THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

High-Definition Field Texture Measurements for Predicting Pavement Friction

Presented at the 98th Annual Meeting of the Transportation Research Board, Washington, DC, January 2019.

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January 15th, 2019

Cite as:
Zuniga-Garcia, N., and J.A. Prozzi. High-Definition Field Texture Measurements for Predicting Pavement Friction. Transportation Research Record, 2673(1), 246–260. https://doi.org/10.1177/0361198118821598.

Outline

- Introduction
- Methodology
- Statistical Analysis
- Results and Discussion
- Conclusions

Introduction

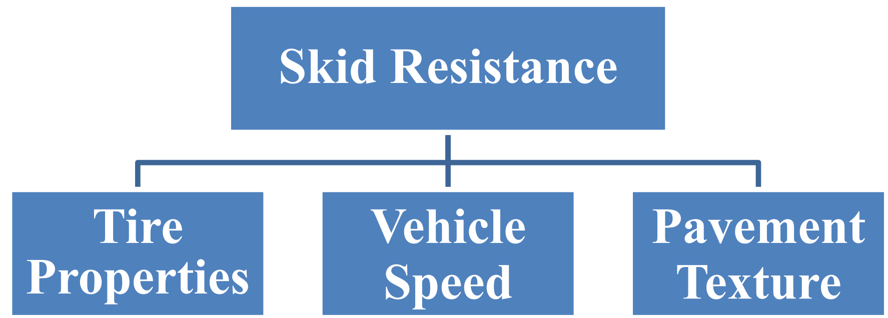
Motivation

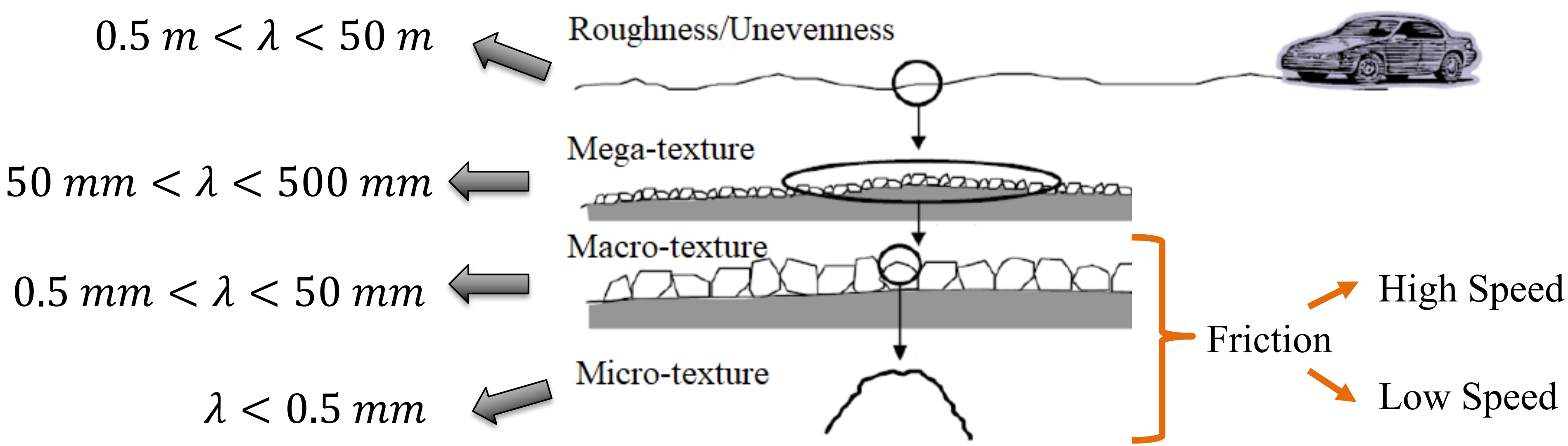
- Monitoring and managing **skid resistance** properties are crucial activities to reduce the number of highway accidents and fatalities.
- Current methodologies to measure pavement surface friction present several disadvantages that make them impractical.
- It is necessary to evaluate alternative methods to estimate friction.

Introduction

Skid resistance is the ability of the traveled surface to prevent the loss of tire traction.

- **Macrotexture:** Aggregate particles size and arrangement.
- **Microtexture:** Aggregate particles texture and mineralogy.





Introduction

Objective

Investigate the effect of different **texture** components and their parametric description on the **skid resistance** of a pavement surface.

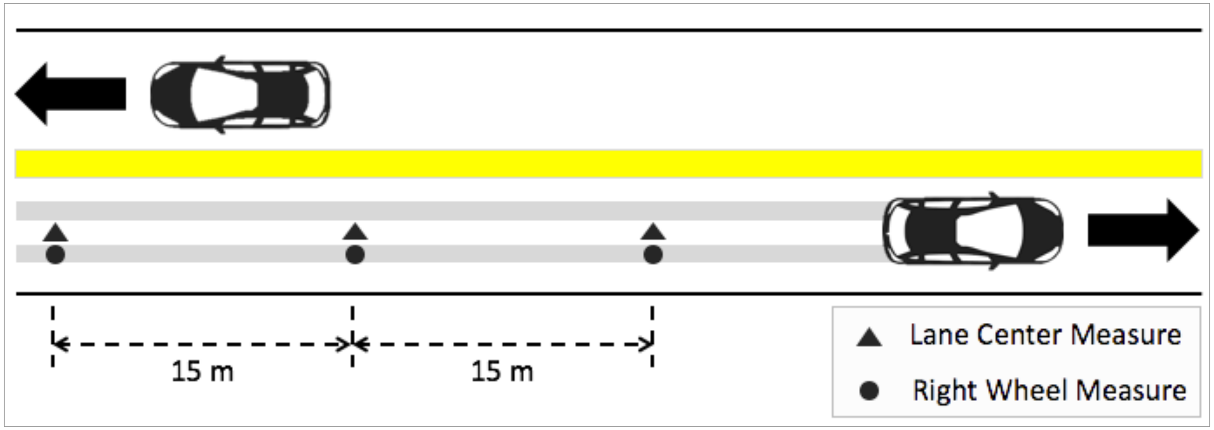
Contributions

1. Evaluation of the effect of predicting skid resistance using both macrotexture and microtexture.
2. Quantification of different macrotexture and microtexture parameters.
3. Evaluation of texture and friction characteristic of different surface types.

Methodology

Data Collection

- Measurements of friction and texture in the Texas highway network using different tests methods.
- Test sections included a broad range of friction coefficients and texture characteristics.
- Total number of field samples was twenty-four.
- Sampling: three different measurements at each section, with a separation of 15 m.



Methodology

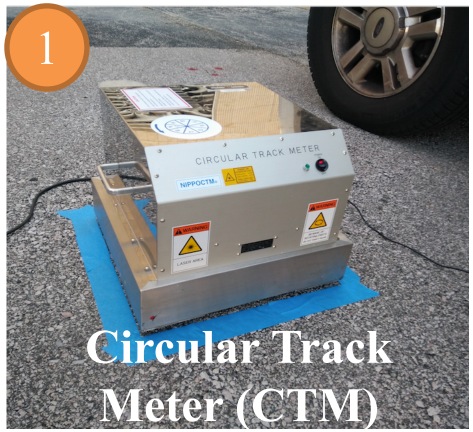
Friction and Skid Resistance

1 British Pendulum Test (BPT) ~10 km/h

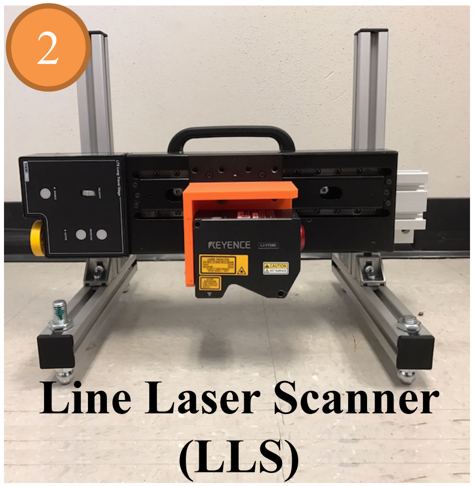
2 Dynamic Friction Test (DFT) 10 to 80 km/h

3 Micro-GripTester ~ 2.5 km/h

Texture



1 Circular Track Meter (CTM)

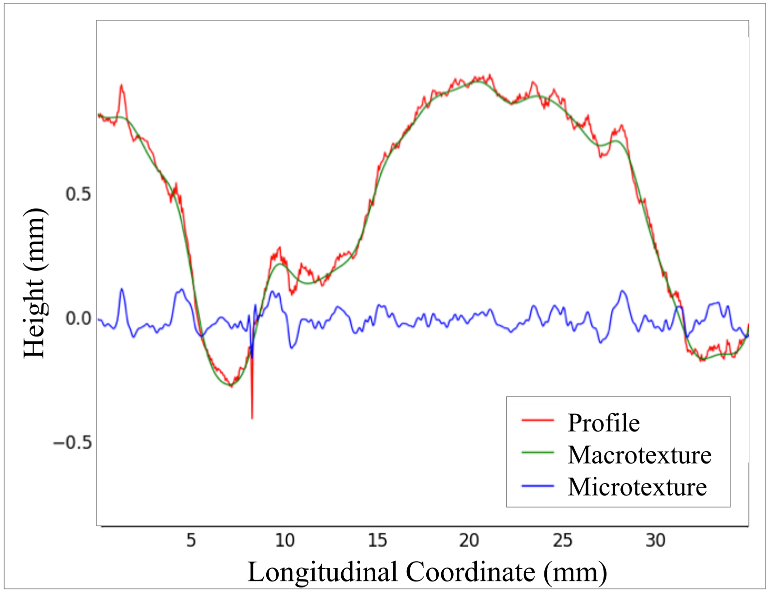


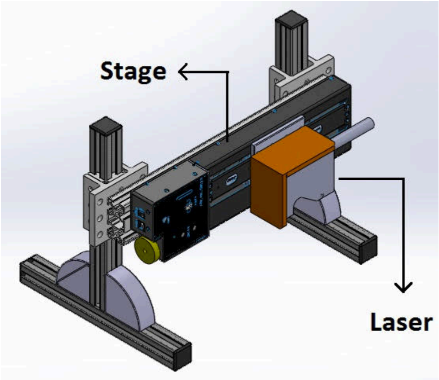
2 Line Laser Scanner (LLS)

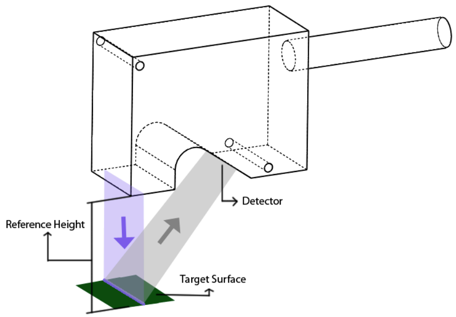
Methodology

Line Laser Scanner (LLS) Implementation

- Two-dimensional non-contact laser sensor.
- A prototype, called LLS, was developed to enable the laser to travel and capture three-dimensional data.
- Captures small changes in the height due to the texture irregularities.
- The sampling rate used is 8 µm, and the total covered area is 120 x 3.26 mm.



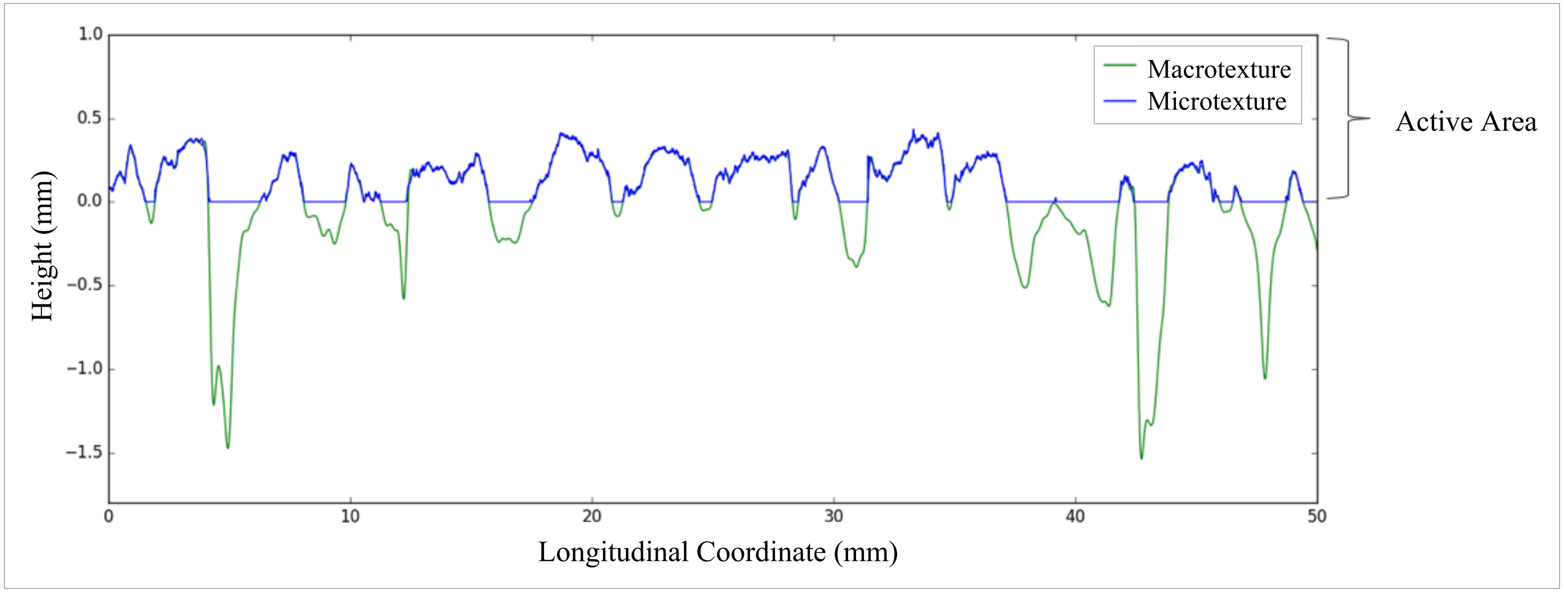




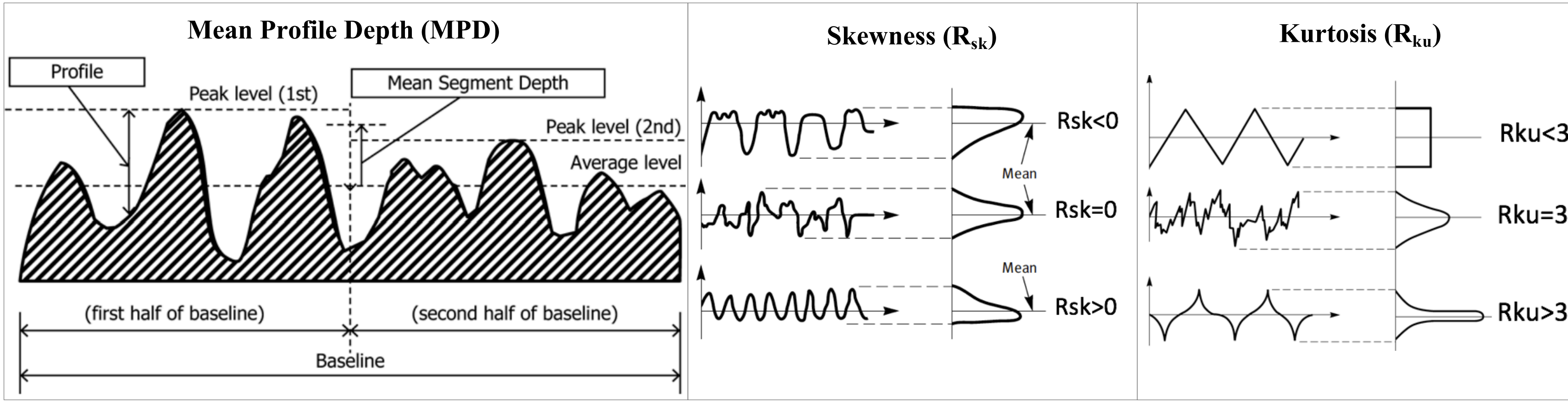
Methodology

LLS Texture Characterization

- Macrotexture baseline: 100 mm | Microtexture baseline: 1.0 mm.
- Microtexture characterization only to the contact (active) area.
- Profiles were characterized using different parameters for the macrotexture and the microtexture, independently.



LLS Texture Characterization

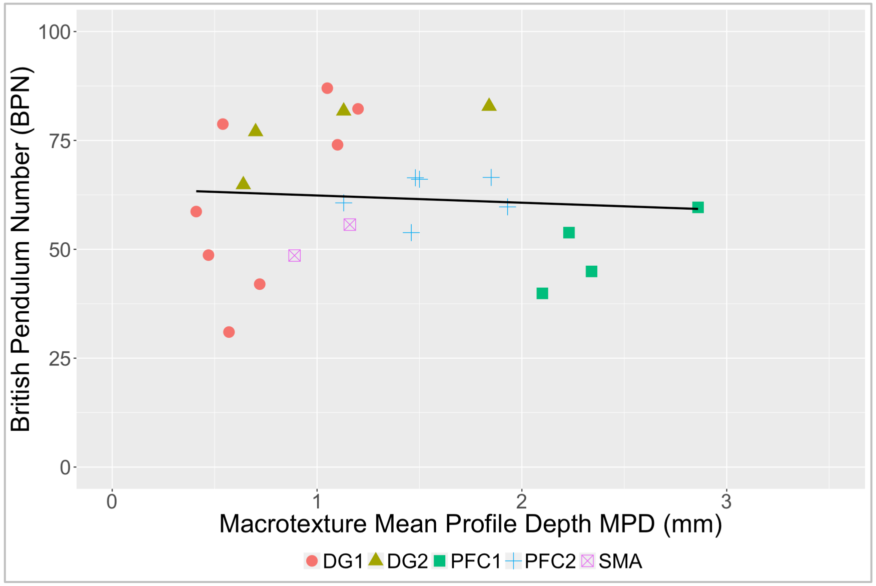


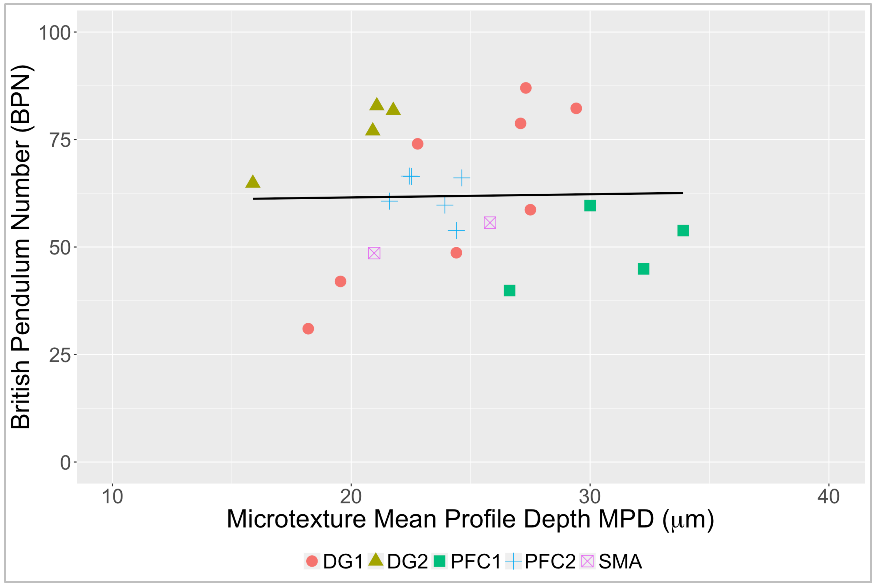
Amplitude	
Mean Profile Depth (MPD)	$MPD = \frac{1}{2}\left[\max\left(h_1,..,h_{N/2}\right) + \max\left(h_{N/2+1},..,h_N\right)\right]$
Height Average (R_a)	$R_a = \frac{1}{N}\sum_{i=1}^{N}\lvert h_i\rvert$
Maximum Height (R_z)	$R_z = \max(h_i) - \min(h_i),\ \ i = 1..N$
Root Mean Square (RMS)	$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} h_i^2}$
Skewness (R_{sk})	$R_{sk} = \frac{1}{RMS^3}\sqrt{\frac{1}{N}\sum_{i=1}^{N} h_i^3}$
Kurtosis (R_{ku})	$R_{ku} = \frac{1}{RMS^4}\sqrt{\frac{1}{N}\sum_{i=1}^{N} h_i^4}$
Hybrid	
Two Points Slope Variance (SV_{2pts})	$SV_{2pts} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{h_{i+1}+h_i}{\Delta x}\right)^2}$
Six Points Slope Variance (SV_{6pts})	$SV_{6pts} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{h_{i+3}-9*h_{i+2}+45*h_{i+1}-45*h_{i-1}+9*h_{i-2}-h_{i-3}}{60*\Delta x}\right)^2}$

Where, h_i = height value for coordinate "i"; N = number of coordinates; and Δx = horizontal distance between coordinates.

Statistical Analysis

- Simple linear regression (SLR) analysis cannot be used for the purpose of modeling friction based on the available texture data.
- A better relation was found when accounting also for the surface type.
- A **panel data analysis** was proposed.
- Incorporates the use of multiple regression analysis (MRA).

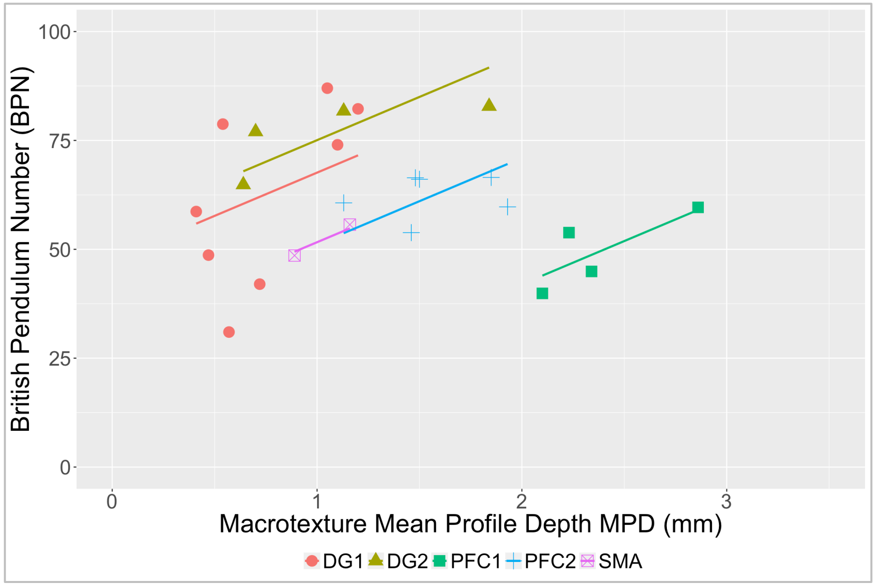


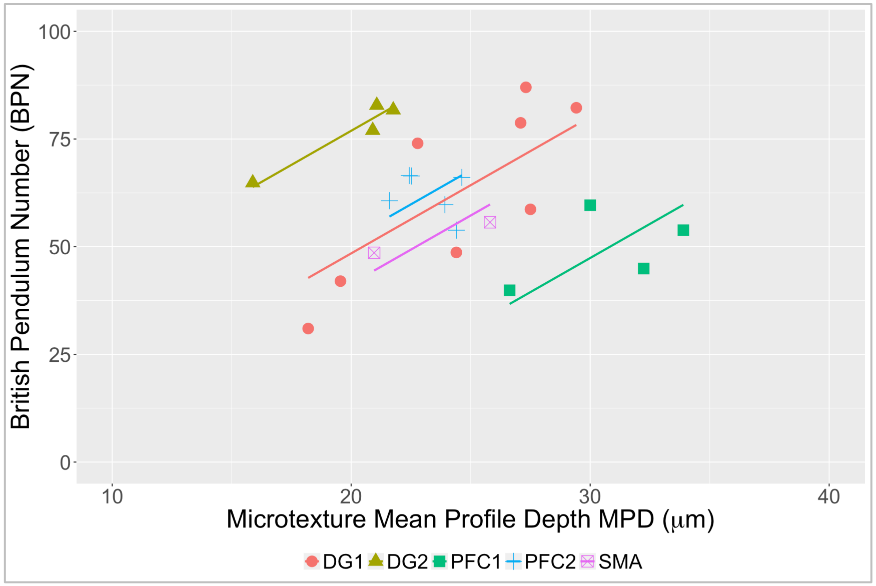


Statistical Analysis

We aggregated the samples by surface type and conformed five different HMA homogeneous groups.

- Type 1 (PFC1): Porous friction course 1
- Type 2 (PFC2): Porous friction course 2 and Novachip
- Type 3 (DG1): Dense-graded Type C
- Type 4 (DG2): Dense-graded Types D and F
- Type 5 (SMA): Stone matrix asphalt Type C



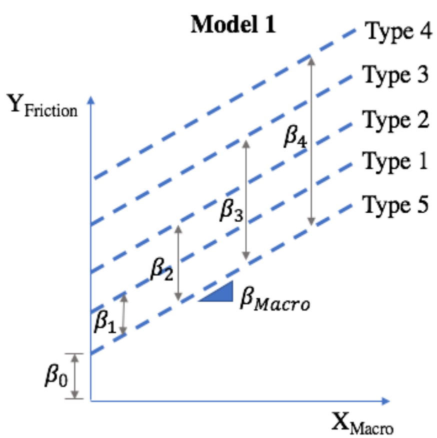


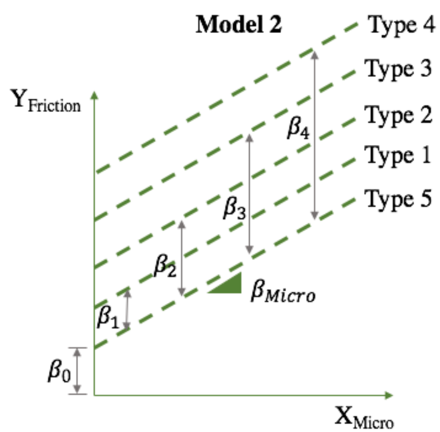
Statistical Analysis

Friction Models

- We proposed three friction models to evaluate the texture effect on friction.
- The **fixed-effect model** considers heterogeneity across surface-type groups and keeps "fixed" (holds constant) the average effect of the texture.

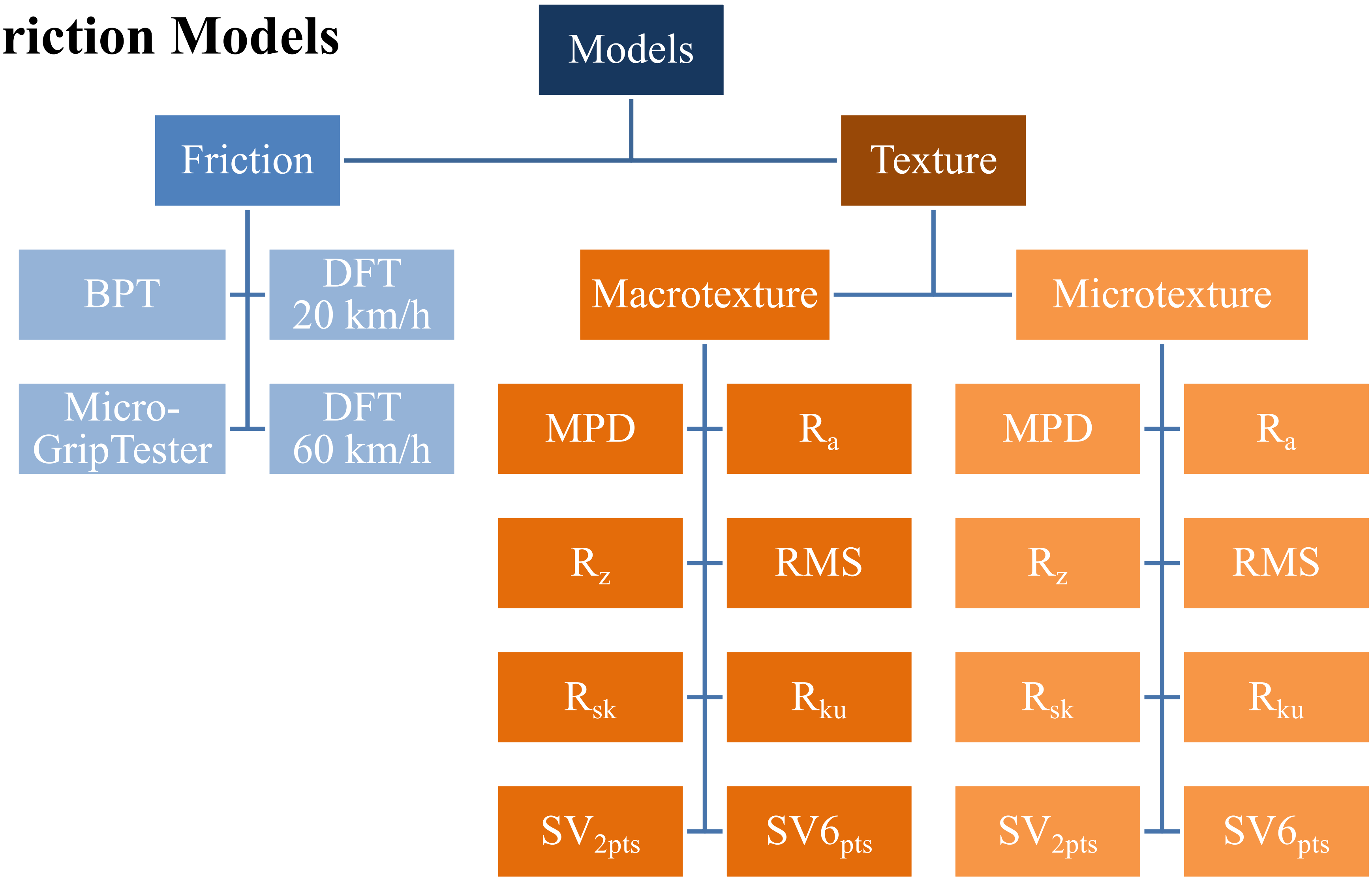
Model 1 (macrotexture only)	$Y_{Fr} = \beta_0 + \beta_{Macro} X_{Macro} + \sum_{i=i}^{4} \beta_i X_{Type\ i}$ (1)
Model 2 (microtexture only)	$Y_{Fr} = \beta_0 + \beta_{Micro} X_{Micro} + \sum_{i=i}^{4} \beta_i X_{Type\ i}$ (2)
Model 3 (macro and micro)	$Y_{Fr} = \beta_0 + \beta_{Macro} X_{Macro} + \beta_{Micro} X_{Micro} + \sum_{i=i}^{4} \beta_i X_{Type\ i}$ (3)





Statistical Analysis

Friction Models



Results

- Confidence level selected was 95%, i.e., a significance level $\alpha=0.05$
- H_0: $\beta_i = 0$ and H_a: $\beta_i \neq 0$
- Fail to reject the null hypothesis if $|t\text{-stat}| < |1.96|$ and/or p-value > 0.05

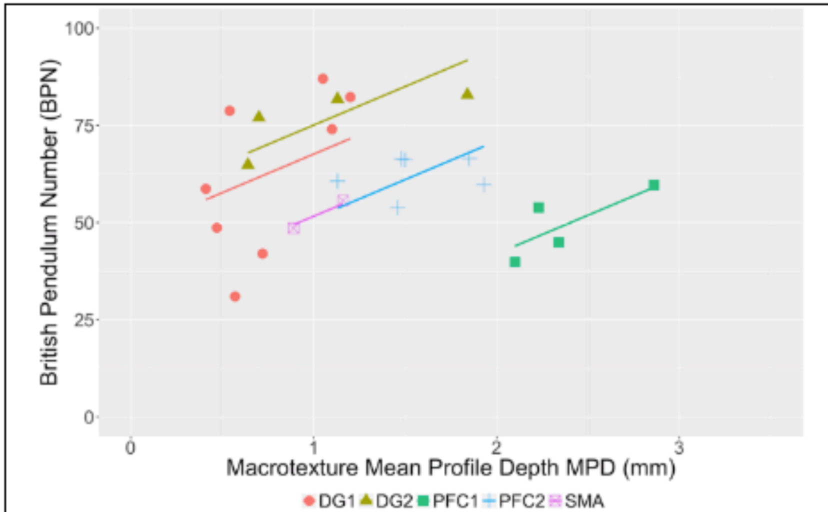
Using the MPD as Texture Parametric Description

Friction Model	**Friction Measure**											
	British Pendulum Number (BPN)			Grip Number (GN)			Dynamic Friction Test 20 km/h (DFT20)			Dynamic Friction Test 60 km/h (DFT60)		
	$\boldsymbol{\beta}$	t-stat (p-value)	R^2_{adj}	$\boldsymbol{\beta}$	t-stat (p-value)	R^2_{adj}	$\boldsymbol{\beta}$	t-stat (p-value)	R^2_{adj}	$\boldsymbol{\beta}$	t-stat (p-value)	R^2_{adj}
Texture parameter: Mean profile depth (MPD)												
1-Macro	$\boldsymbol{\beta}_{macro}$	2.533 (0.021)	0.357	$\boldsymbol{\beta}_{macro}$	1.709 (0.106)*	0.338	$\boldsymbol{\beta}_{macro}$	2.602 (0.018)	0.733	$\boldsymbol{\beta}_{macro}$	2.786 (0.012)	0.609
2-Micro	$\boldsymbol{\beta}_{micro}$	4.397 (0.000)	0.579	$\boldsymbol{\beta}_{micro}$	3.491 (0.003)	0.548	$\boldsymbol{\beta}_{micro}$	3.479 (0.003)	0.780	$\boldsymbol{\beta}_{micro}$	4.472 (0.000)	0.735
3-Macro & Micro	$\boldsymbol{\beta}_{macro}$	2.135 (0.048)	0.649	$\boldsymbol{\beta}_{macro}$	1.047 (0.310)*	0.551	$\boldsymbol{\beta}_{macro}$	2.136 (0.048)	0.816	$\boldsymbol{\beta}_{macro}$	2.487 (0.024)	0.794
	$\boldsymbol{\beta}_{micro}$	3.996 (0.001)		$\boldsymbol{\beta}_{micro}$	3.008 (0.008)		$\boldsymbol{\beta}_{micro}$	3.034 (0.007)		$\boldsymbol{\beta}_{micro}$	4.148 (0.000)	

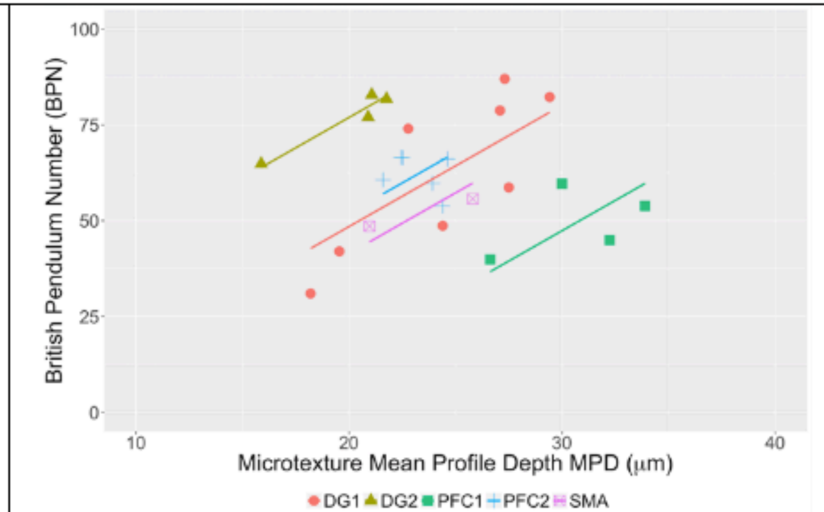
* Note: the marked t-statistic and p-values represent the conditions of failing to reject the null hypothesis (|t-stat|<|1.96| and/or p-value>0.05).

Results

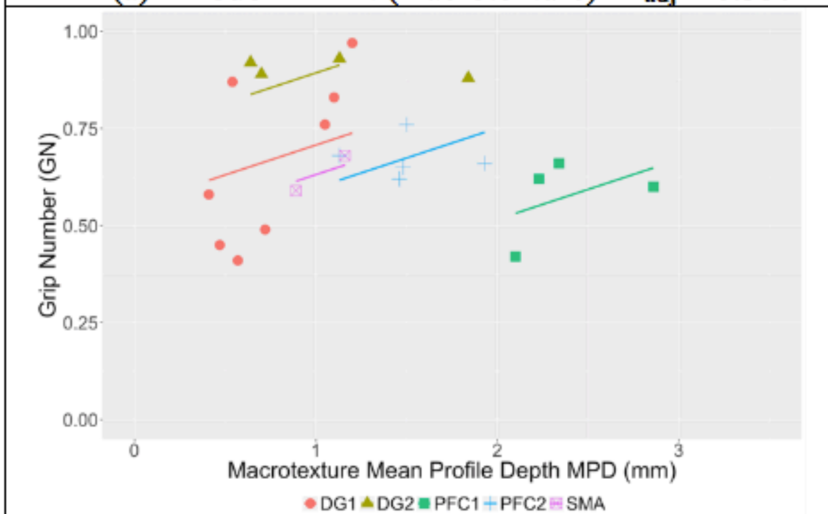
MPD Parameter



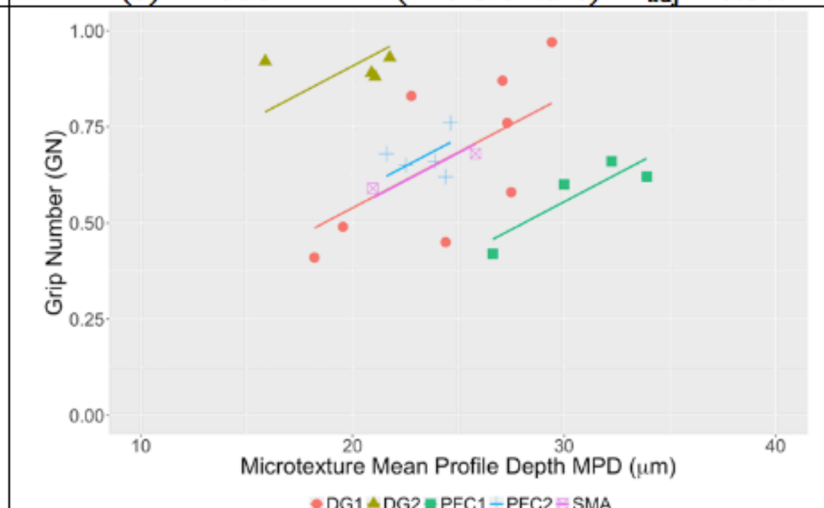
(a) **Model 1** BPN (macrotexture) $\mathbf{R^2_{adj} = 0.357}$



(b) **Model 2** BPN (microtexture) $\mathbf{R^2_{adj} = 0.579}$



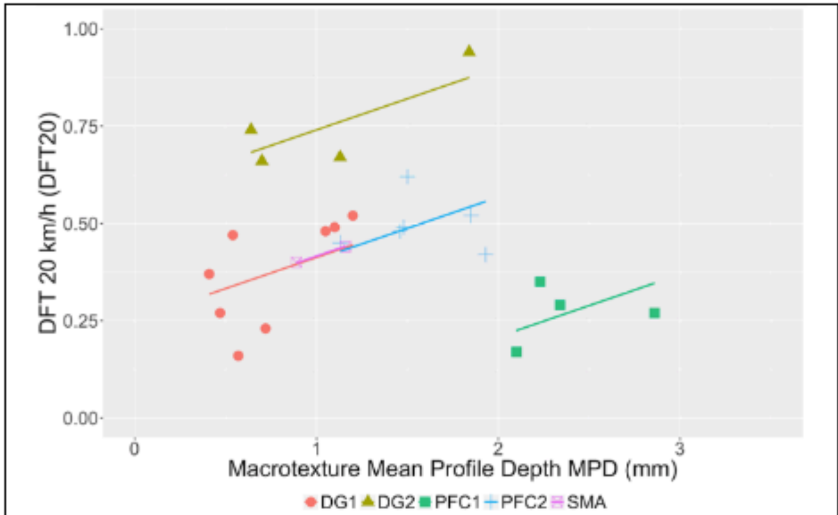
(c) **Model 1** GN (macrotexture) $\mathbf{R^2_{adj} = 0.338}$



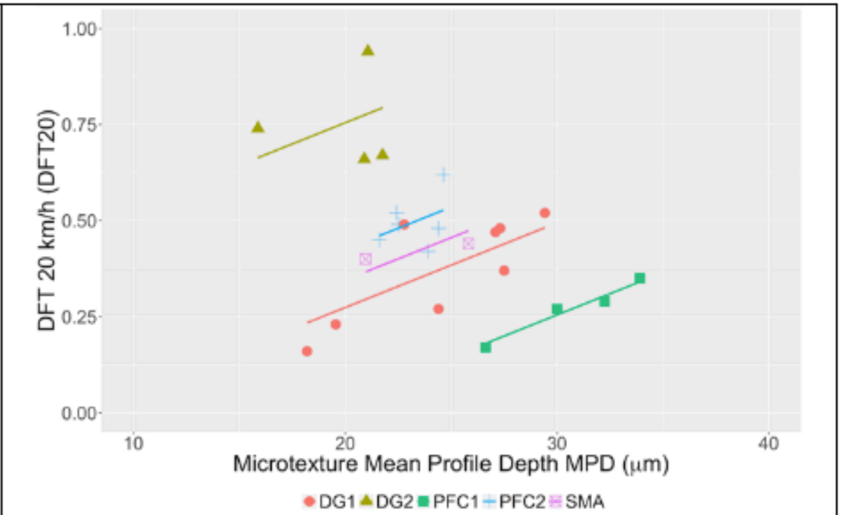
(d) **Model 2** GN (microtexture) $\mathbf{R^2_{adj} = 0.548}$

Results

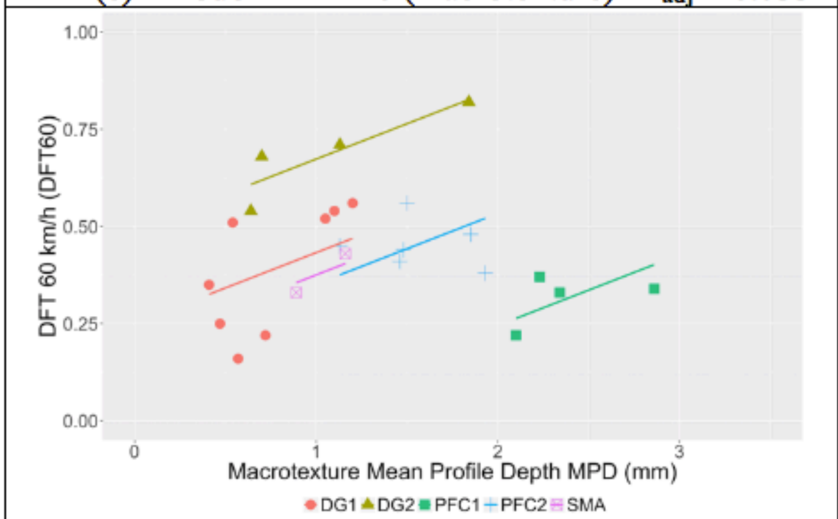
MPD Parameter



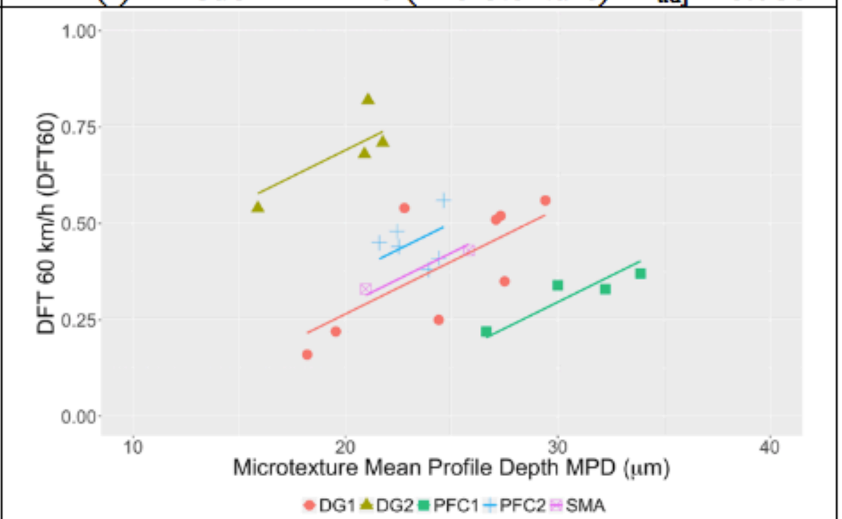
(e) **Model 1** DFT20 (macrotexture) $\mathbf{R^2_{adj} = 0.733}$



(f) **Model 2** DFT20 (microtexture) $\mathbf{R^2_{adj} = 0.780}$



(g) **Model 1** DFT60 (macrotexture) $\mathbf{R^2_{adj} = 0.609}$



(h) **Model 2** DFT60 (microtexture) $\mathbf{R^2_{adj} = 0.735}$

Results

Evaluation of Different Texture Parameters

- Only the R_z parameter (maximum height) presented statistical significance for the GN and the DFT measures.
- The other six parameters do not seem to provide a good correlation with the friction measures.
- Only the parameters R_a, RMS and SV_2, and SV_6 offer significant models for the GN values but not for the BPN and DFT values.
- The **MPD** appeared to be the best texture characterization parameter to model friction.

Conclusions

- There is not a unique relationship between texture and friction, its relation is strong, but it is different for each type of surface.
- A measure of microtexture should be included into friction models based on texture.
- There is a need to provide standard procedures for uniform and comparable microtexture characterization techniques.
- MPD was the most significant parameter.

Future work

- Include a wider variety of surfaces and friction measuring techniques.
- Develop equipment to capture microtexture at highway speed.
- Evaluation using the Locked Wheel Tester and the GripTester, these devices use higher testing speeds and simulate better real conditions.

Questions or Comments?

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THANKS