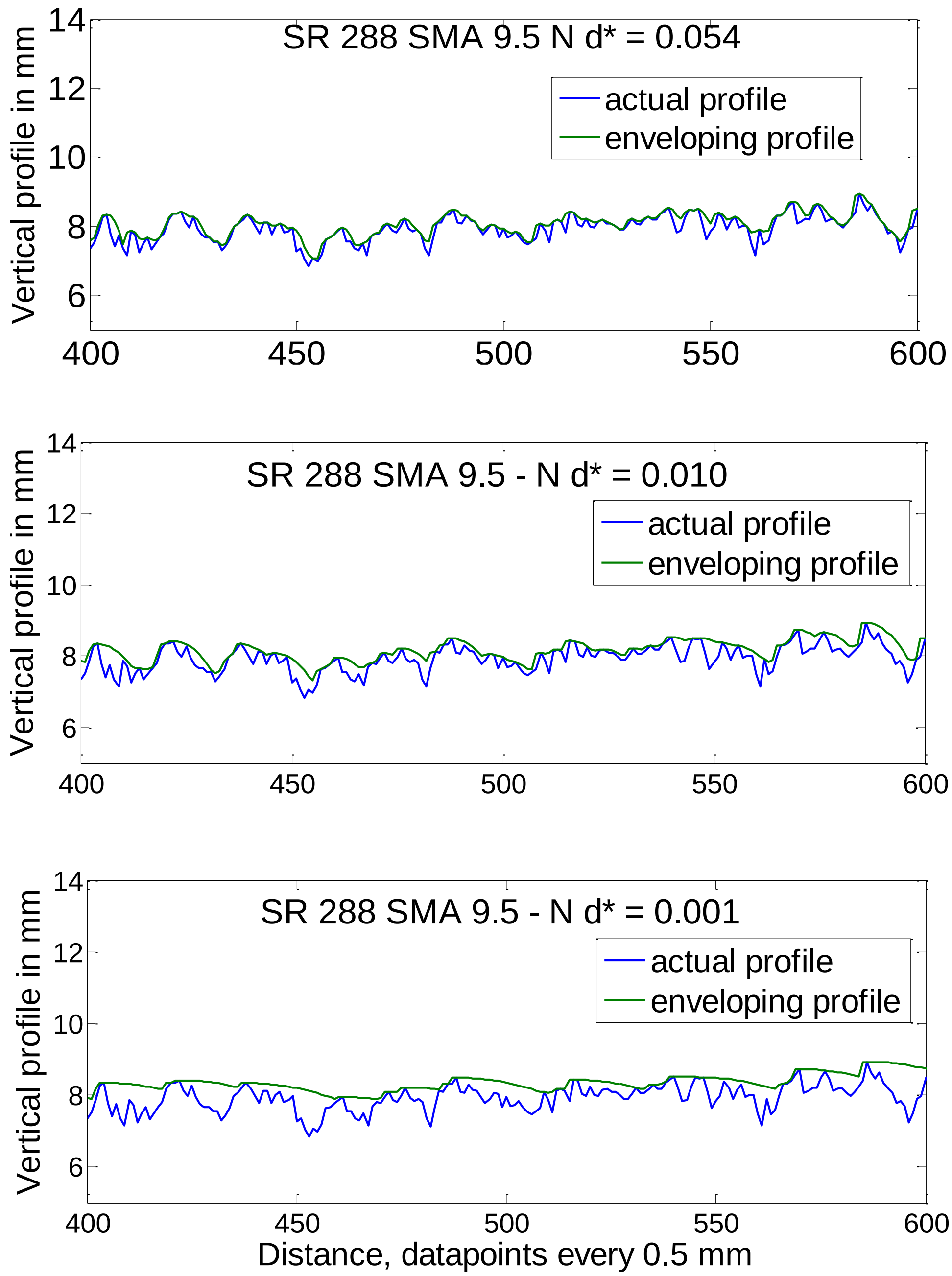


FIGURE 6 Enveloping profile illustration calculated for different tire stiffnesses for a gap-graded asphalt mix (e.g., 100 mm for Section SR-288 SMA 9.5 N).

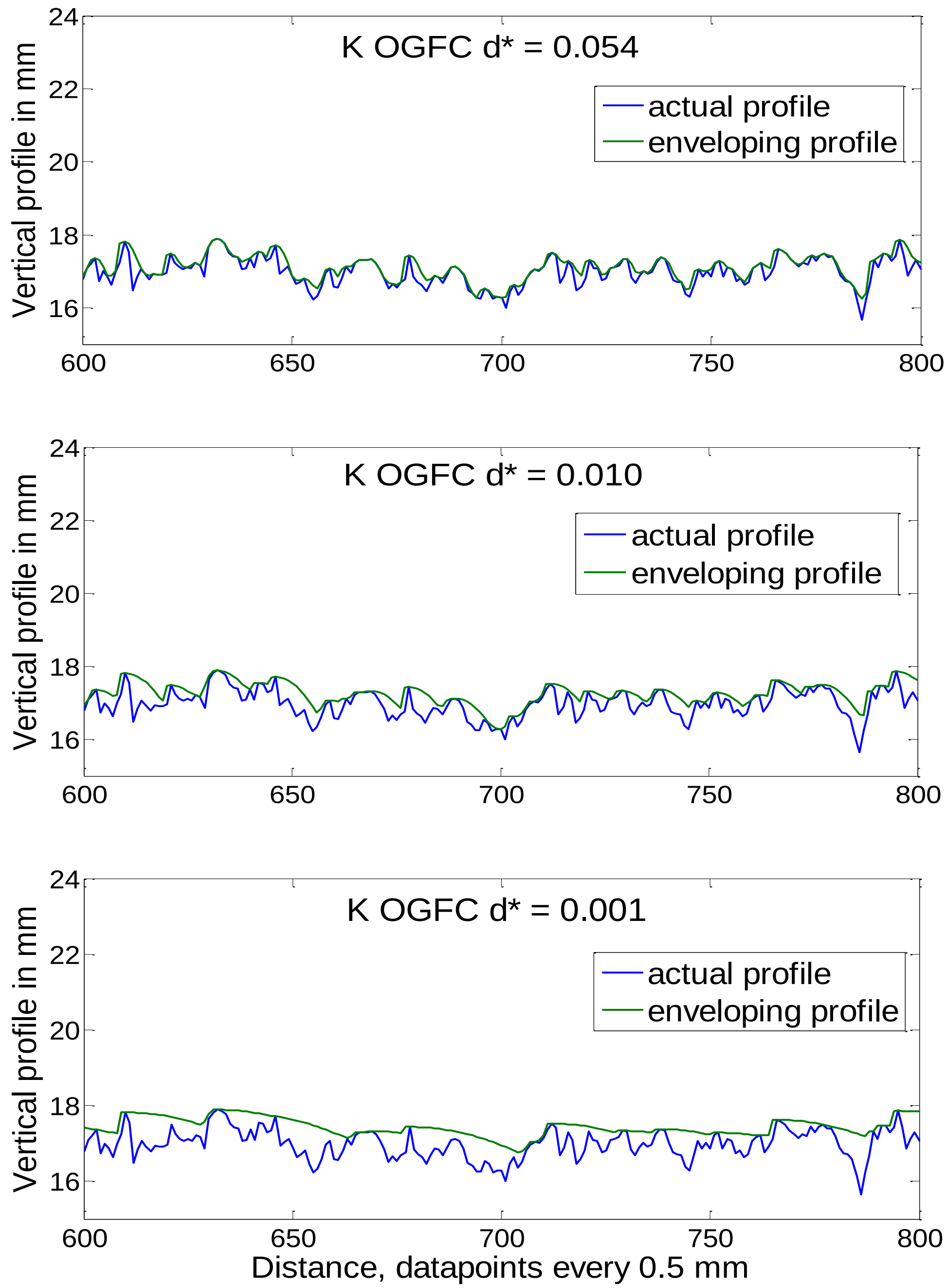


FIGURE 7 Enveloping profile illustration calculated for different tire stiffnesses for a porous asphalt mix (e.g., 100 mm for Section K - OGFC).

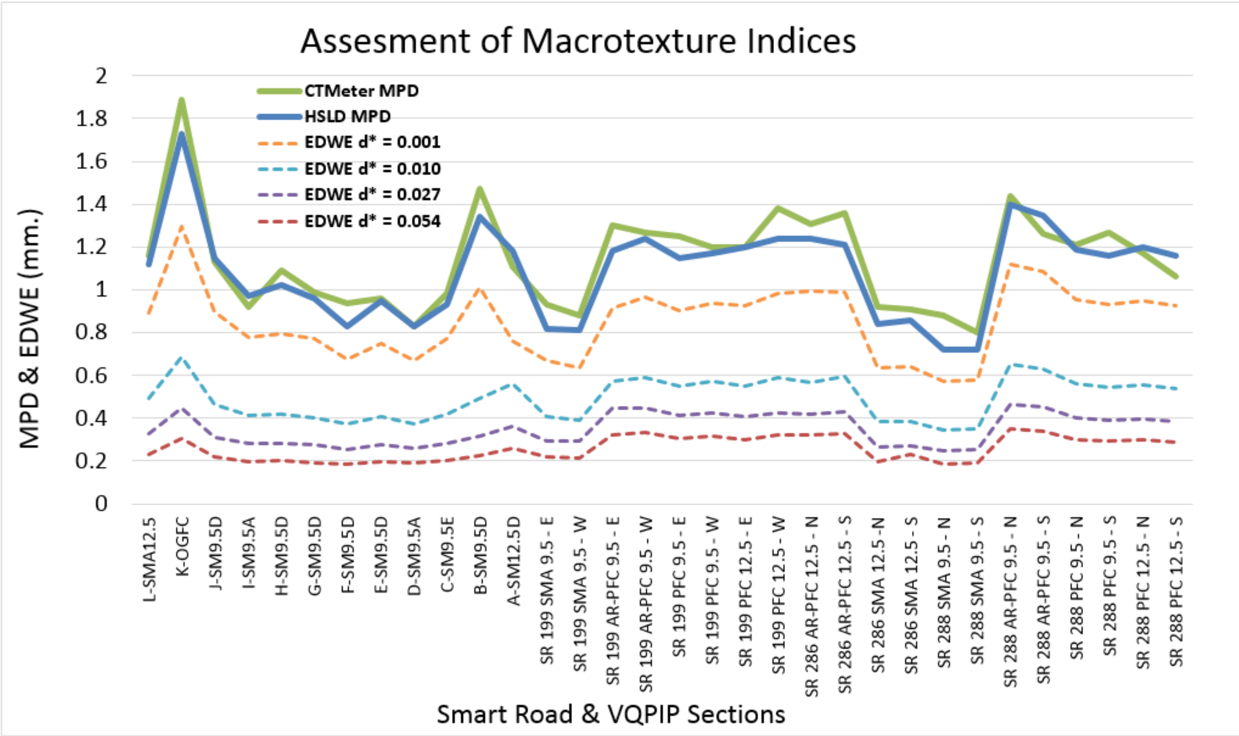


FIGURE 8 Comparison of macrotexture characterization indices.

TABLE 1 summarizes summarizes the macrotexture, friction (GripTester), and tire-pavement noise (OBSI) data. It represents 340 CTMeter runs for texture (CTMeter-MPD); 180 HSLD runs for texture (HSLD-MPD); 720 HSLD runs for texture (EAWE); 204 GripTester runs for friction (grip number [GN]); and 101 OBSI runs for noise (intensity level [IL]).

For both the CTMeter and the HSLD, the correlations with friction and tire/pavement noise, which are two pavement surface characteristics that are heavily influenced by macrotexture *(2, 3)*, improve when using the EAWE instead of MPD for all tire stiffnesses. Figure 9 and Figure 10 show that EAWE, being a more realistic representation of the texture, correlates better with these pavement characteristics than MPD.

TABLE 1 Summary of Texture, Friction, and Noise Indices

Sections	Macrotexture										Friction	Noise
	MPD (mm)		EAWE (mm) for varying d*				EDWE (mm) for varying d*				GN	IL
	CTMeter	HSLD	0.054	0.027	0.010	0.001	0.054	0.027	0.010	0.001		dBA
L-SMA12.5	1.16	1.12	23.29	33.09	49.14	89.33	0.23	0.33	0.49	0.89	0.53	101.1
K-OGFC	1.89	1.73	30.54	44.56	68.43	129.49	0.31	0.45	0.68	1.29		99.7
J-SM9.5D	1.13	1.15	21.92	31.30	46.52	89.85	0.22	0.31	0.47	0.90	0.57	
I-SM9.5A	0.92	0.97	19.72	28.14	41.34	77.78	0.20	0.28	0.41	0.78	0.66	
H-SM9.5D	1.09	1.02	20.00	28.34	41.75	79.58	0.20	0.28	0.42	0.80		102.3
G-SM9.5D	0.99	0.96	19.15	27.44	40.40	77.07	0.19	0.27	0.40	0.77		102.3
F-SM9.5D	0.94	0.83	18.42	25.65	37.10	67.40	0.18	0.26	0.37	0.67		102.3
E-SM9.5D	0.96	0.95	19.72	27.86	40.73	74.95	0.20	0.28	0.41	0.75		102.3
D-SM9.5A	0.83	0.83	18.98	26.09	37.59	66.83	0.19	0.26	0.38	0.67	0.52	
C-SM9.5E	0.98	0.93	20.47	28.41	42.00	77.35	0.20	0.28	0.42	0.77	0.56	
B-SM9.5D	1.47	1.34	22.53	31.80	49.59	100.88	0.23	0.32	0.50	1.01	0.67	101.1
A-SM12.5D	1.11	1.18	25.89	36.32	56.38	75.82	0.26	0.36	0.56	0.76	0.61	100.7
SR 199 SMA 9.5 - E	0.93	0.82	21.85	29.43	40.62	67.25	0.22	0.29	0.41	0.67	0.65	102
SR 199 SMA 9.5 - W	0.88	0.81	21.30	29.18	39.33	63.62	0.21	0.29	0.39	0.64	0.64	102.2
SR 199 AR-PFC 9.5 - E	1.3	1.18	32.06	44.75	57.38	91.31	0.32	0.45	0.57	0.91	0.72	99.2
SR 199 AR-PFC 9.5 - W	1.27	1.24	33.34	44.87	58.89	96.59	0.33	0.45	0.59	0.97		99.3
SR 199 PFC 9.5 - E	1.25	1.15	30.56	41.60	55.08	90.43	0.31	0.42	0.55	0.90	0.73	
SR 199 PFC 9.5 - W	1.2	1.17	31.58	42.56	57.41	94.00	0.32	0.43	0.57	0.94	0.68	100.1
SR 199 PFC 12.5 - E	1.2	1.2	30.20	40.72	54.97	92.36	0.30	0.41	0.55	0.92	0.67	
SR 199 PFC 12.5 - W	1.38	1.24	32.08	42.51	58.84	98.31	0.32	0.43	0.59	0.98	0.68	100.9
SR 286 AR-PFC 12.5 - N	1.31	1.24	31.98	42.06	56.74	99.33	0.32	0.42	0.57	0.99		98.7
SR 286 AR-PFC 12.5 - S	1.36	1.21	32.94	43.18	59.54	98.90	0.33	0.43	0.60	0.99	0.68	97.5
SR 286 SMA 12.5 -N	0.92	0.84	19.68	26.51	38.66	63.32	0.20	0.27	0.39	0.63	0.67	103.1
SR 286 SMA 12.5 - S	0.91	0.86	23.06	26.91	38.77	64.28	0.23	0.27	0.39	0.64	0.62	103.2
SR 288 SMA 9.5 - N	0.88	0.72	18.60	24.89	34.32	57.51	0.19	0.25	0.34	0.58	0.66	103.3
SR 288 SMA 9.5 - S	0.8	0.72	18.89	25.30	34.94	58.09	0.19	0.25	0.35	0.58	0.60	103
SR 288 AR-PFC 9.5 - N	1.44	1.4	35.10	46.46	65.28	111.98	0.35	0.46	0.65	1.12	0.67	100.9
SR 288 AR-PFC 9.5 - S	1.26	1.35	33.88	45.22	63.21	108.40	0.34	0.45	0.63	1.08	0.70	101.2
SR 288 PFC 9.5 - N	1.21	1.19	30.17	40.10	56.14	95.18	0.30	0.40	0.56	0.95	0.69	101.7
SR 288 PFC 9.5 - S	1.27	1.16	29.35	39.00	54.60	93.03	0.29	0.39	0.55	0.93	0.67	102.2
SR 288 PFC 12.5 - N	1.17	1.2	30.06	39.86	55.65	94.84	0.30	0.40	0.56	0.95	0.70	101.2
SR 288 PFC 12.5 - S	1.06	1.16	28.98	38.53	53.96	92.65	0.29	0.39	0.54	0.93	0.64	100.6

*Empty spaces: data not collected due to different circumstances.

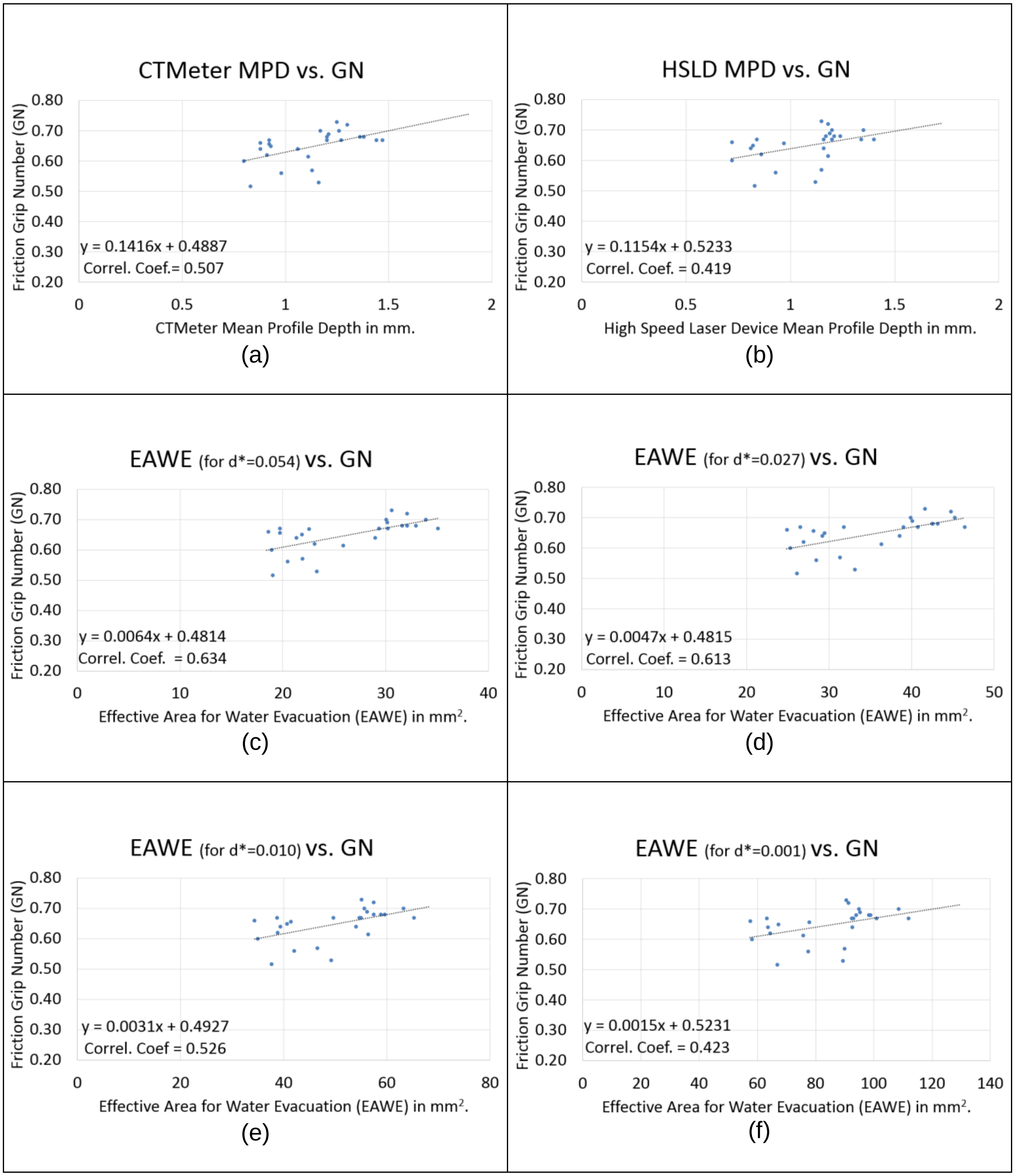


FIGURE 9 Macrotexture vs. friction - correlations.

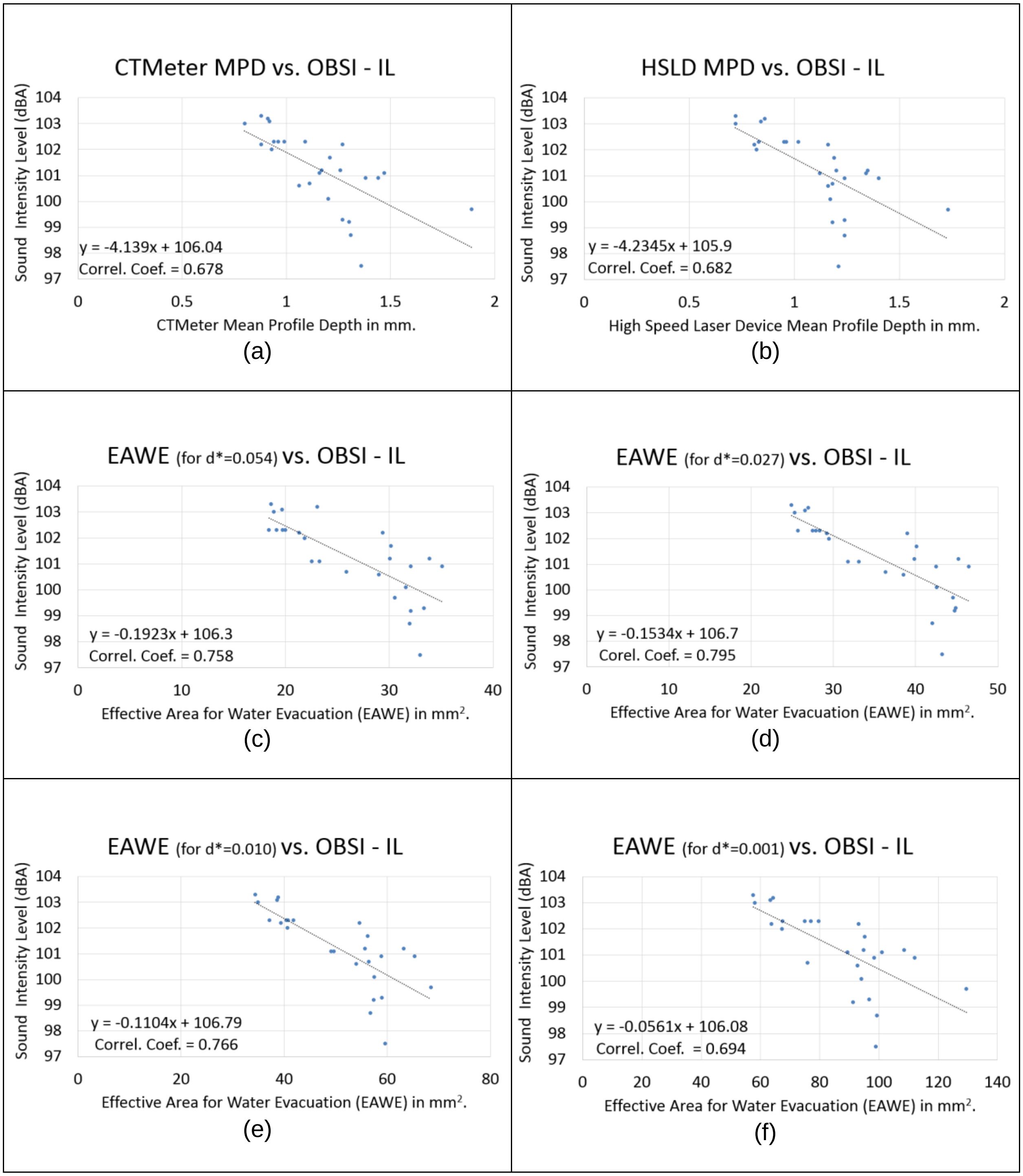


FIGURE 10 Macrotexture vs. noise - correlations.

The corresponding correlation coefficients are calculated and summarized in Table 2. The correlation between the EAWE and friction or EAWE and noise changes depending on *d**. For a very low values of *d** EAWE becomes similar to MPD (see Figure 8) which explains why the correlations are reduced and similar to the correlations obtained with the MPD. This confirms the fact that characterizing macrotexture in the "peaks" range (as MPD does by definition) is not the best approach.

TABLE 2 Goodness of Correlations for All Comparisons

Indices		Correlation Coefficient	
		Friction	**Noise**
MPD (mm)	CTMeter	0.507	0.678
	HSLD	0.419	0.682
EDWE (mm)	d* = 0.054	**0.634**	**0.758**
	d* = 0.027	**0.613**	**0.795**
	d* = 0.01	**0.526**	**0.766**
	d* = 0.001	**0.423**	**0.694**

DISCUSSION

A high proportion of the tested sections with high macrotexture are open-graded asphalt mixes. These surfaces achieve high macrotexture with "negative" features and interconnected voids, which absorb some of the noise generated at the tire-pavement interface. Properties of the dataset therefore create a confounding effect that likely leads to the strong positive correlation between macrotexture and noise. Macrotexture created by strong "positive" features (e.g., chipseals) would be expected to correlate in an opposite fashion with noise.

By definition, MPD is an index that is heavily weighted by 2 data points in every 100 mm base-length (the highest peak for each 50 mm half base-length). It is therefore roughly equivalent to 2 stages of a rigid and flat tire only making contact in the two highest peaks; thus, the corresponding predicted area (voids between the tire and the pavement) is too large. On the other hand, the EAWE takes into account all data points (not just the 2 peaks every 100mm) along the whole tire-pavement contact area. It also better predicts the tire rubber deformation over the pavement profile and leads to a better estimation of the actual area between the tire and the pavement that is available to drain water. In this interpretation, the MPD is a very simplistic model when compared with EAWE. Consequently, the use of the proposed EAWE index is recommended.

CONCLUSIONS

The following conclusions can be drawn from the results:

- ✓ The EAWE index for characterizing pavement macrotexture appears to represent a significant improvement to the MPD.
- ✓ A comprehensive comparison between MPD and EAWE (with different tire configurations) involving different asphalt sections confirmed that MPD effectively overestimates the ability of the pavement to drain water under a real tire.

- ✓ The macrotexture values computed using the EAWE (for all tire stiffnesses tested) instead of MPD (calculated using either the CTMeter or HSLD) correlate better with friction and noise measurements.

The use of a continuous HSLD to measure texture, and the consequent possibility of presenting macrotexture data for every single location along the analyzed section, also represents a significant improvement for macrotexture characterization. This feature may represent an important step toward more useful macrotexture characterization, not just at the project level but also at the network level.

RECOMMENDATIONS

The positive (but improved) correlation between macrotexture and noise is expected to be a function of the surface types that were included in this study. Future work should include more "positively" textured, non-porous materials to better understand (and characterize) not just how much, but in what way water drains under real tires.

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