RESEARCH LEVEL PROTOCOL AND SOFTWARE FOR MICHIGAN DOT'S TEXTURE SCANNING LASER

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WHY WOULD WE DO THIS?

THE FHWA SET A TARGET TEXTURE SIZE:

1. TARGET MEAN TEXTURE DEPTH BETWEEN 0.8 MM TO 1.0 MM

2. MAXIMUM TEXTURE CONTENT IN *WAVELENGTHS* BETWEEN 2 MM TO 8 MM

3. MINIMAL TEXTURE CONTENT IN *WAVELENGTHS* BETWEEN 50 MM AND 100 MM

IT'S ALL ABOUT THE WAVELENGTHS


CE 53903


LMI Selcom
MEASUREMENT & CONTROL
BOX 250 S-433 25 PARTILLE SWEDEN
PART NO
TYPE
S-N
OUTPUT
MANUFACTURED:
MONTH YEAR
Made in The Netherlands

No Sir, Mr. Customs Agent, there is no 50 cal. amo in that amo-box…….


63.48
DELL
LATITUDE

Electric Screw Motor Pull Rate is constant

Number of laser elevation samples per second is set in the Software controls.

Number of samples per second is related to sample distance interval for constant pull velocity.

Electric Screw Motor is pretty smooth but vibrates the laser significantly with respect to measuring ultra-smooth surfaces like glass.

By measuring the texture of surfaces like glass, you can define the texture scanning device’s overall apparent precision, which is affected by many things.

MiDOT Texture Laser Precision

Absolute Smallest Texture Scanned-
Fine Sanded Lumber, No Coating

ASTM MPD = 0.081 mm

Macro Texture Elev. StDev = 0.034 mm

Micro Texture/Noise Elev. Stdev = ***0.054 mm***

“Macro is Smaller than Micro/Noise”

MiDOT Texture Laser Precision

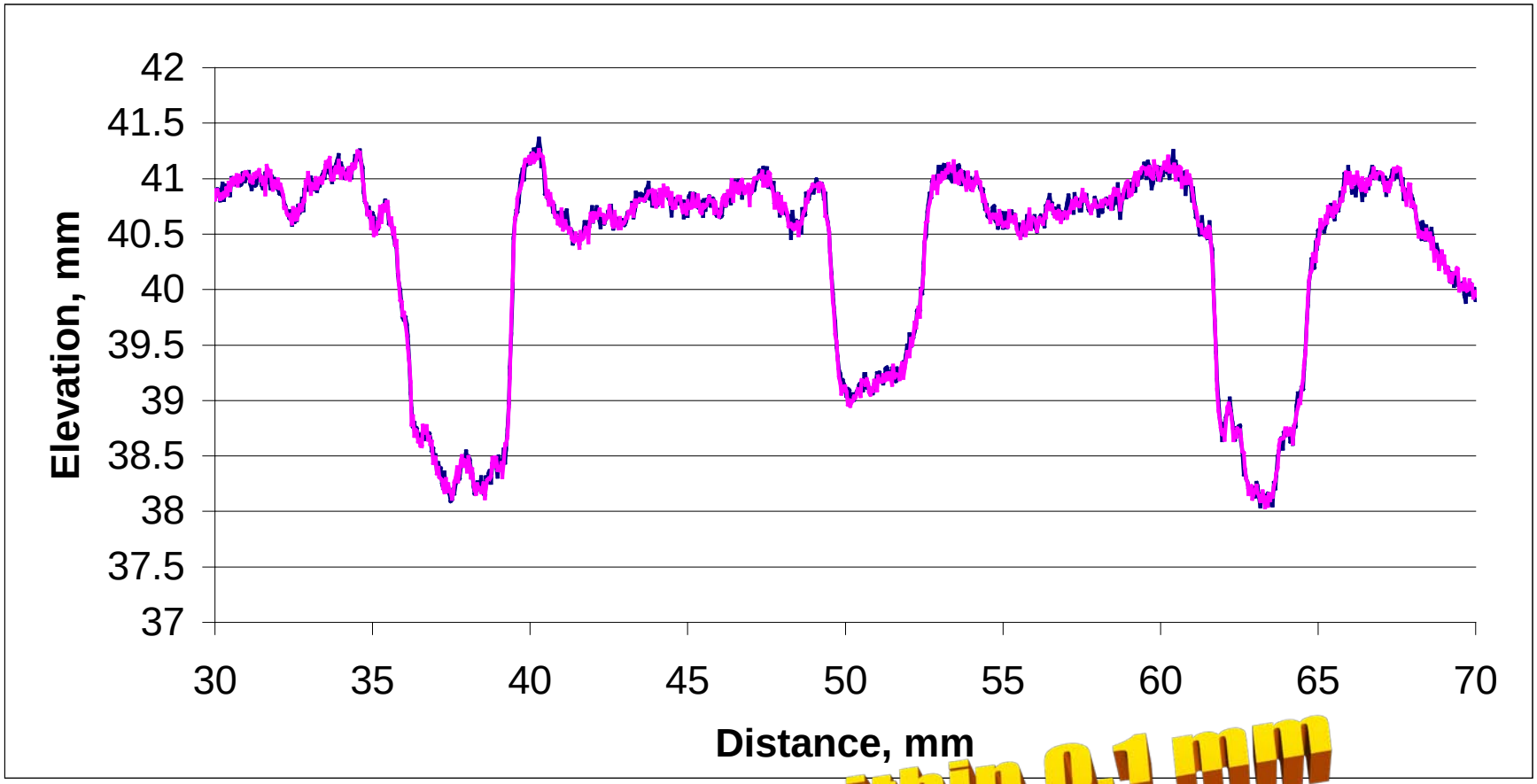
Texture of Smooth Glass- Fine-Sanded Wood

ASTM MPD = 0.134 mm (0.081 mm)
Macro Elev. StDev = 0.047 mm (0.034)
Micro/Noise Elev. Stdev = ***0.068 mm*** (0.054)

But, some of this is real

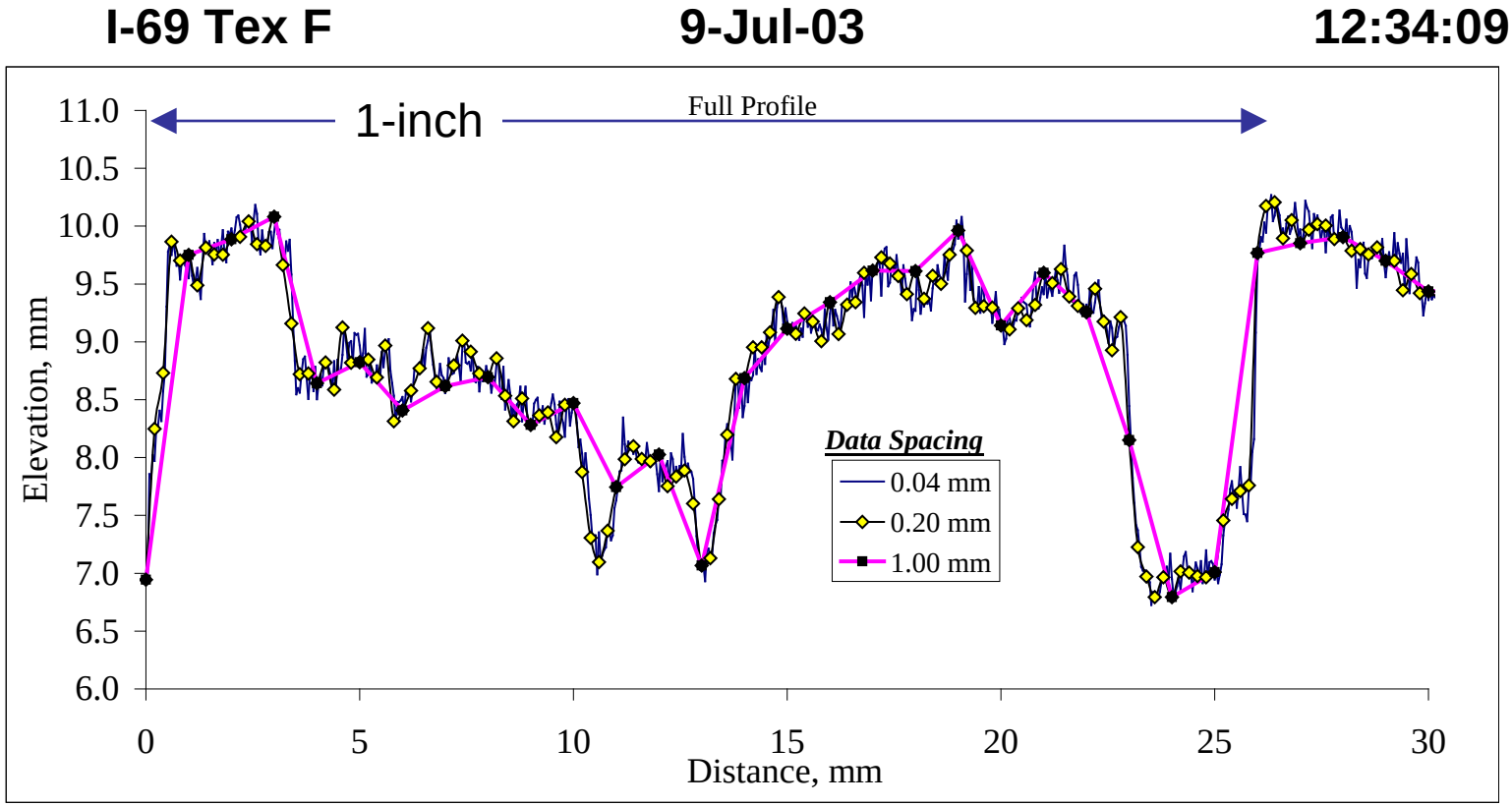
But, some of this is real

Repeatability at 0.04 mm per sample



So, Almost Always within 0.1 mm
usually <0.05 mm

What Sample Interval to Use?

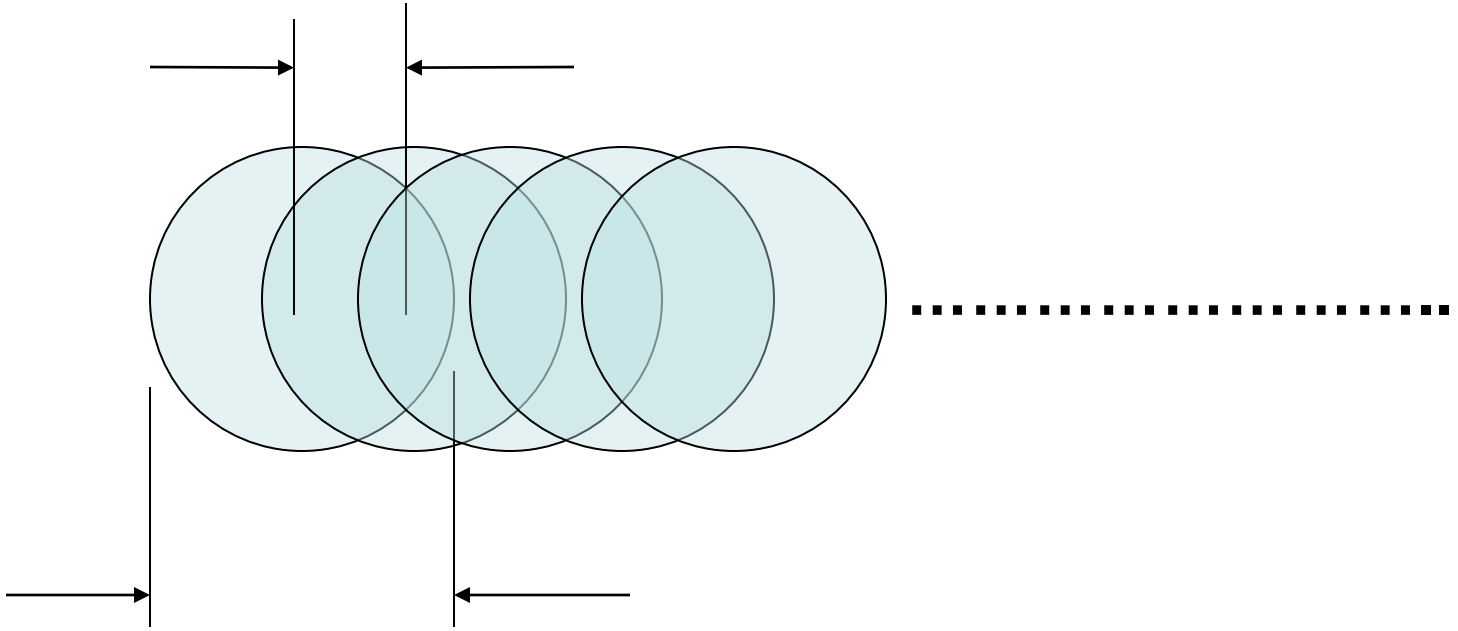


1 mm Sample Data is OK for SIZE but not for SHAPE

0.20 to 0.25 mm MAX for Texture Shape

MiDOT Texture Laser Sample Pattern Used

0.2 mm Sample Interval

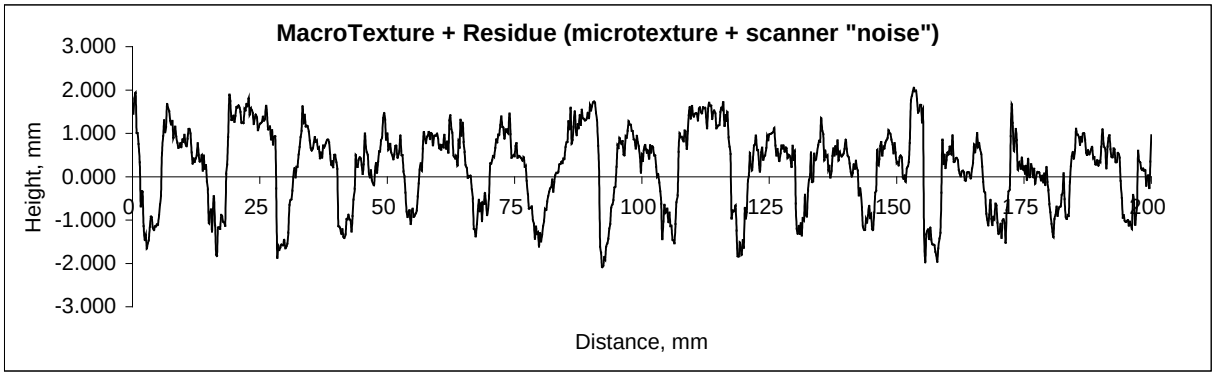


0.5 mm Laser Footprint Diameter

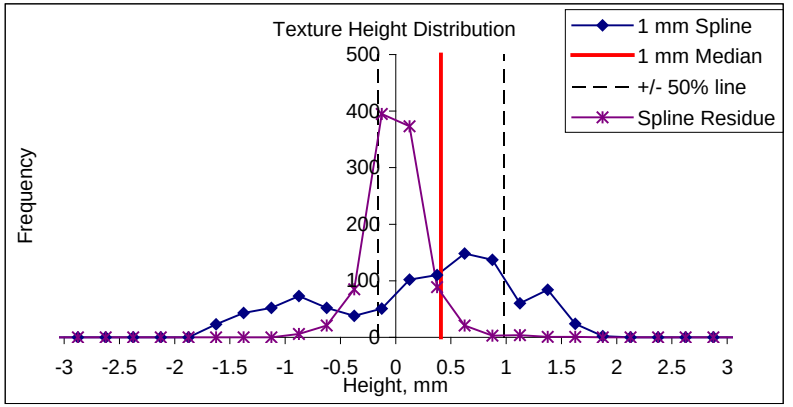
No use having really short spacing with big footprint, low resolution,…..

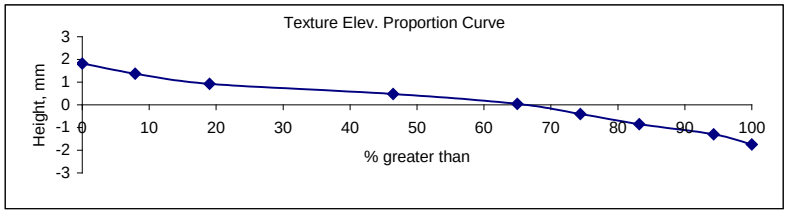
Texture Scan Summary Report

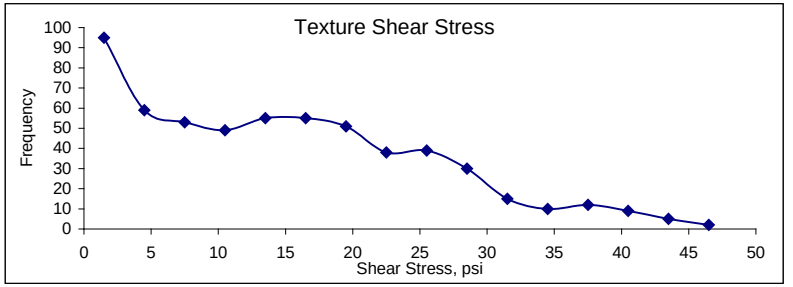
I-69 Tex F **12:34:09** **9-Jul-03**



ASTM MPD, mm =	1.486
ASTM ETD, mm =	1.389
ASTM Peak Value, mm =	1.721
ASTM Avg Height, mm =	0.235
Texture Tortuosity, mm/mm =	1.161
Macro Median Value, mm =	0.410
Macro Spline StDev, mm =	0.849
Residue StDev, mm =	0.251
# of Sharp 1.1 mm (+) =	22
Avg Size of 1.1+, mm =	2.24
Total Sum of 1.1+, mm =	49.38
Avg Spacing of 1.1+, mm =	8.70
CVT for 1.1 =	2.80
% too smooth =	0.078
4mm "smooth" stdev, mm =	0.20
Curvature 0.2 stdev =	91.49
0.4 stdev =	30.11
0.6 stdev =	16.84
0.8 stdev =	11.16
1.0 stdev =	8.03
1.2 stdev =	6.27
1.4 stdev =	5.06
1.6 stdev =	4.35
SRI(0.3 without), lb/lb =	0.427
SRI(0.3 with), lb/lb =	0.381
%Contact =	68.4%
Tire Bottom Elev, mm =	-0.073
Volume Beneath Tire, in^3 =	0.468
Area Beneath Tire, in^2 =	0.067
# Voids beneath rubber =	15
Avg. Void Width, in =	0.14121
Avg Void Depth, in =	0.03156
0.5" Flow Distance Index, mm =	333.4
Avg Shear Stress, psi =	15.17
Median Shear Stress, psi, =	13.80
Shear Stress StDev, psi =	11.30
Max Shear Stress, psi, =	66.35

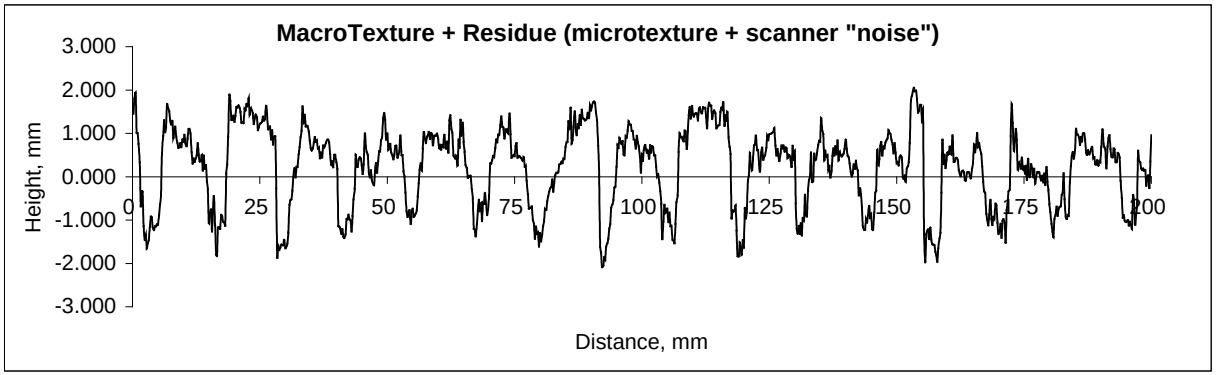






I-69 Tex F 12:34:09 9-Jul-03

Summary Report



Old Size Data (ASTM)

ASTM MPD, mm =	1.486
ASTM ETD, mm =	1.389
ASTM Peak Value, mm =	1.721
ASTM Avg Height, mm =	0.235

New Size Data

Texture Tortuosity, mm/mm =	1.161
Macro Median Value, mm =	0.410
Macro Spline StDev, mm =	0.849
Residue StDev, mm =	0.251

Sharp Features

# of Sharp 1.1 mm (+) =	22
Avg Size of 1.1+, mm =	2.24
Total Sum of 1.1+, mm =	49.38
Avg Spacing of 1.1+, mm =	8.70
CVT for 1.1 =	2.80

Smooth Areas

% too smooth =	0.078
4mm "smooth" stdev, mm =	0.20

Variation of Curvature of Texture

Curvature 0.2 stdev =	91.49
0.4 stdev =	30.11
0.6 stdev =	16.84
0.8 stdev =	11.16
1.0 stdev =	8.03
1.2 stdev =	6.27
1.4 stdev =	5.06
1.6 stdev =	4.35

Skid Resistance

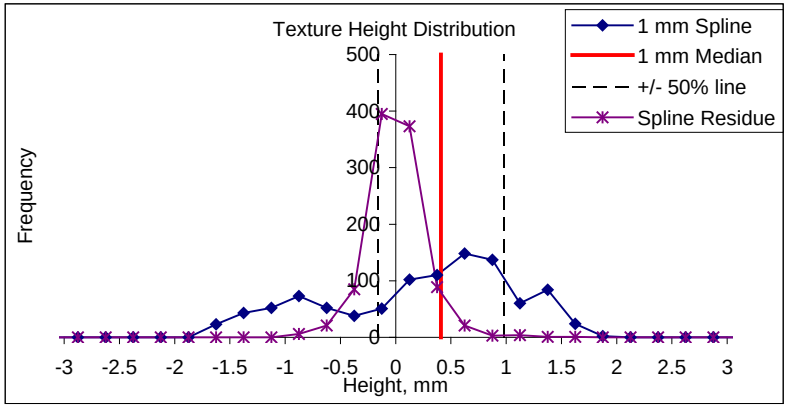
SRI(0.3 without), lb/lb =	0.427
SRI(0.3 with), lb/lb =	0.381
%Contact =	68.4%
Tire Bottom Elev, mm =	-0.073

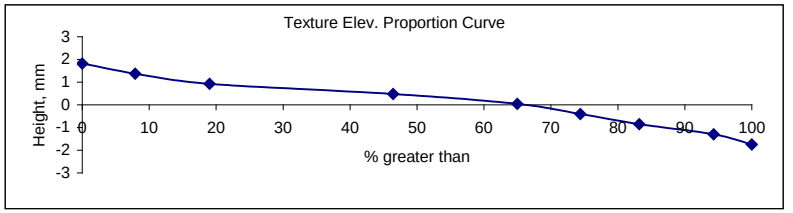
Water Flow

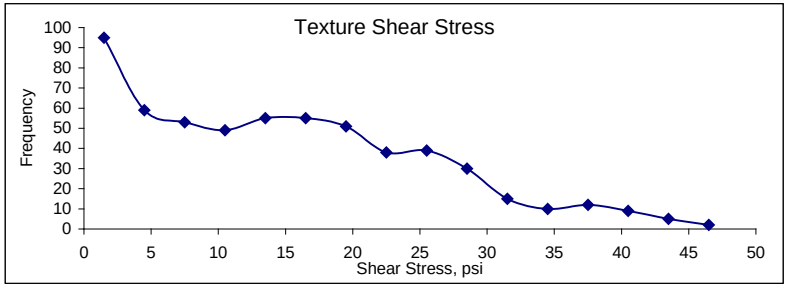
Volume Beneath Tire, in^3 =	0.468
Area Beneath Tire, in^2 =	0.067
# Voids beneath rubber =	15
Avg. Void Width, in =	0.14121
Avg Void Depth, in =	0.03156
0.5" Flow Distance Index, mm =	333.4

Texture Stress

Avg Shear Stress, psi =	15.17
Median Shear Stress, psi, =	13.80
Shear Stress StDev, psi =	11.30
Max Shear Stress, psi, =	66.35







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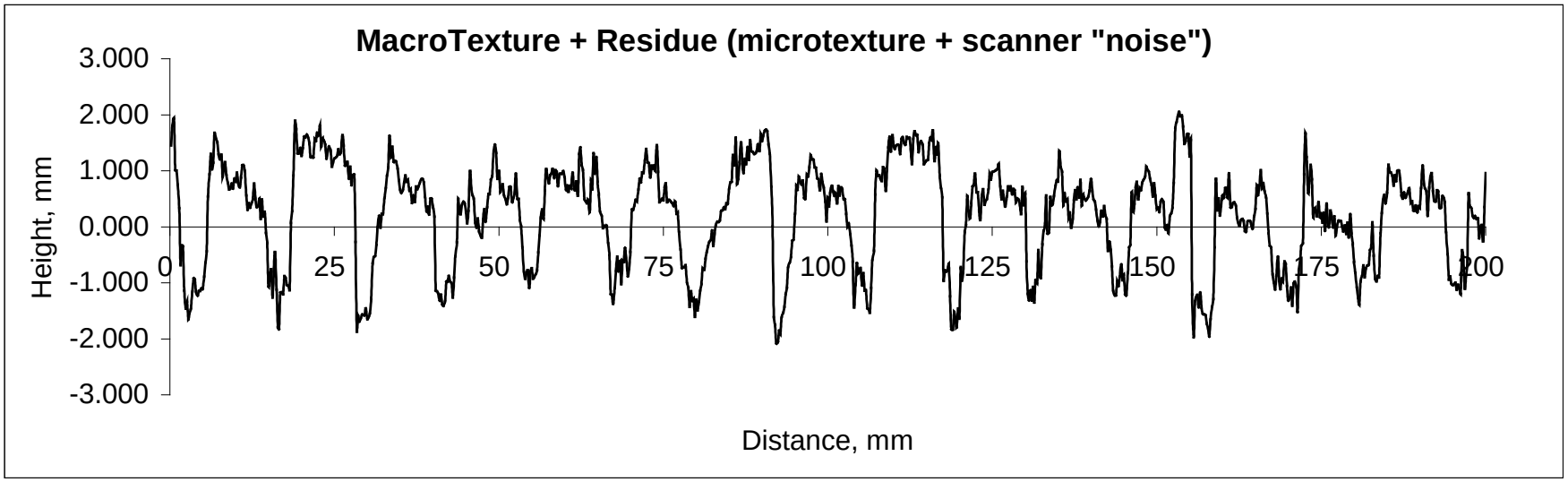
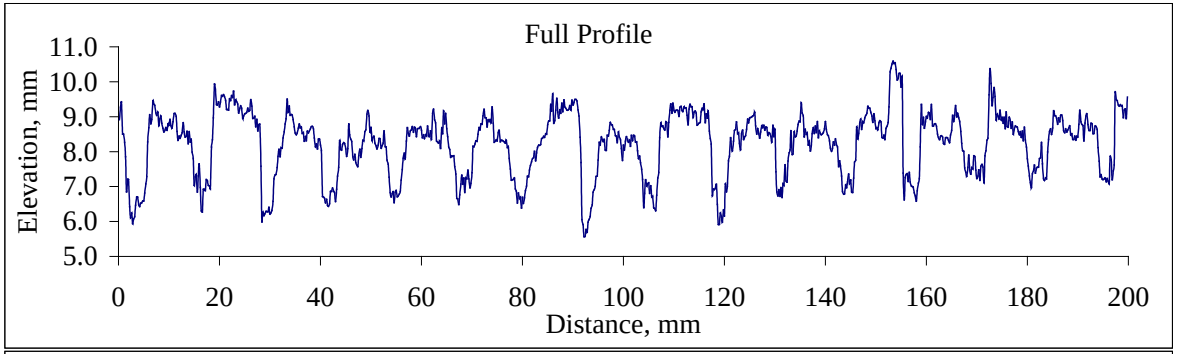
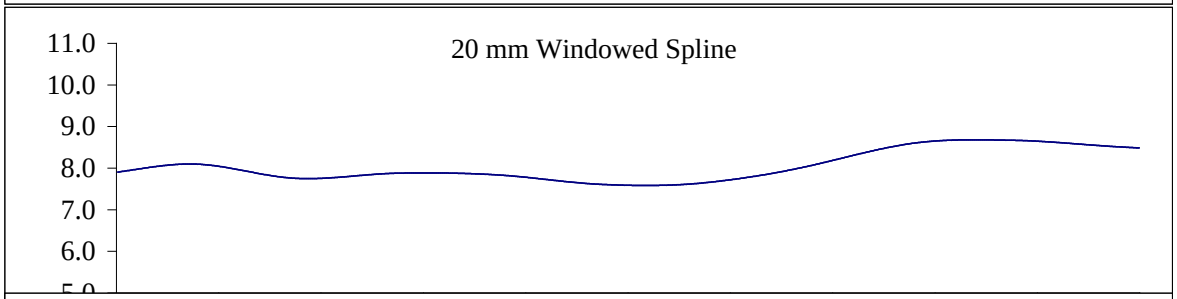


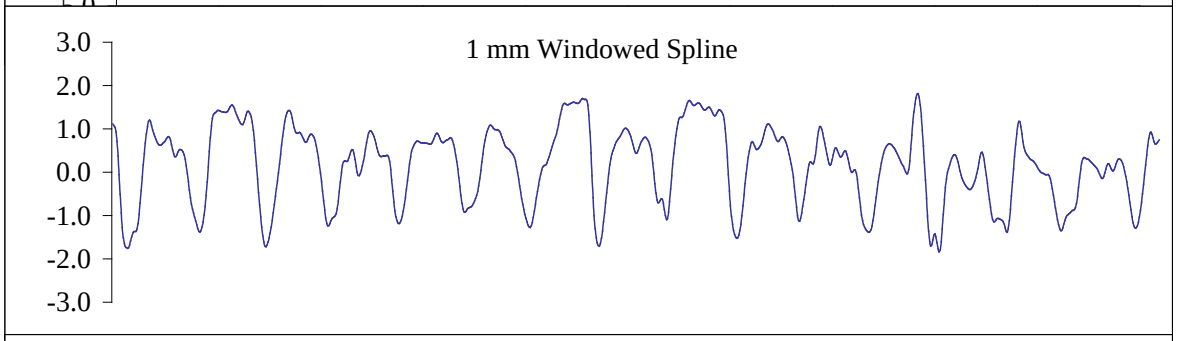
Digital "Sieve Analysis"

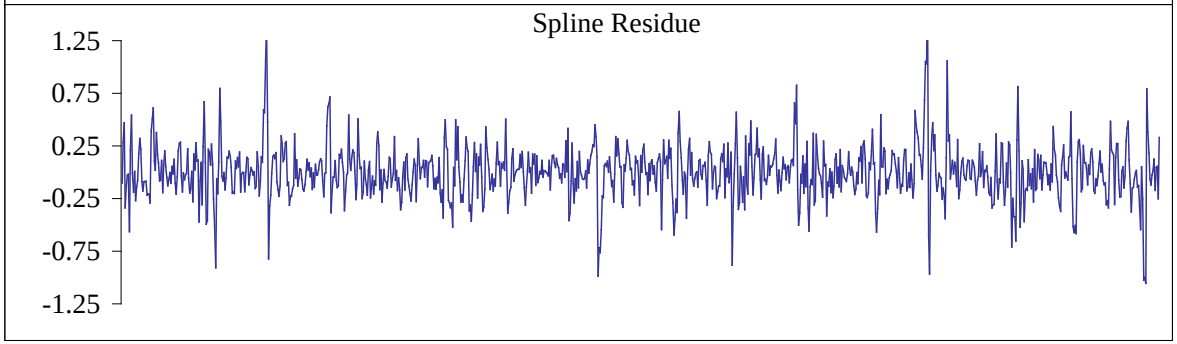
I-69 Tex F **9-Jul-03** **12:34:09**

Dirt	**Texture**
=	**=**
20 mm	**MEGA**
+	**+**
1 mm	**MACRO**
+	**+**
Pan	**MICRO**

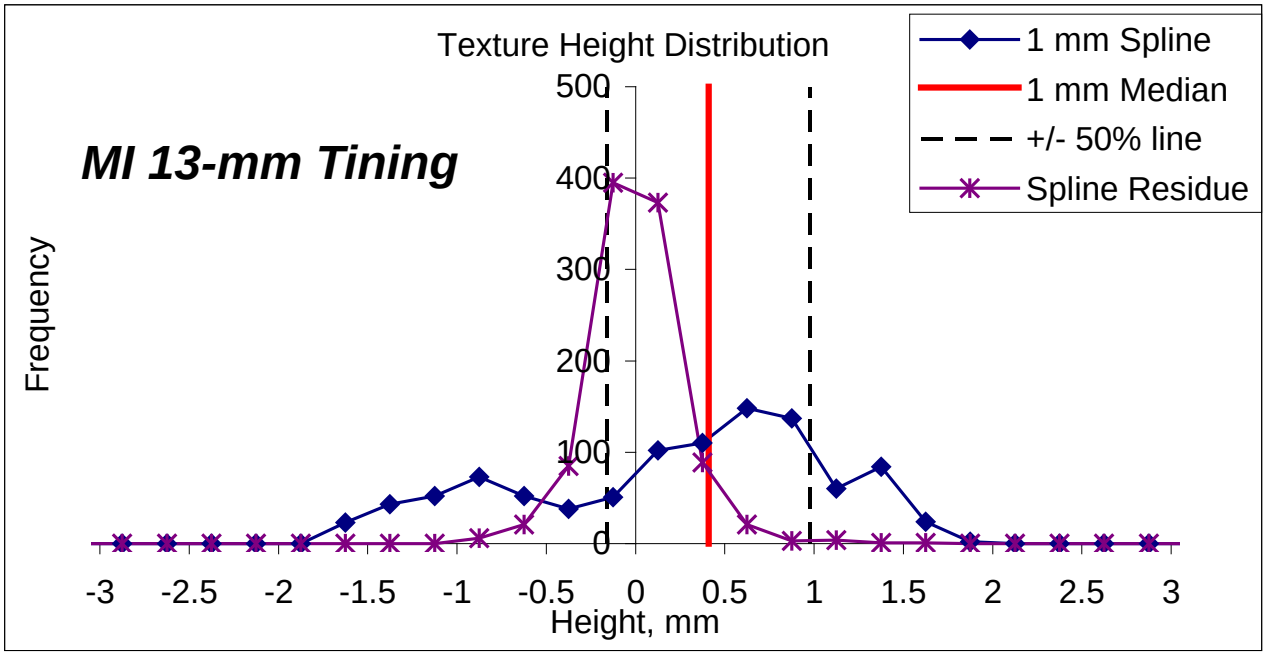








Texture Size Characterization



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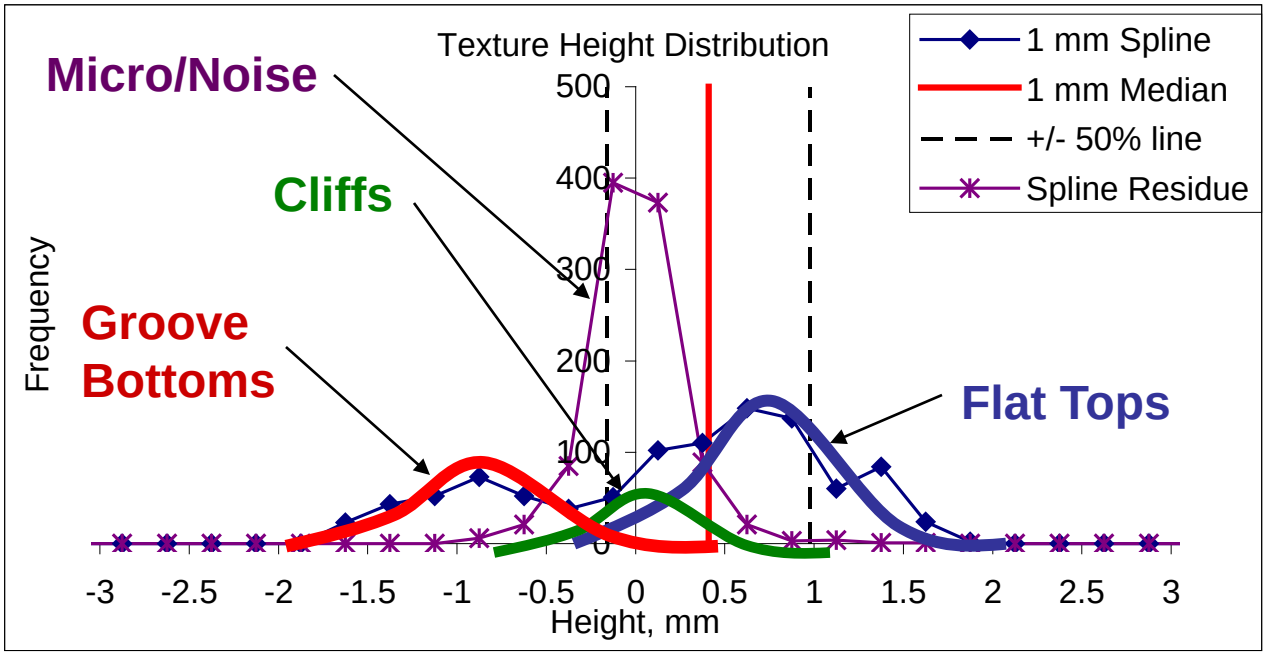
Residue StDev, mm =	0.251

Texture has a "+0.41 mm skew" indicating wide flat tops and narrow down spikes.

Texture Size Characterization

MI 13-mm Tining



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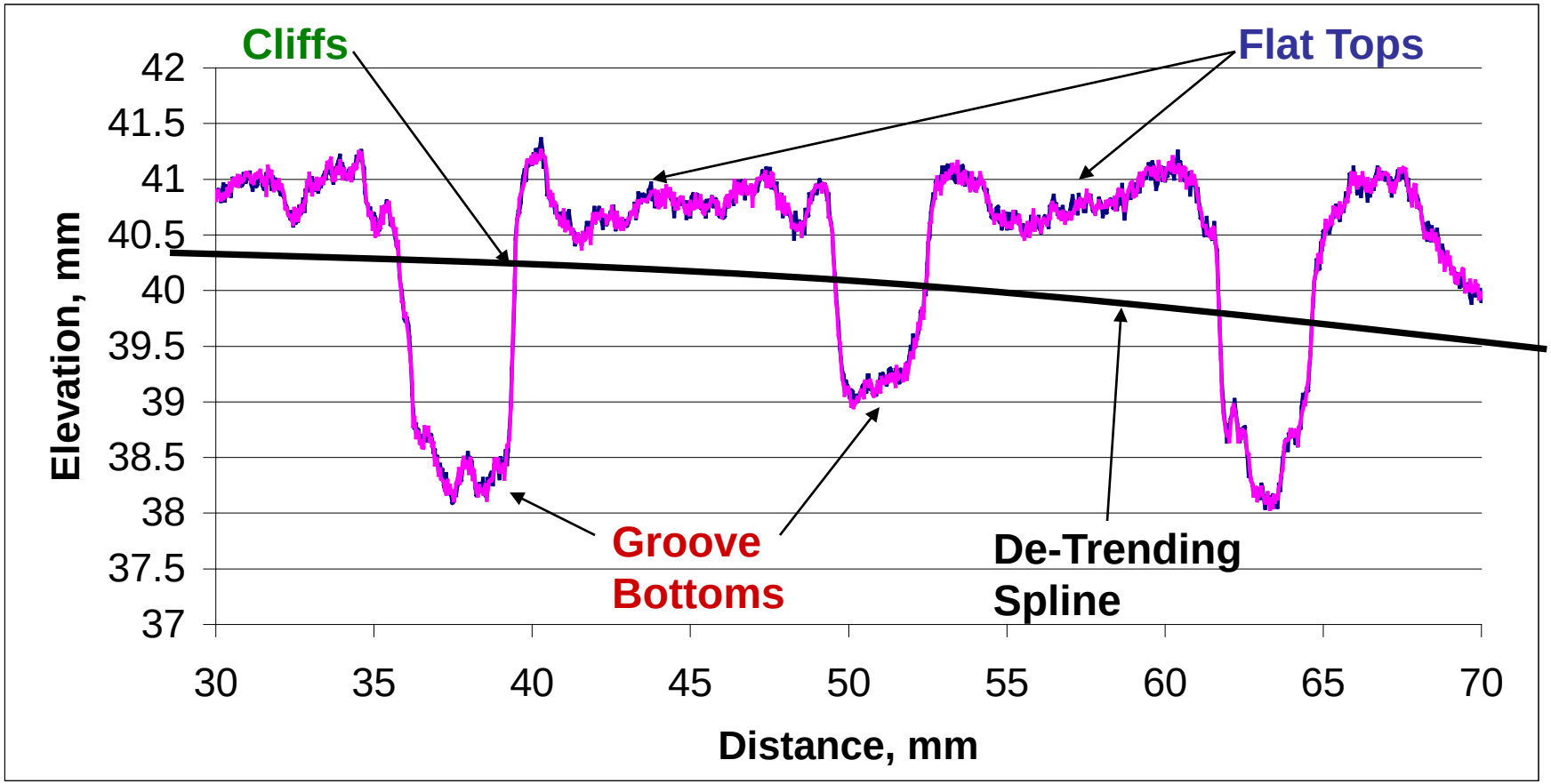
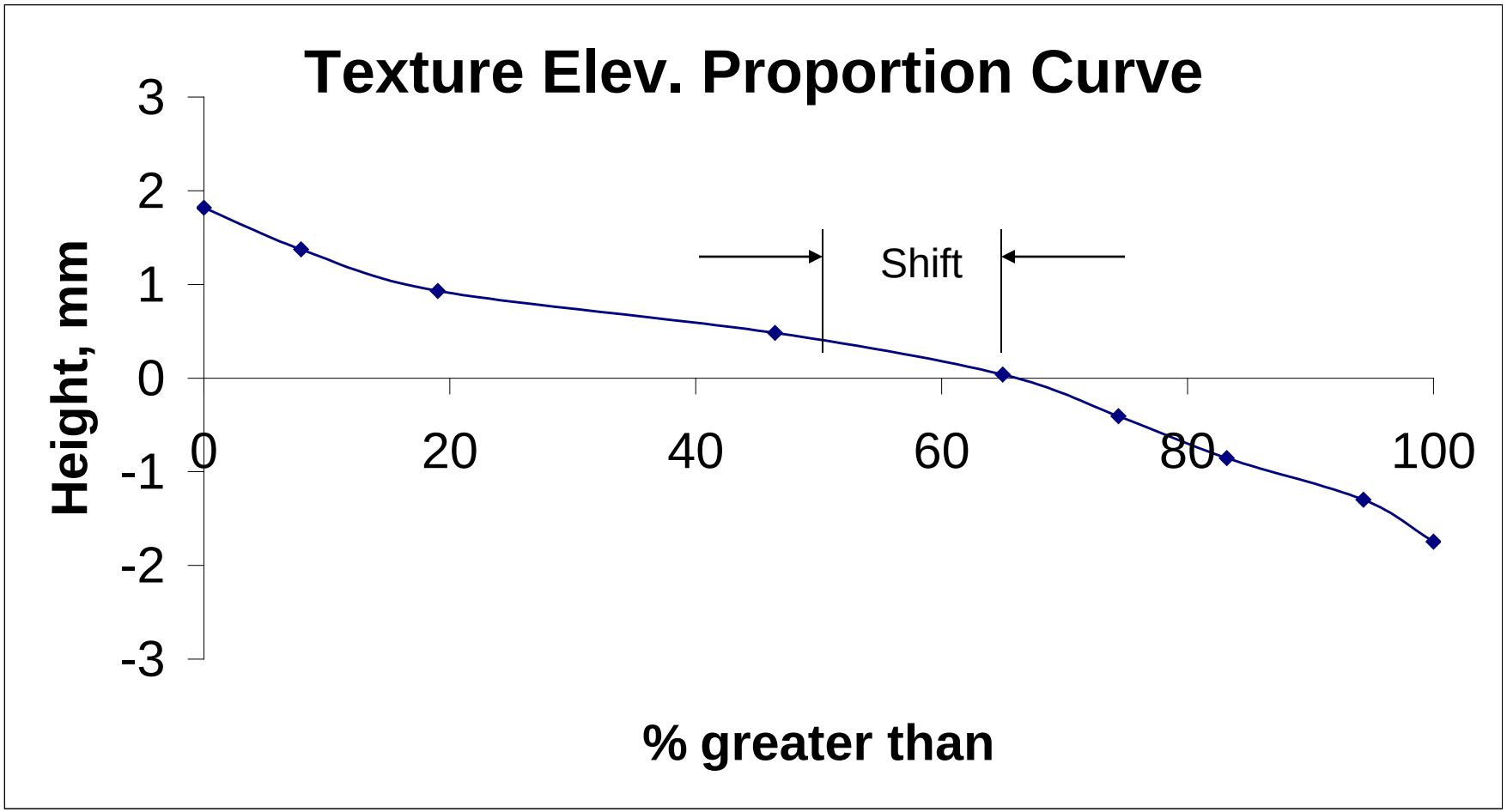
Grooved Pavements have Three Primary Macro-Texture Features

Repeatability at 0.04 mm per sample *MI 13-mm Tining*

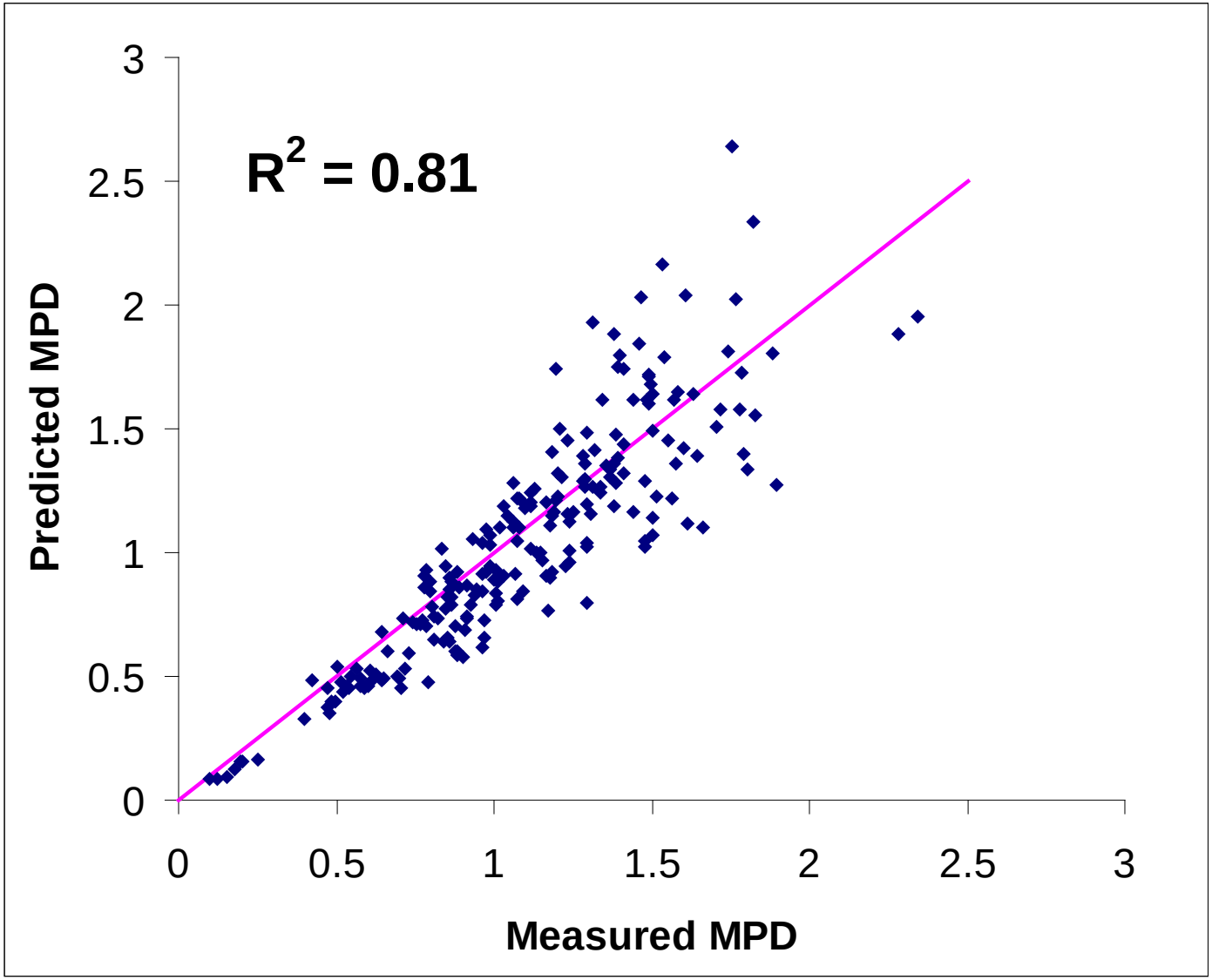


Grooved Pavements have Three Primary Macro-Texture Features

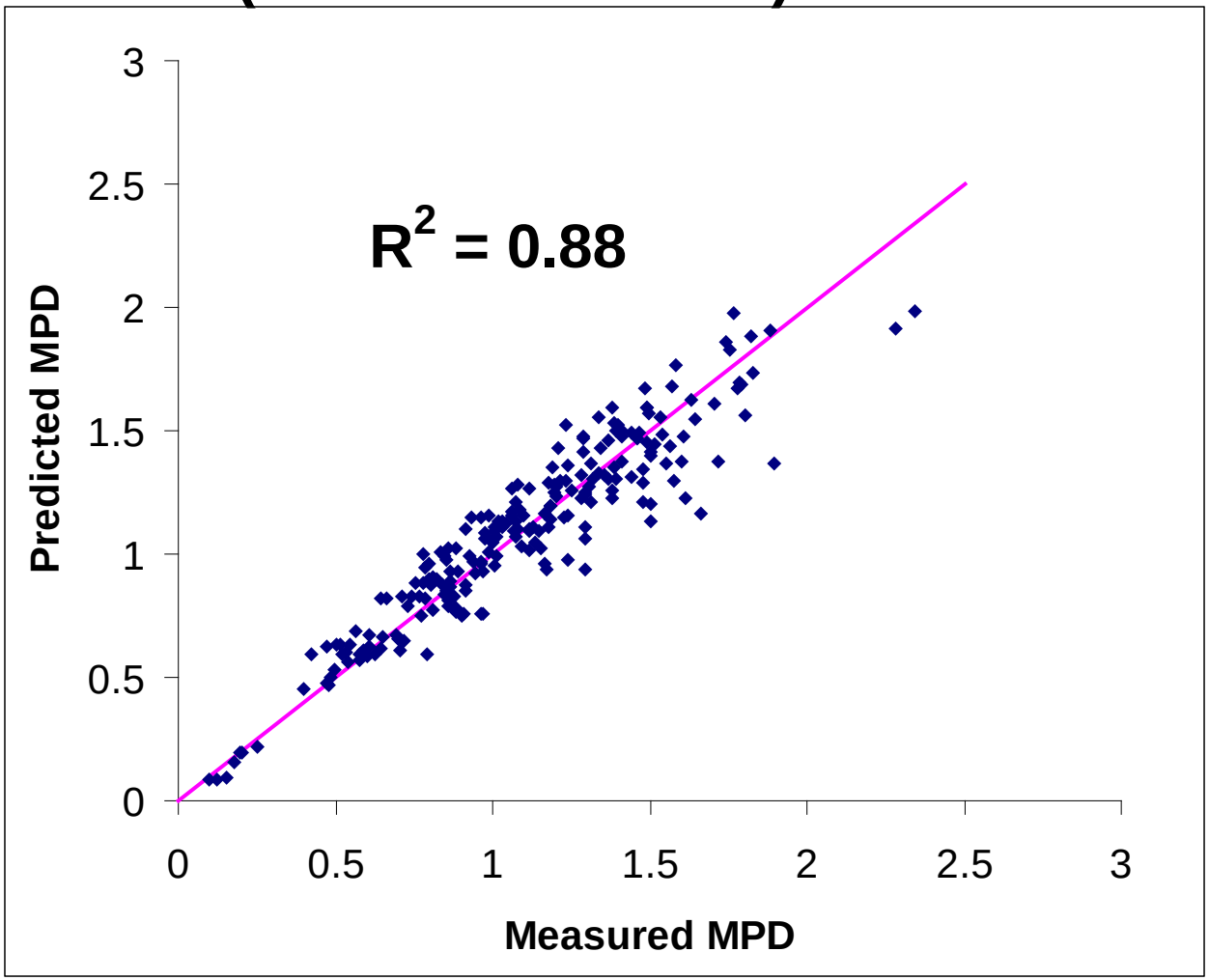


Texture has a “15% Skew”

MPD = 1.923 (Macro Spline Elev. Stdev)



$$MPD = 1.970(\text{Macro Spline Elev. Stdev})^{0.736} - 0.680(\text{abs(median value)})^{0.957} - 0.143(\text{Tortuosity})^{-7.043} + 0.032(1.6\text{ mm arc StDev})^{0.747}$$



Characterizing Texture Shape with Sine Waves

Recommended Procedure

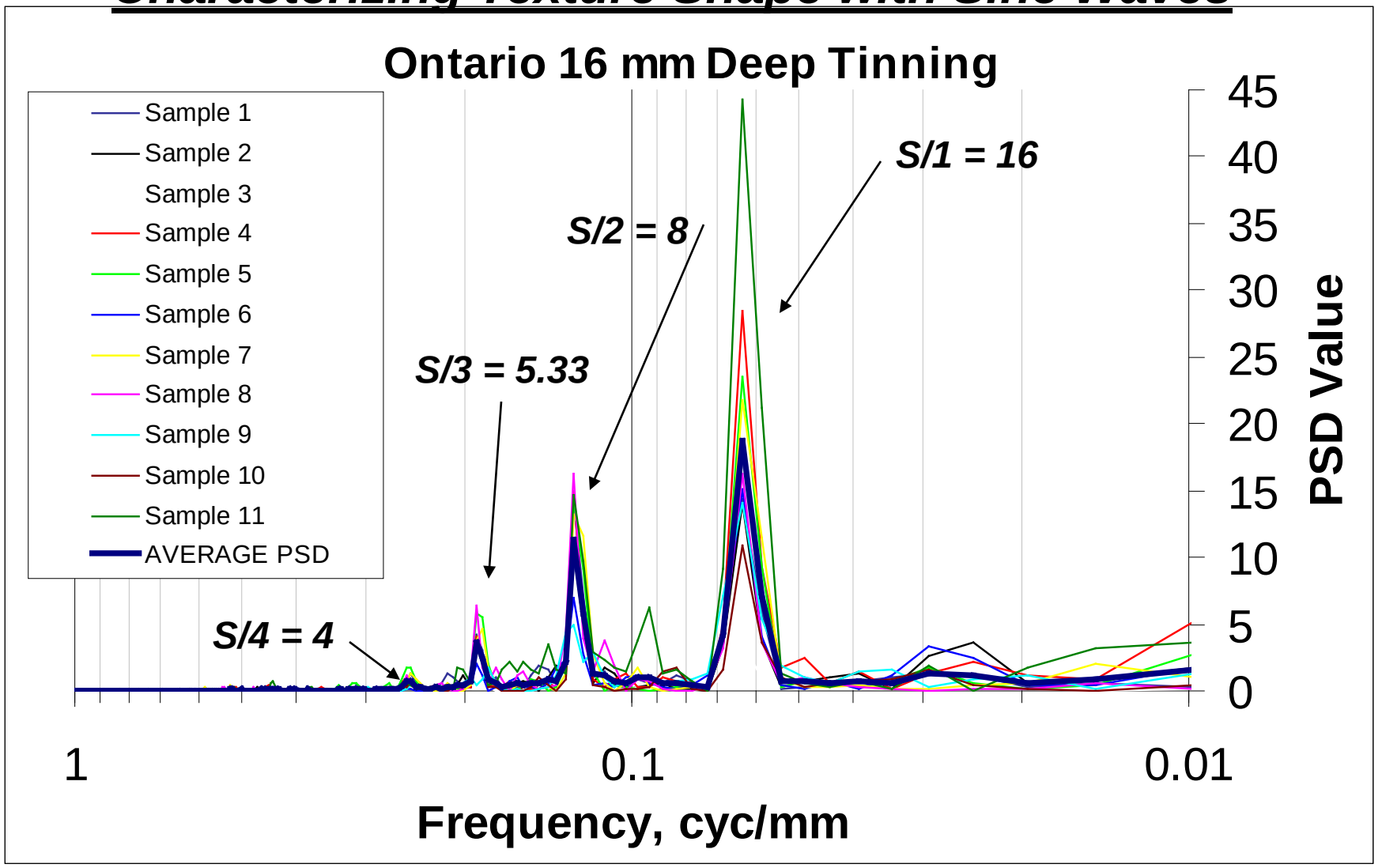
1. Obtain at least six good representative texture scan elevation profiles of the individual road texture, minimum length of 200 mm, which is slightly longer than a car tire foot-print.

2. Develop Fourier-type “Power Spectral Density” PSD data for each individual scan of the texture.

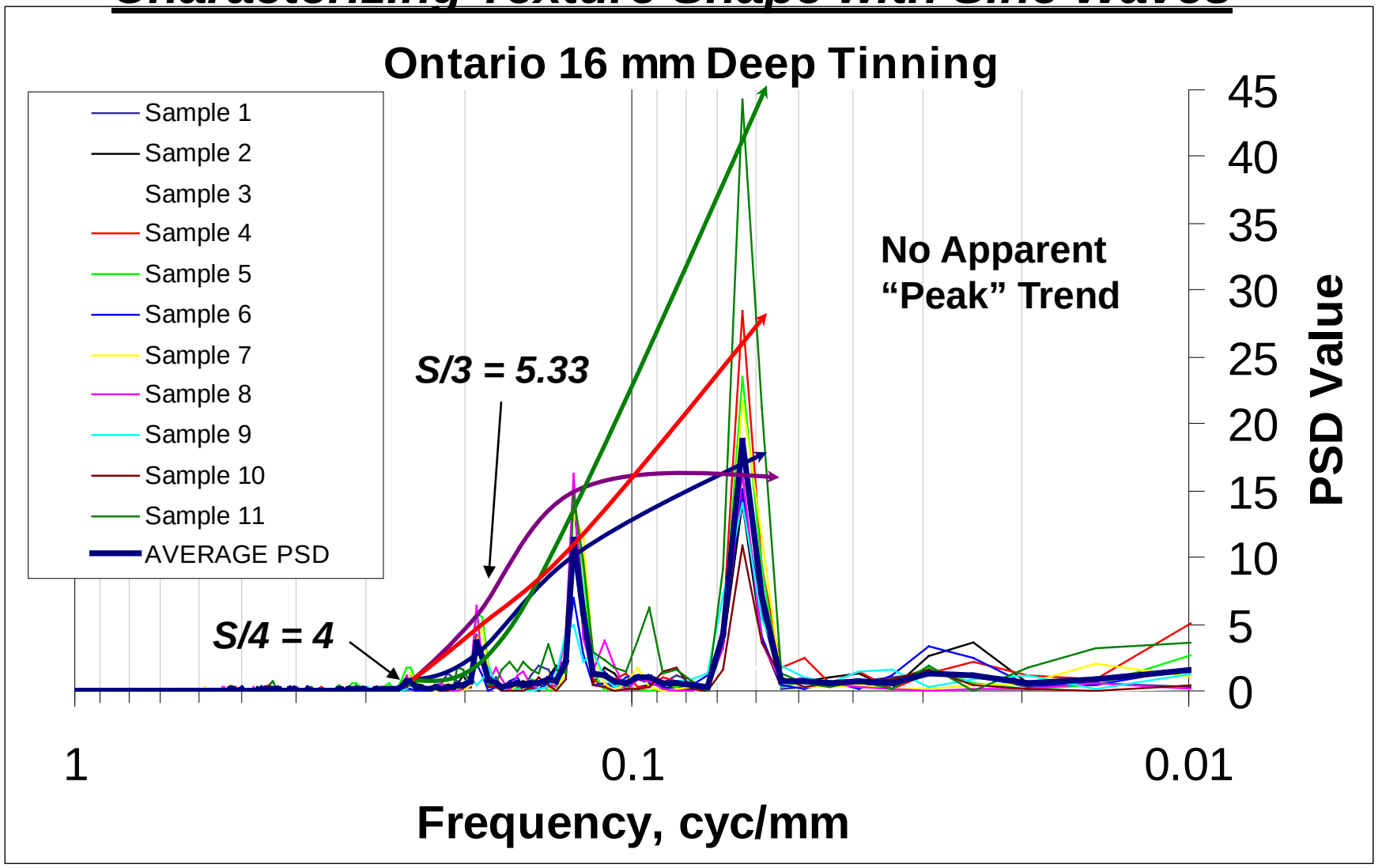
3. Combine all the PSD’s for a texture and Calculate overall average and standard deviation of PSD value for each PSD calculation wavelength.

4. The Average PSD Plot for all of the scans is the “Representative PSD” for that texture.

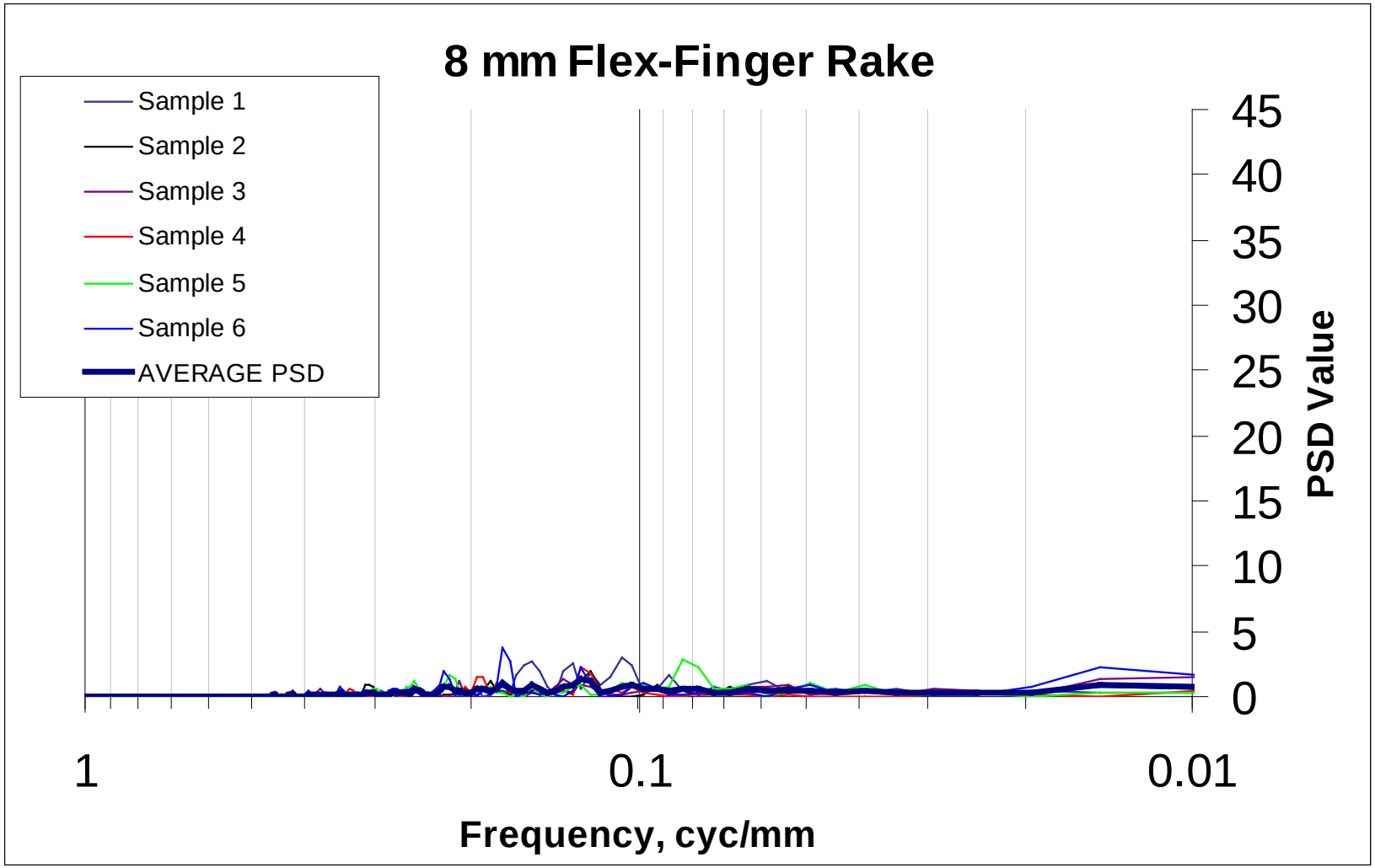
Characterizing Texture Shape with Sine Waves



Characterizing Texture Shape with Sine Waves

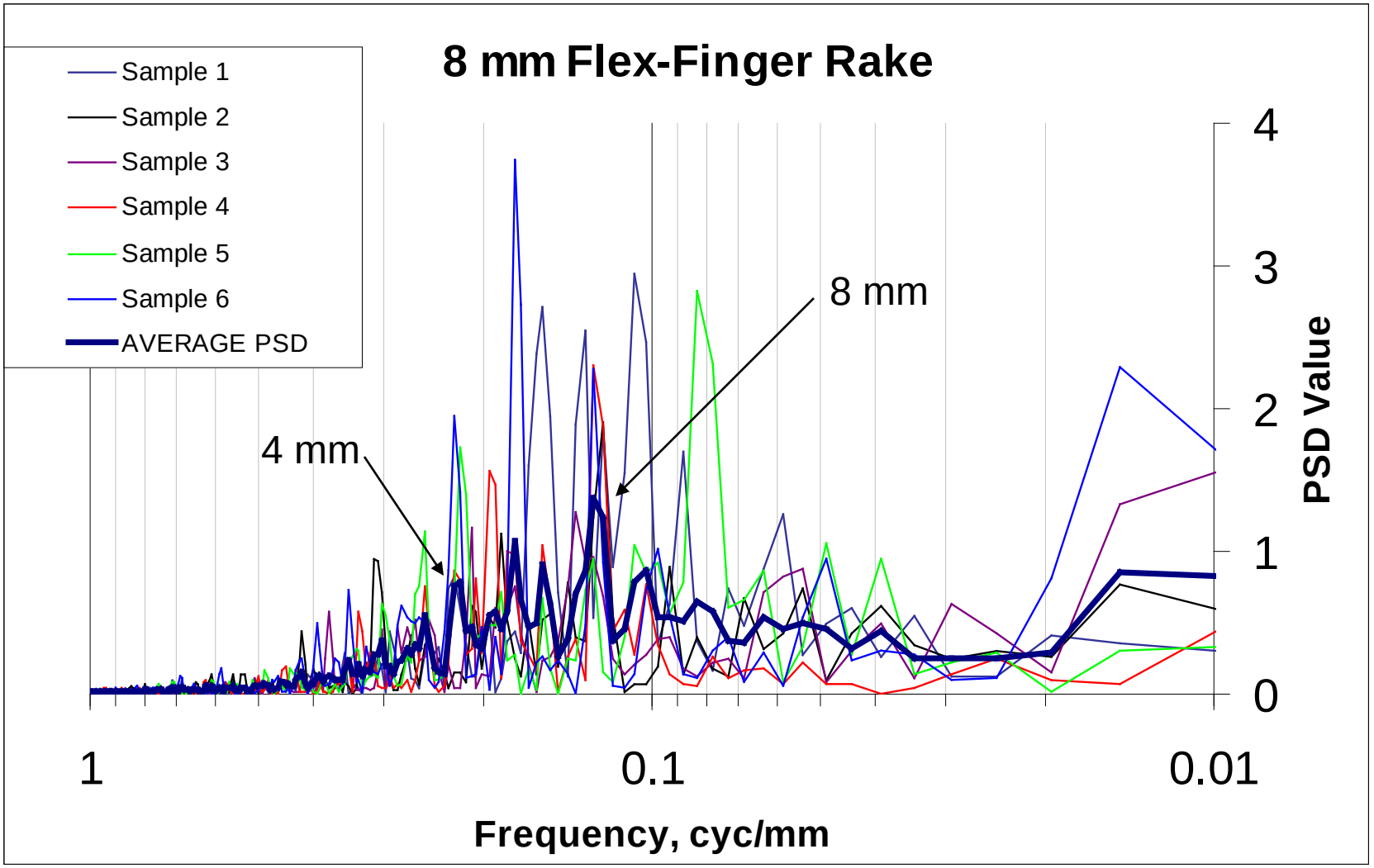


Seeking Transverse Randomness

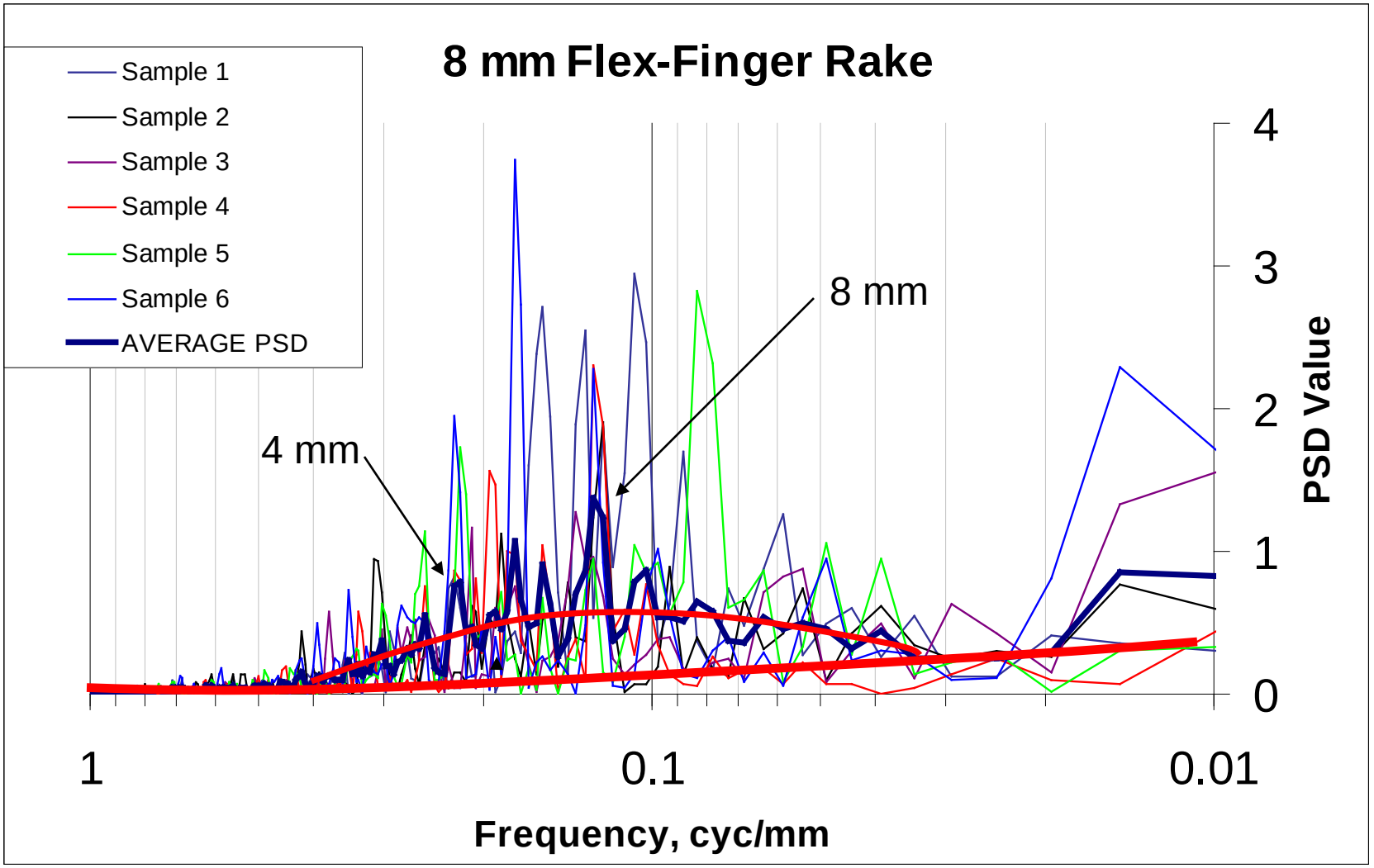



Seeking Transverse Randomness
8 mm Finger Spacing, Flexible-Fingered Rake

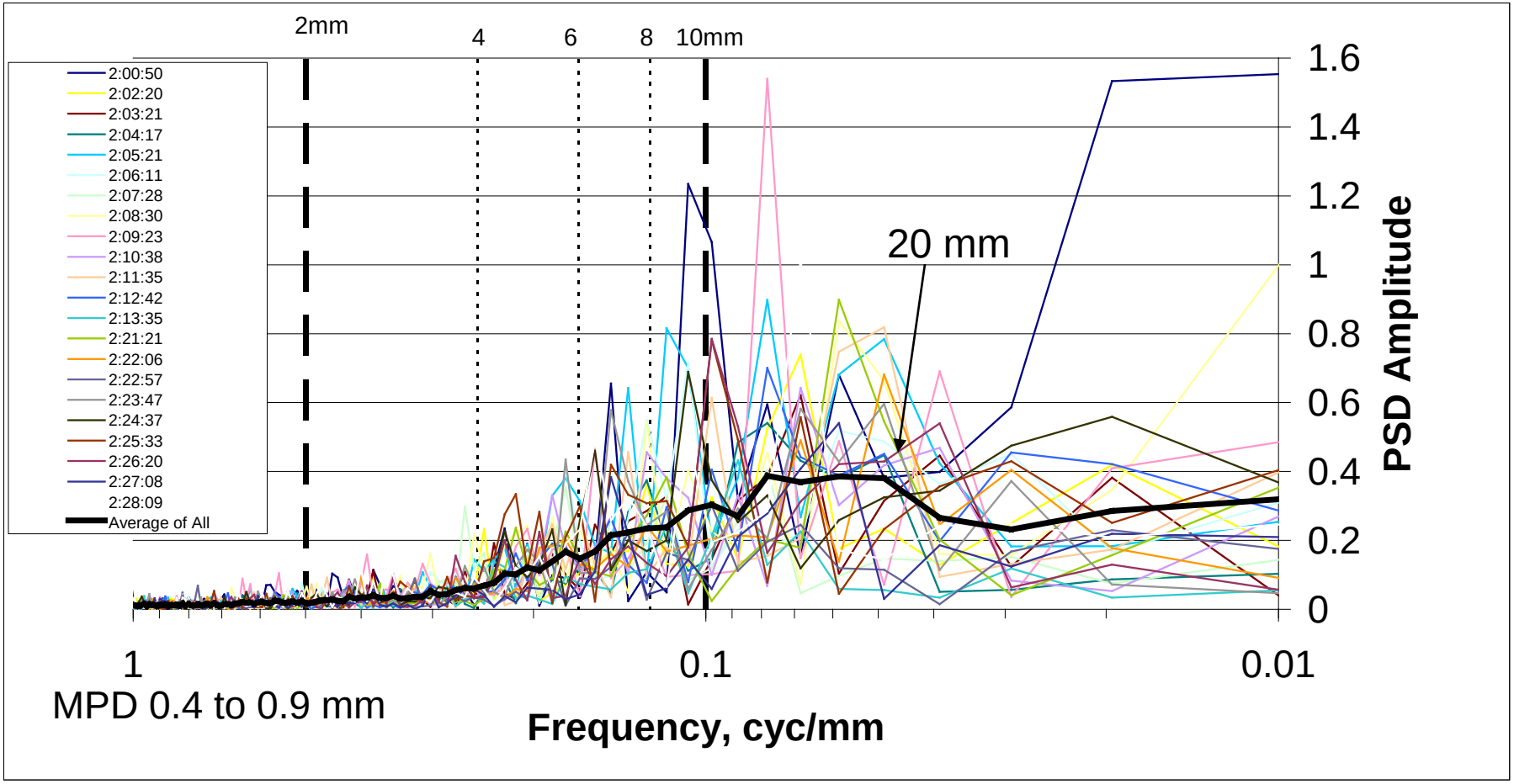
PSD Peaks Never in Same Spot = Randomness



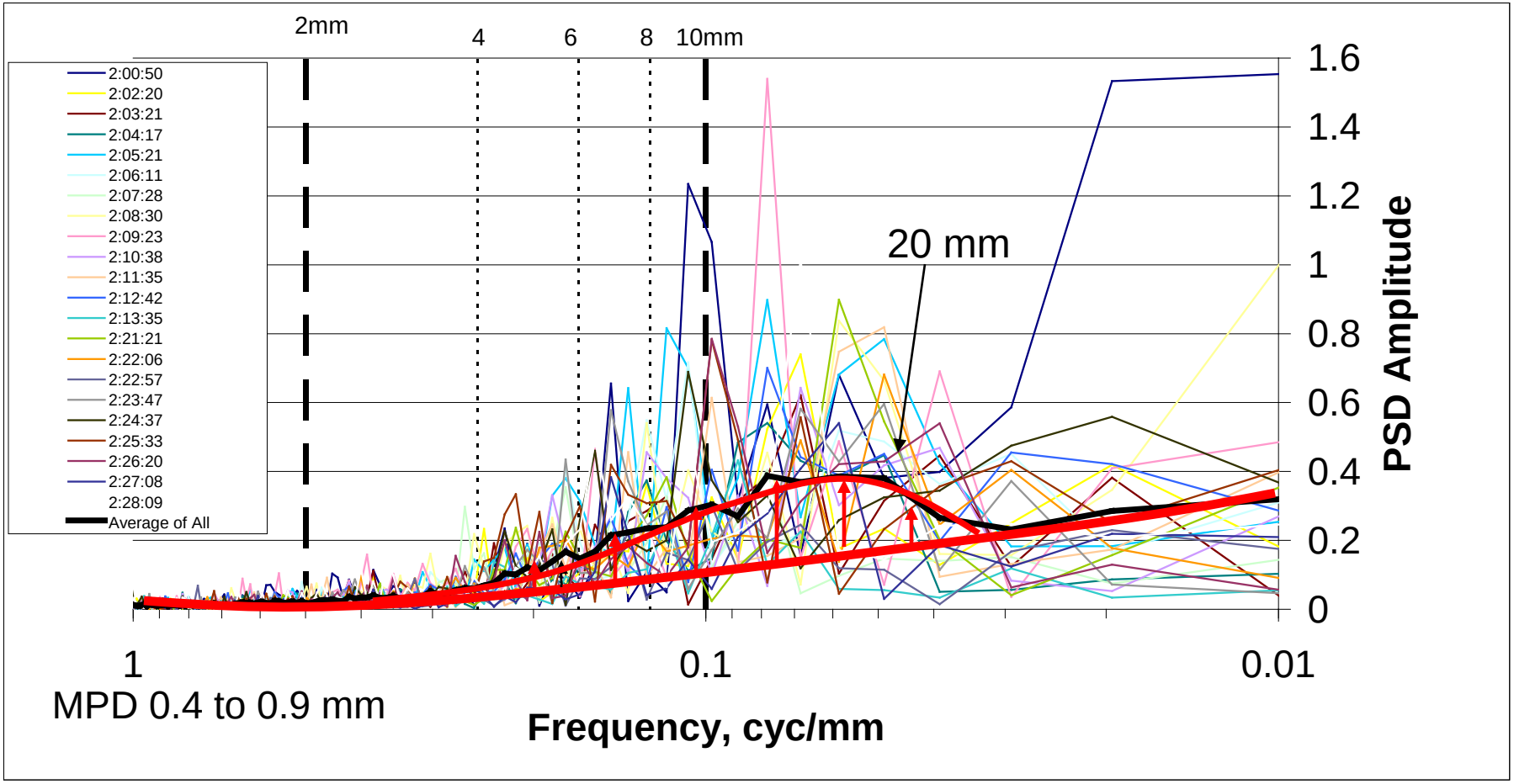
PSD Peaks Never in Same Spot = Randomness

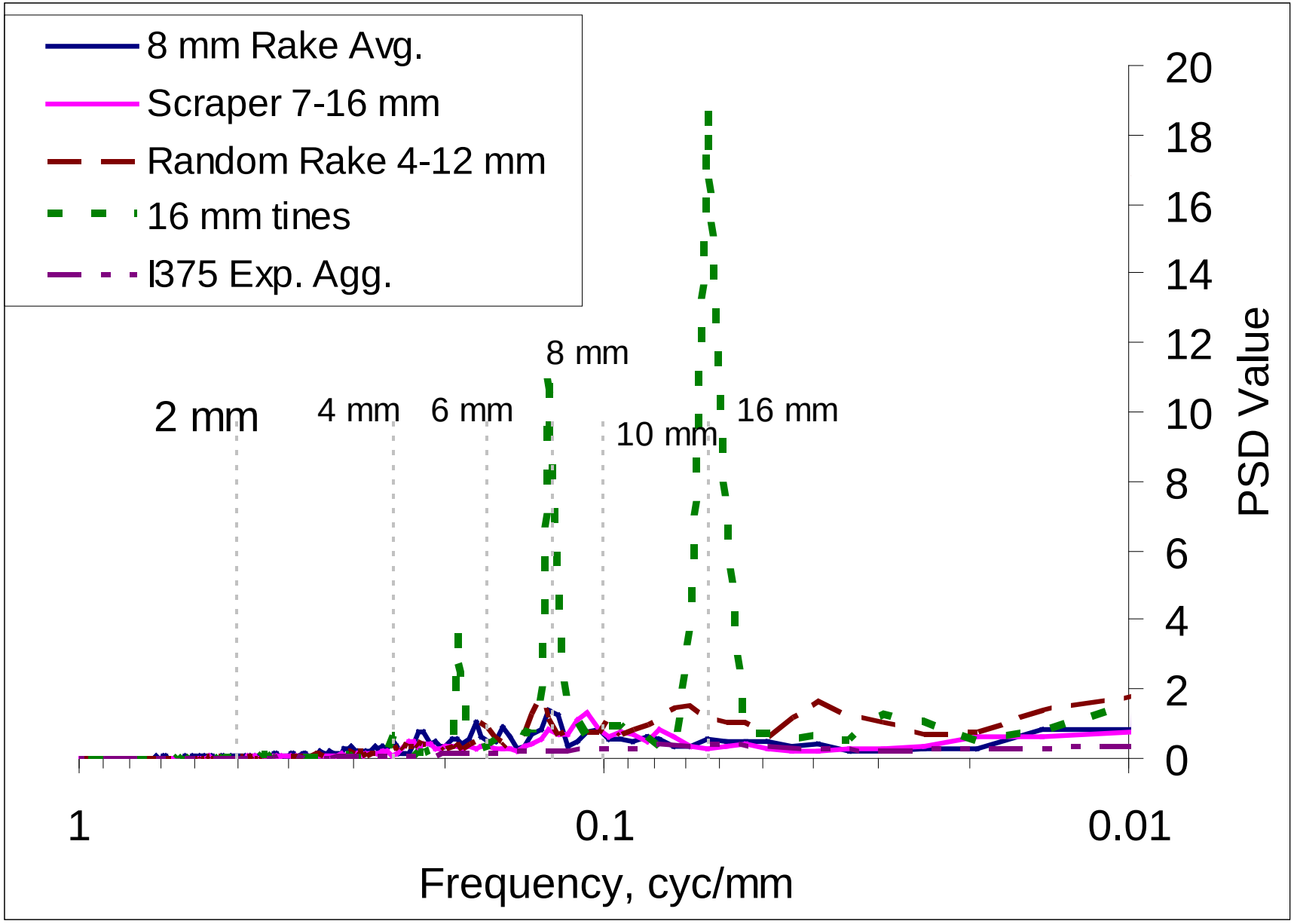


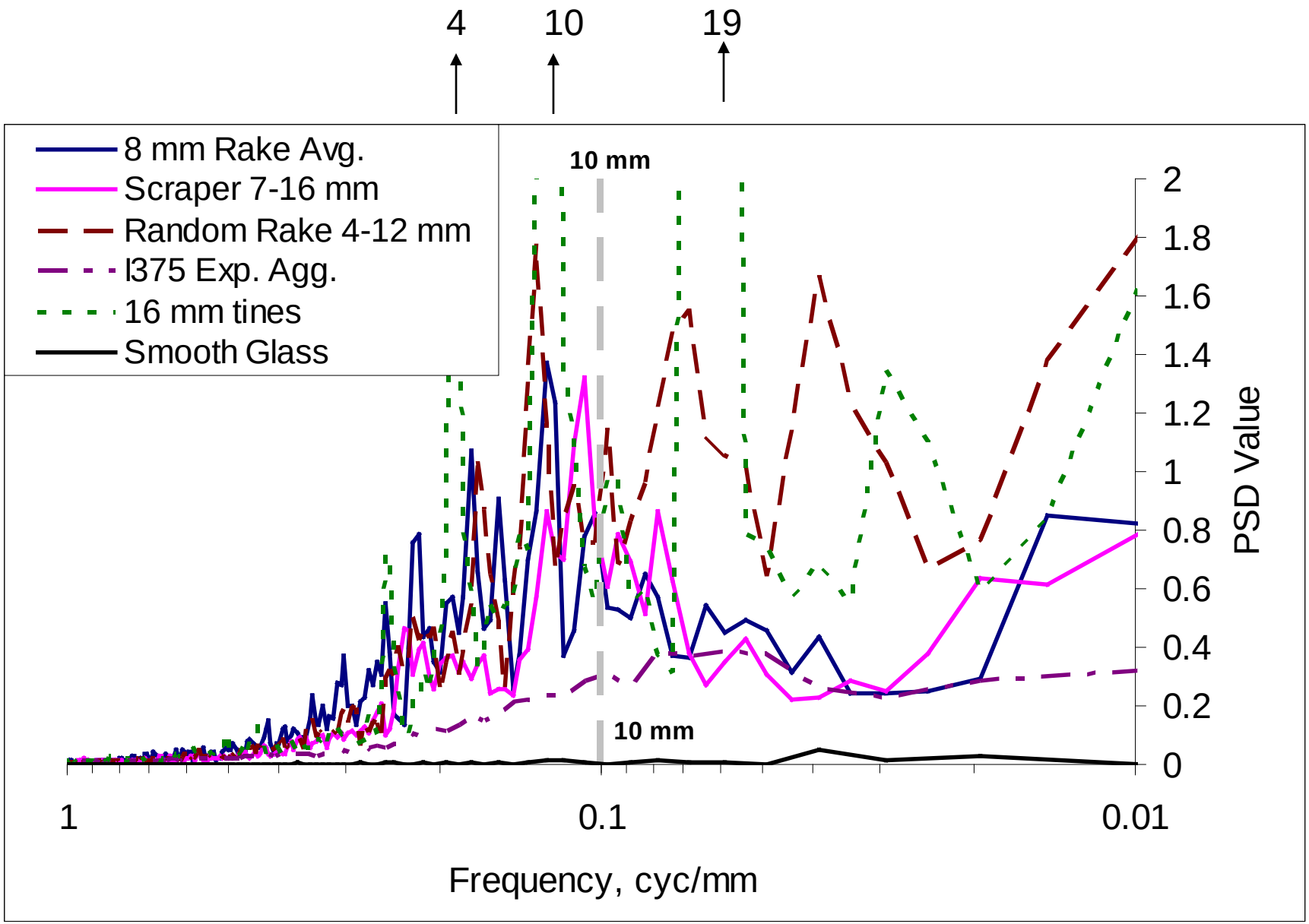
I-375 ROBUCO-type Exposed Aggregate, 13-yrs

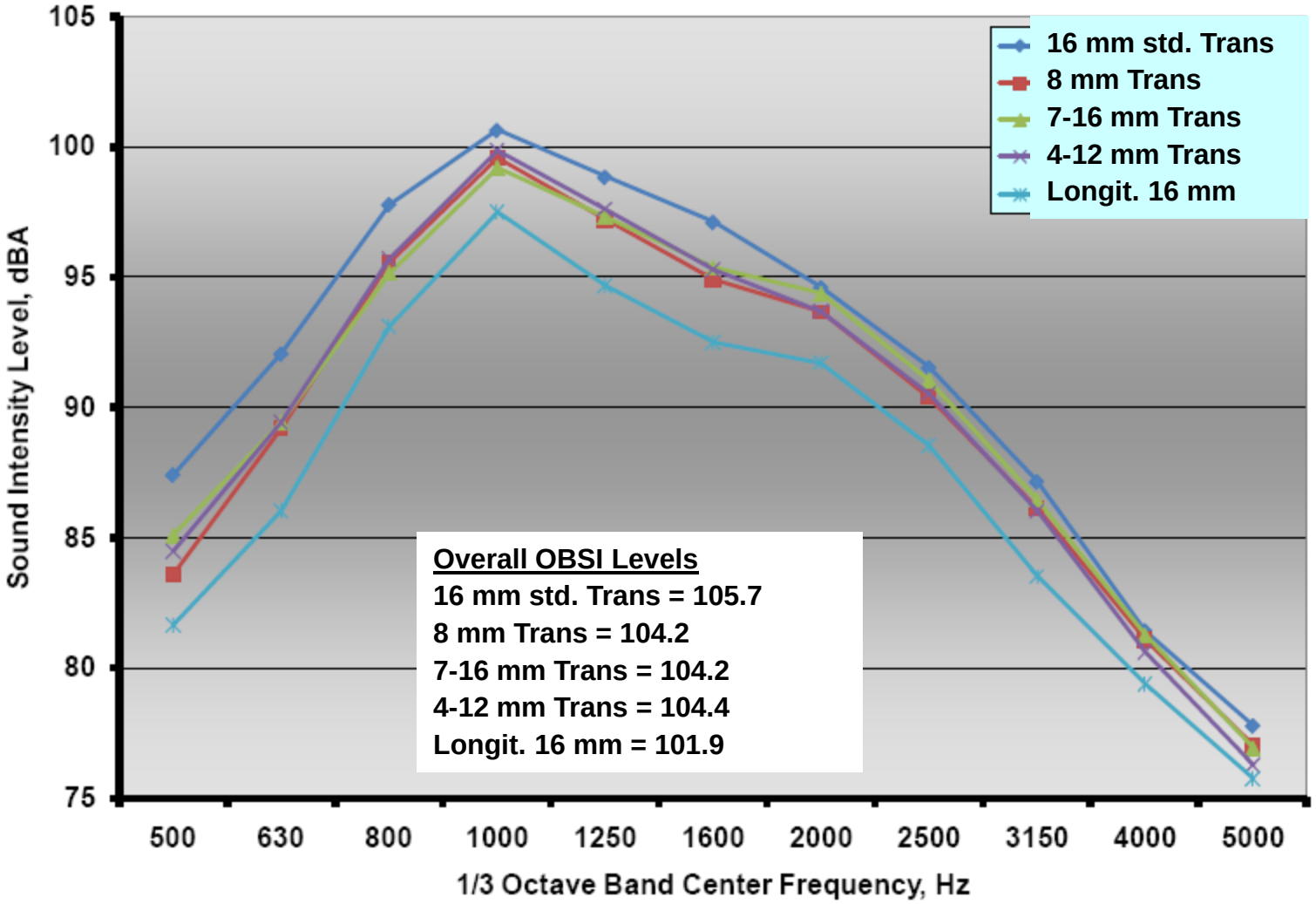


I-375 ROBUCO-type Exposed Aggregate, 13-yrs




8 mm Rake Avg.
Scraper 7-16 mm
Random Rake 4-12 mm
16 mm tines
I375 Exp. Agg.
2 mm
4 mm
6 mm
8 mm
10 mm
16 mm
20
18
16
14
12
10
8
6
4
2
0
PSD Value
1
0.1
0.01
Frequency, cyc/mm


4
10
19
8 mm Rake Avg.
Scraper 7-16 mm
Random Rake 4-12 mm
l375 Exp. Agg.
16 mm tines
Smooth Glass
10 mm
10 mm
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
PSD Value
1
0.1
0.01
Frequency, cyc/mm



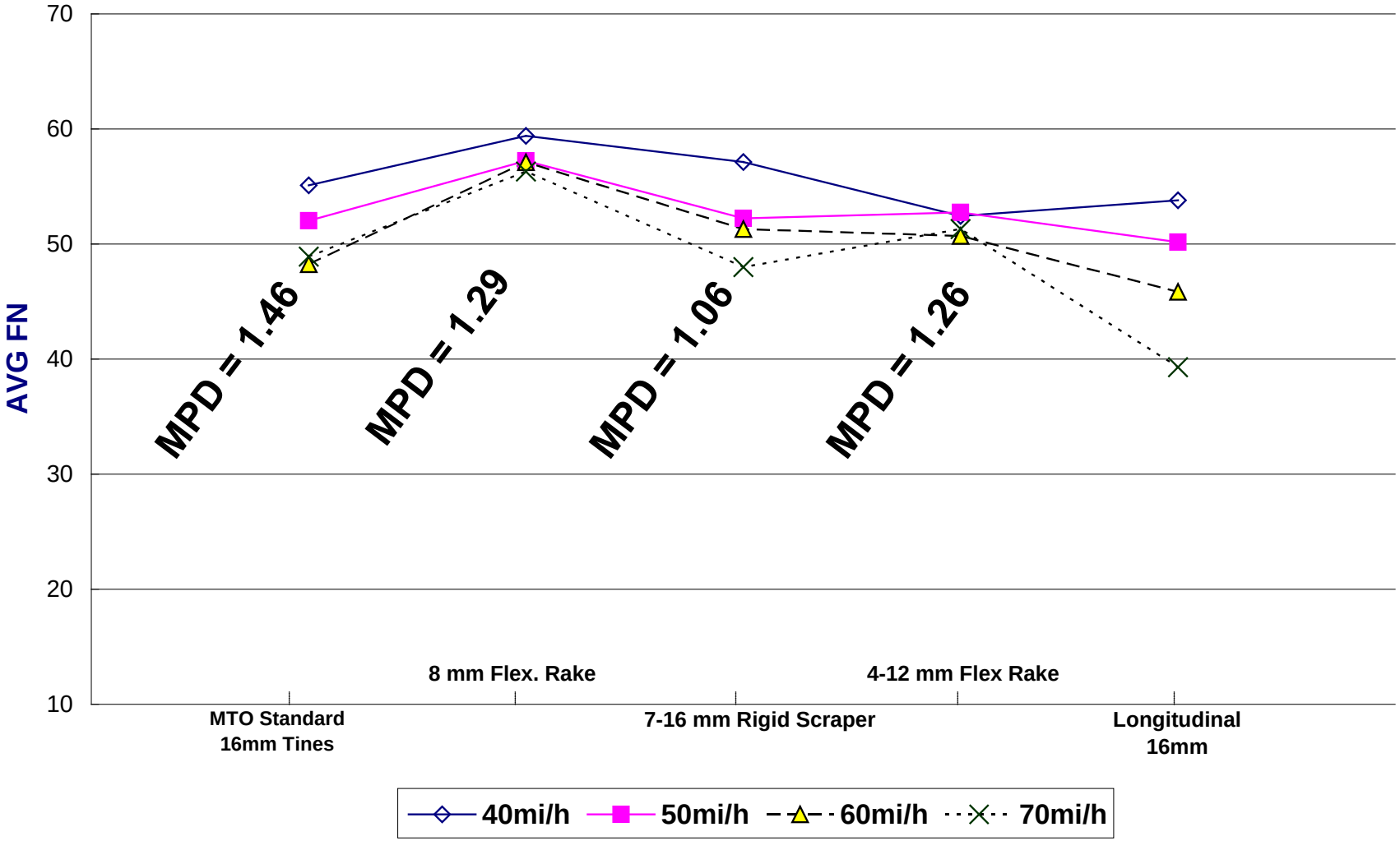
NOTE: Concrete Barrier Next to Test Lane Increased Noise Levels


Deep 16-mm Tining
Ripples and Dimples
2-4 inch waves

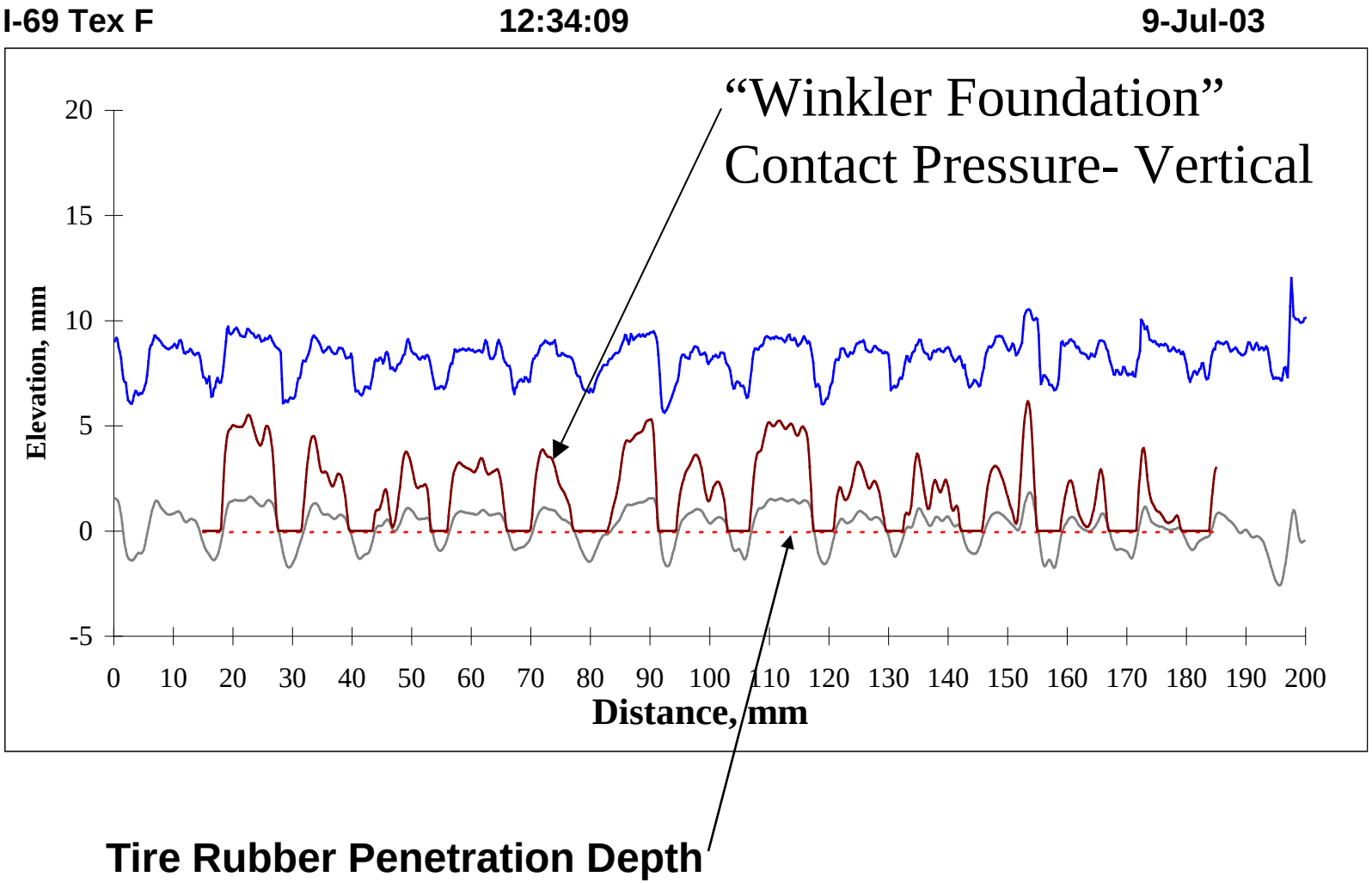
MTO/FHWA Experimental Concrete Textures

Hwy 401 - West of Belle River Rd (IC-34)

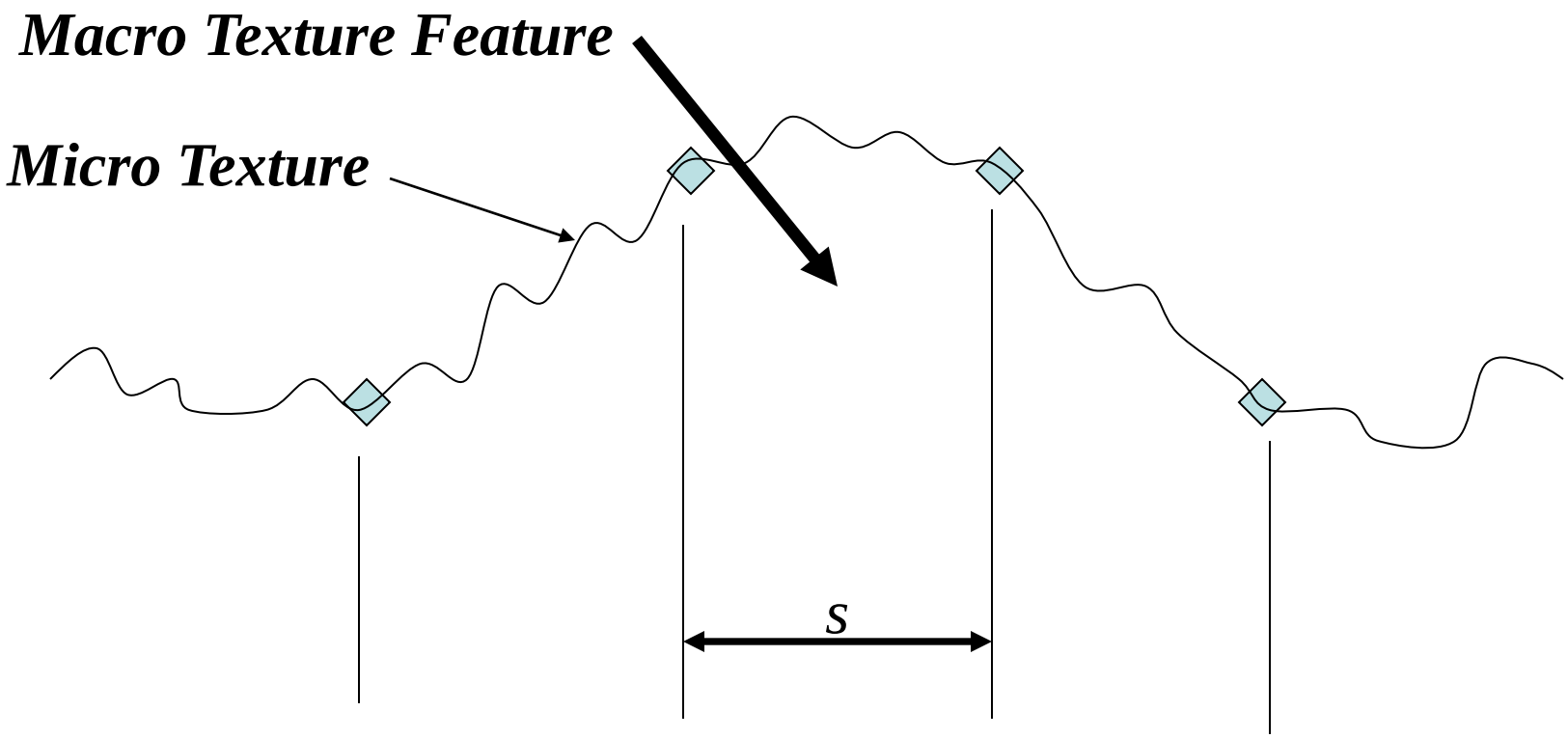
ASTM E501 Ribbed Tires



Digital Friction Simulation

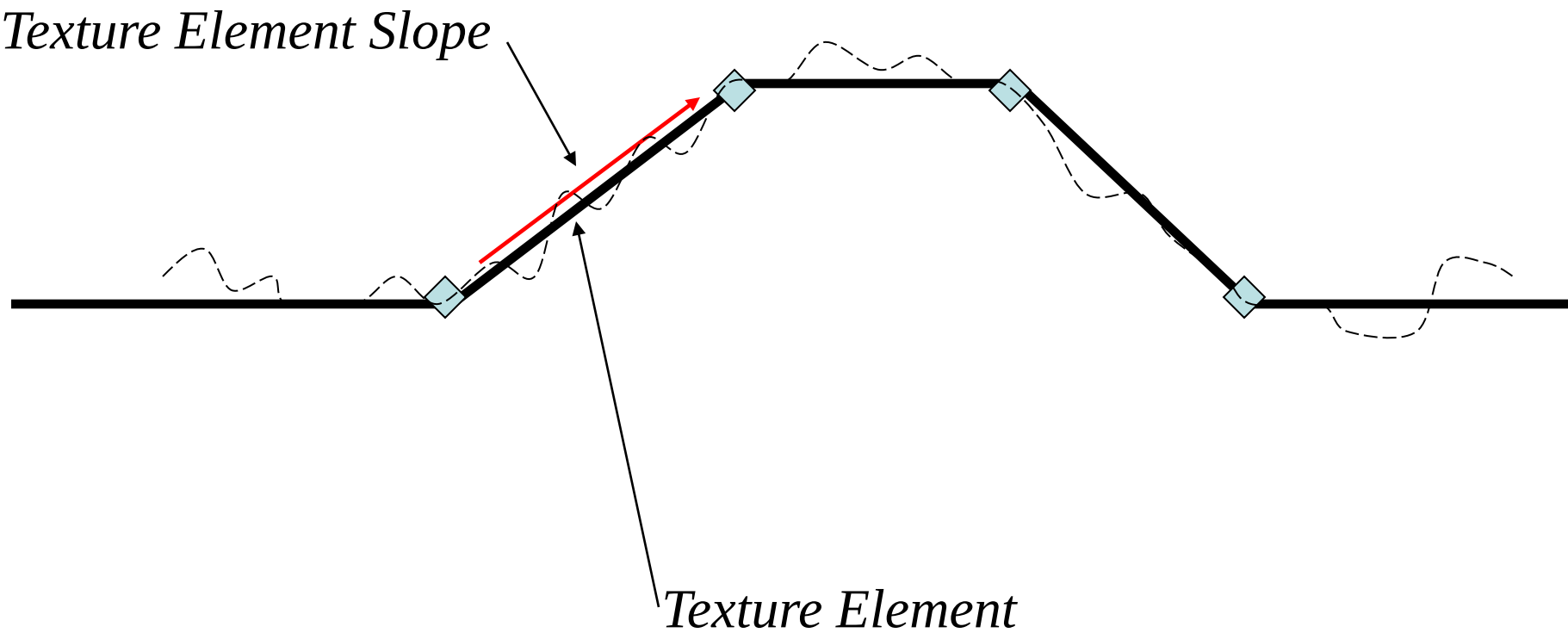


Texture scan data is evenly spaced point elevations

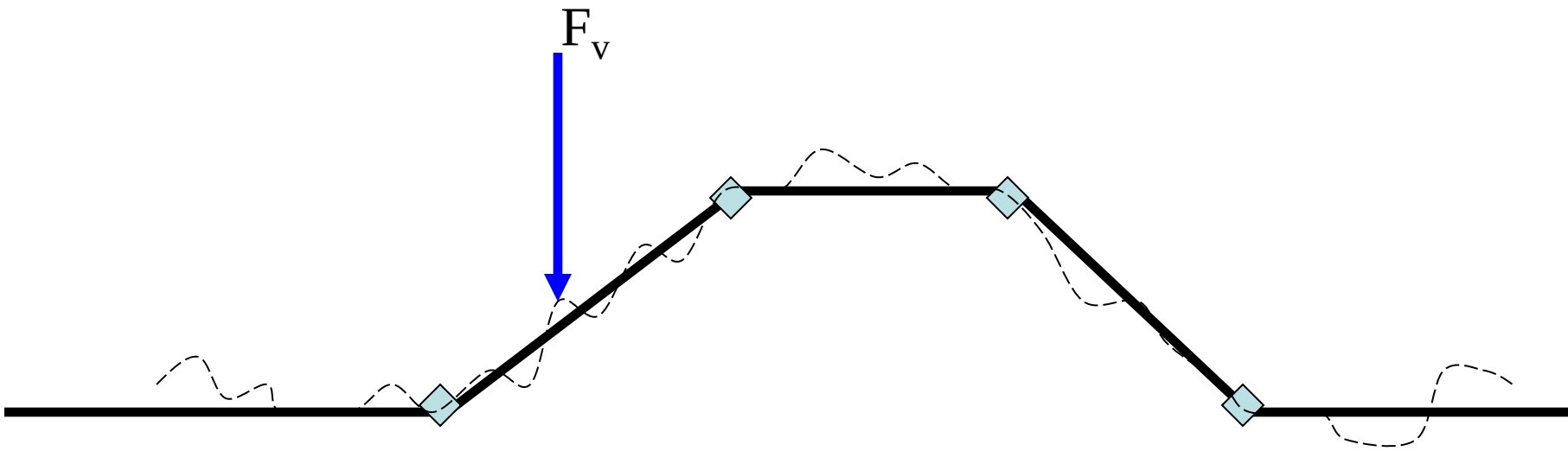


Filtered MDOT Texture Scanning Laser Data, s = 0.2 mm

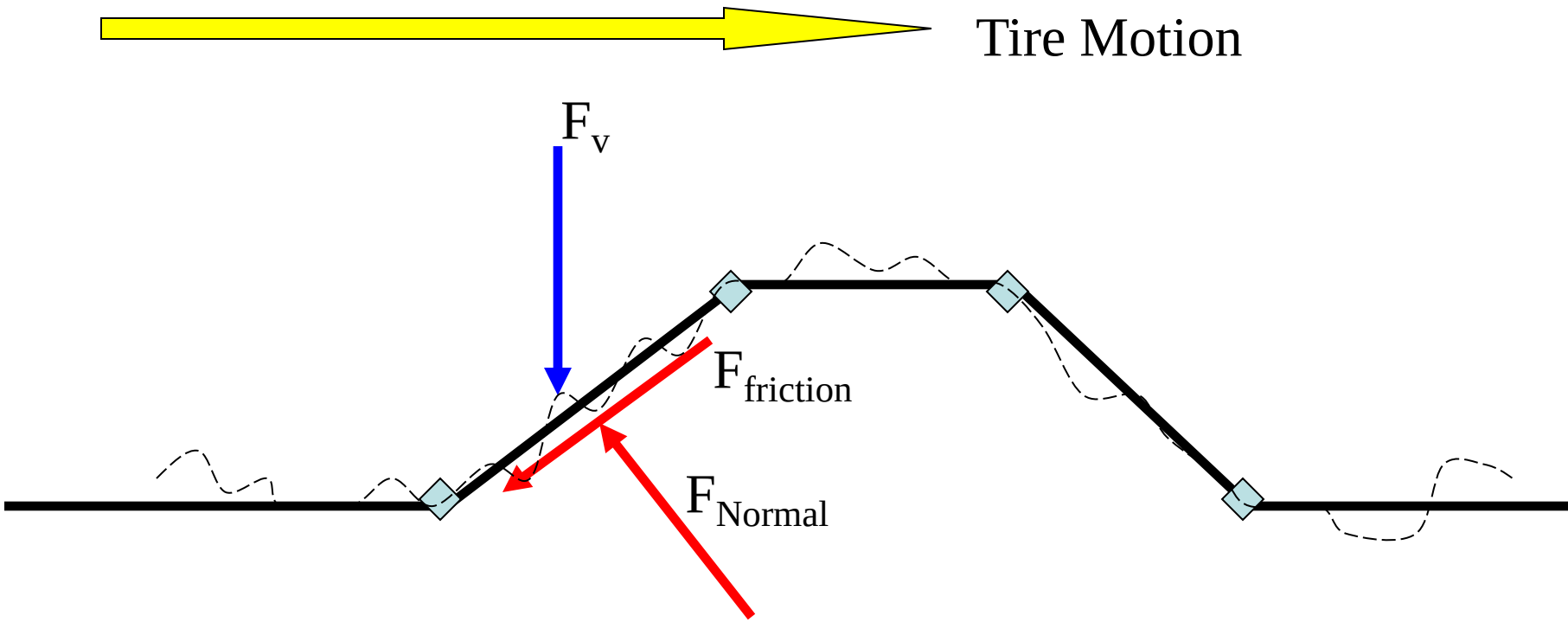
A “Texture Element” has an Average Elevation, and also a Slope Value



A "Texture Element" has an Average Vertical Contact Pressure Calculated from a Winkler Model for tire rubber

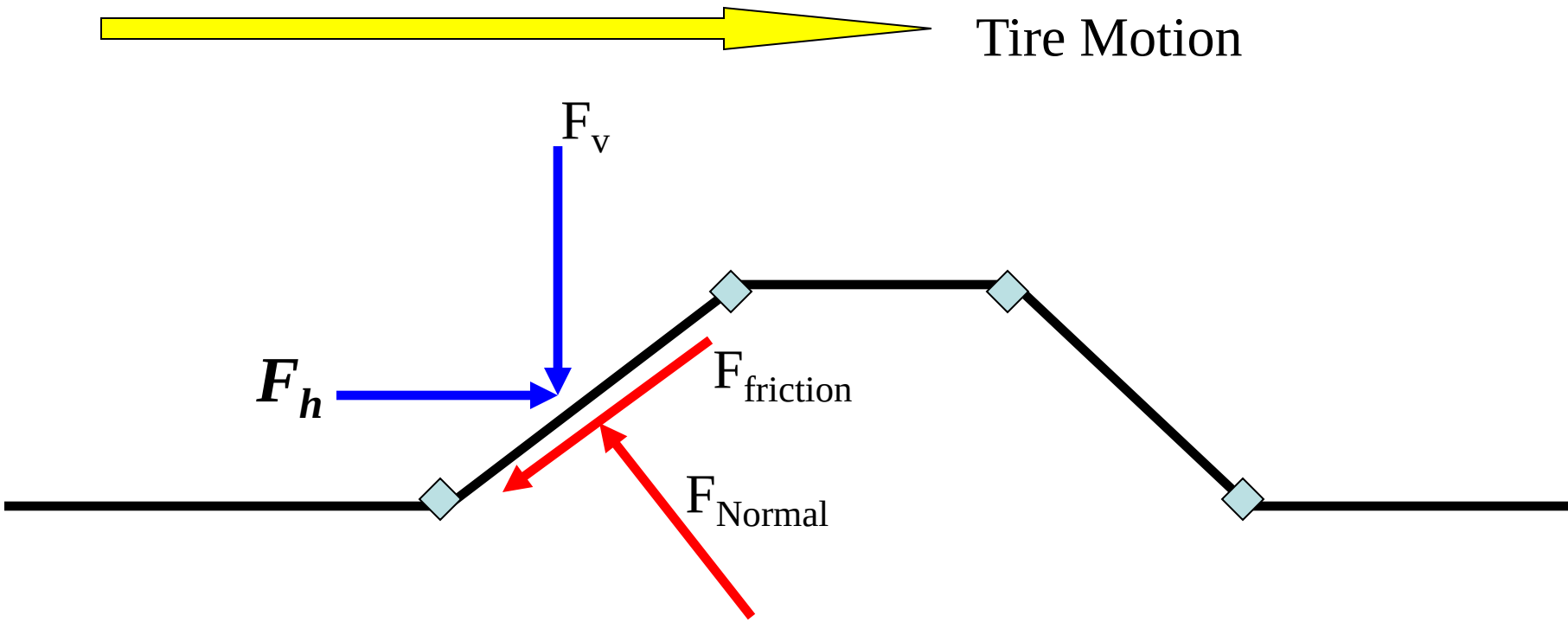


1. F_v is from Winkler Rubber Model



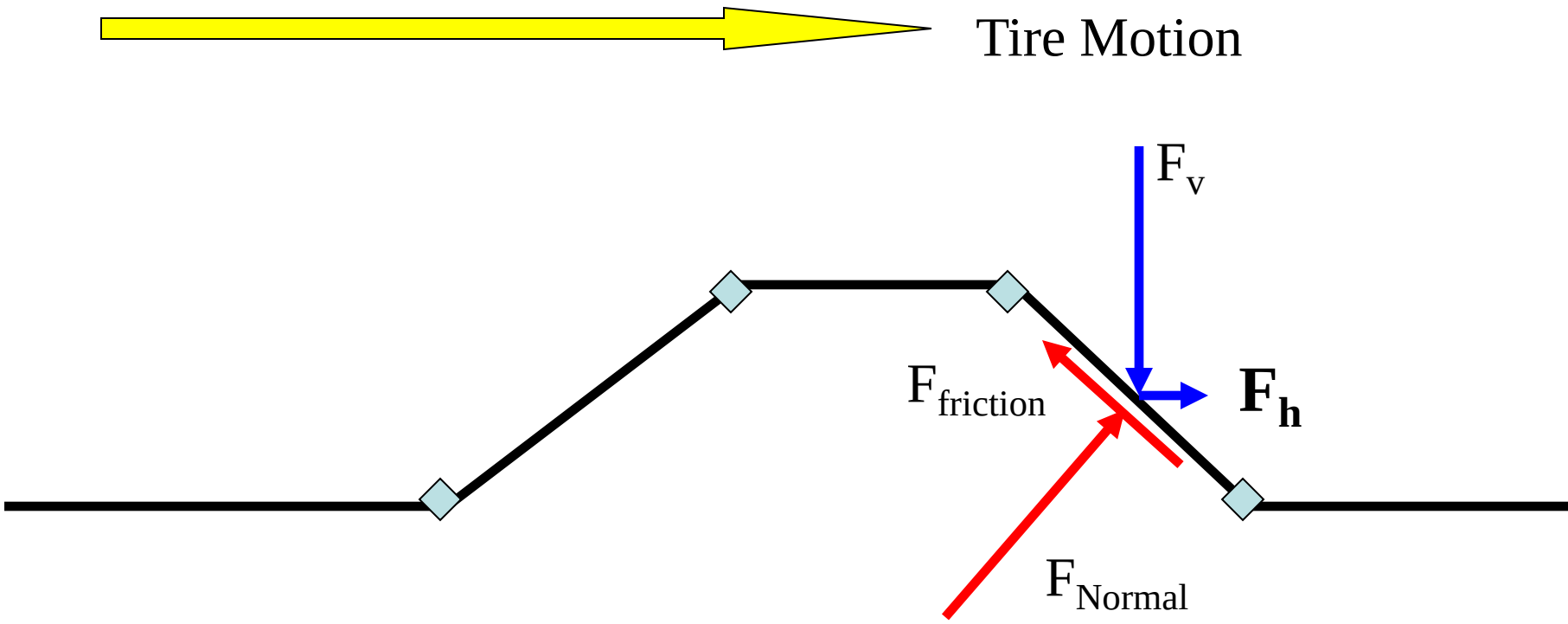
1. F_v is from Winkler Rubber Model
2. Calculate Normal Force, F_{Normal}, and "Mobilized" Friction, $F_{friction}$, on the texture slopes from F_v using Statics.

$$F_{friction} = (\text{assumed } f)F_{Normal}$$



1. F_v is from Winkler Rubber Model
2. Calculate Normal and "mobilized" Friction on the texture slopes from F_v using statics.
3. Calculate F_h from Normal and Friction forces using statics.

F_h = Sliding Resistance for the Texture Element



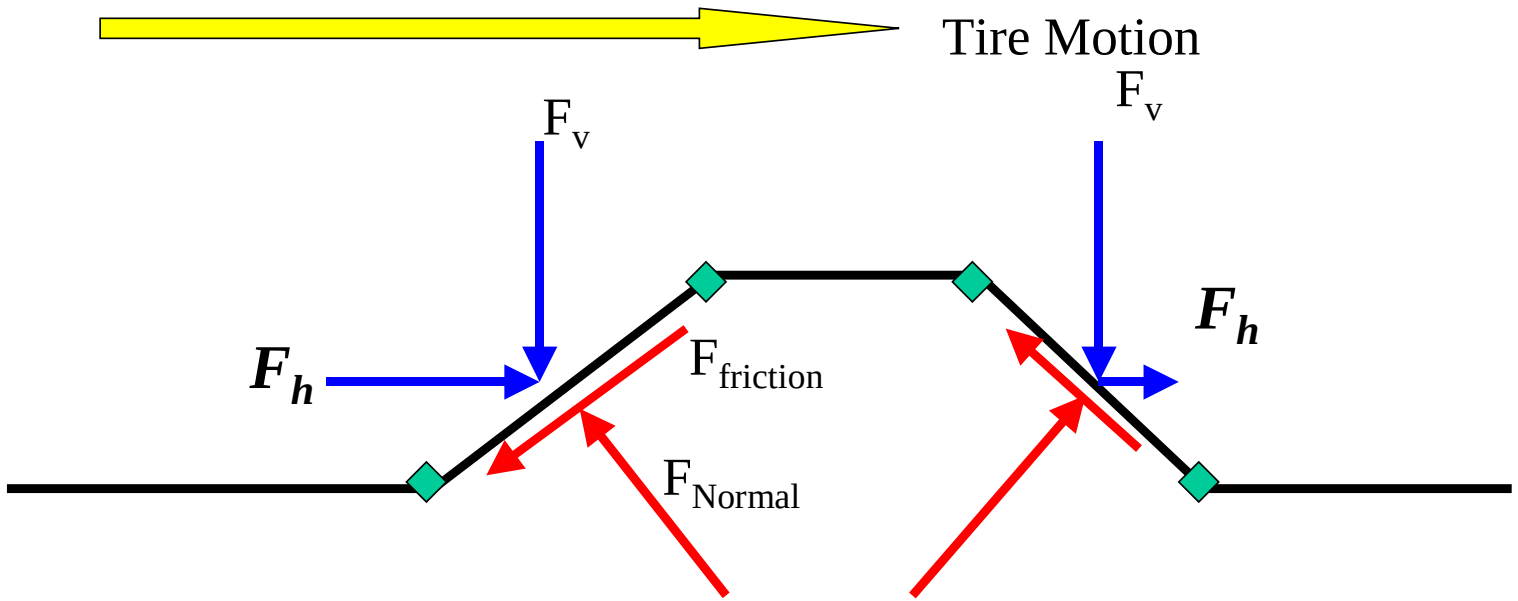
1. F_v is from Winkler Rubber Model
2. Calculate Normal and "mobilized" Friction on the texture slopes from Fv using trigonometry.
3. Calculate $\boldsymbol{F_h}$ from Normal and Friction forces using trigonometry

NOTE – $\boldsymbol{F_h}$ can be "negative" on the "backside" of texture if the slope of the backside is steep ➔normal forces work against you

Sliding Resistance Index =

$$\sum_{i=1}^{n} F_h$$

n = total number of texture elements under a tire contact patch, where each texture element has a width = to the tire width, and length equal to the texture scan data point spacing.



1. F_v is from Winkler Rubber Model
2. Calculate Normal and "mobilized" Friction on the texture slopes from F_v using trigonometry.
3. Calculate $\boldsymbol{F_h}$ from Normal and Friction forces using trigonometry

$$\textbf{Sliding Resistance Index} = \sum_{i=1}^{n} F_h$$

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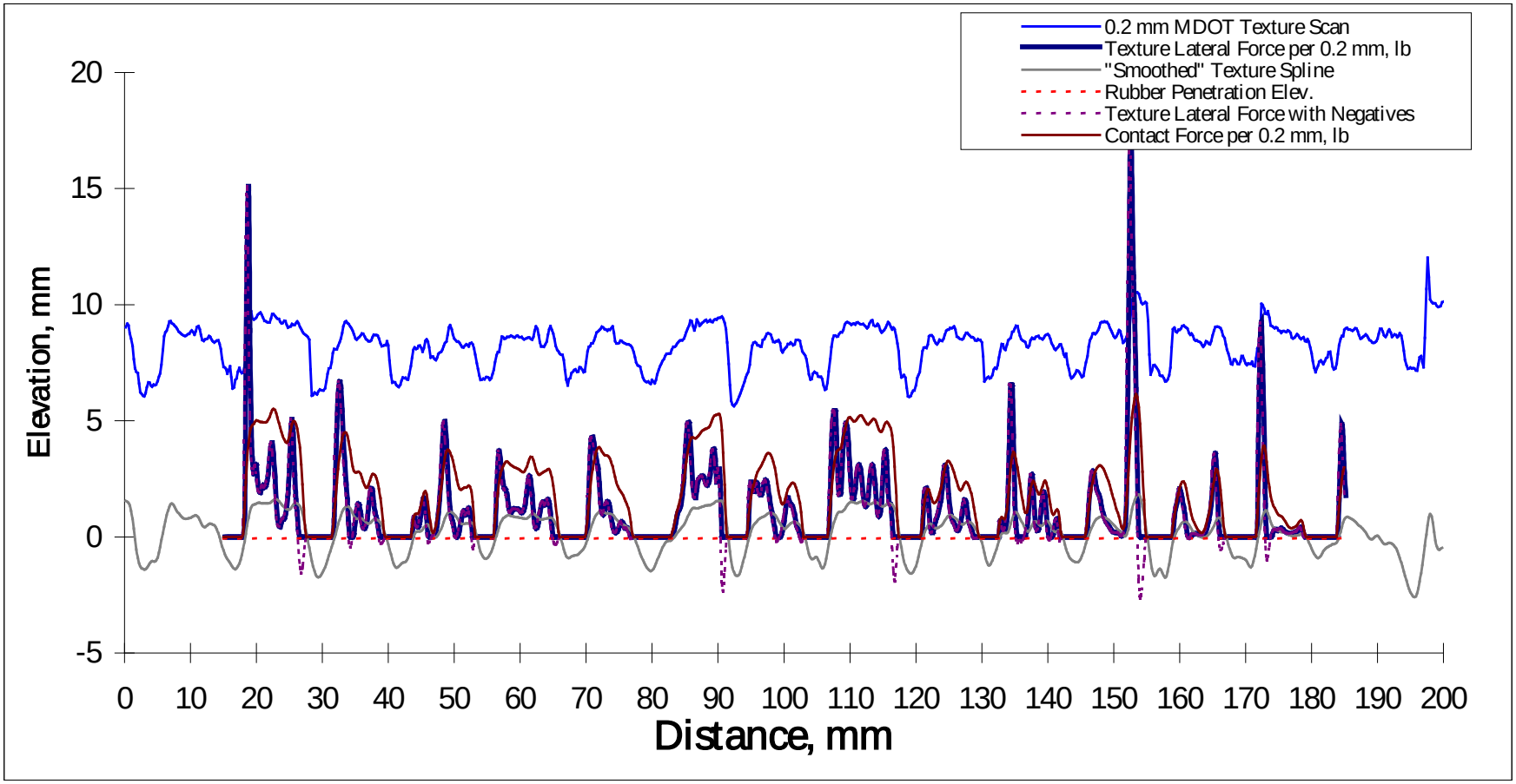
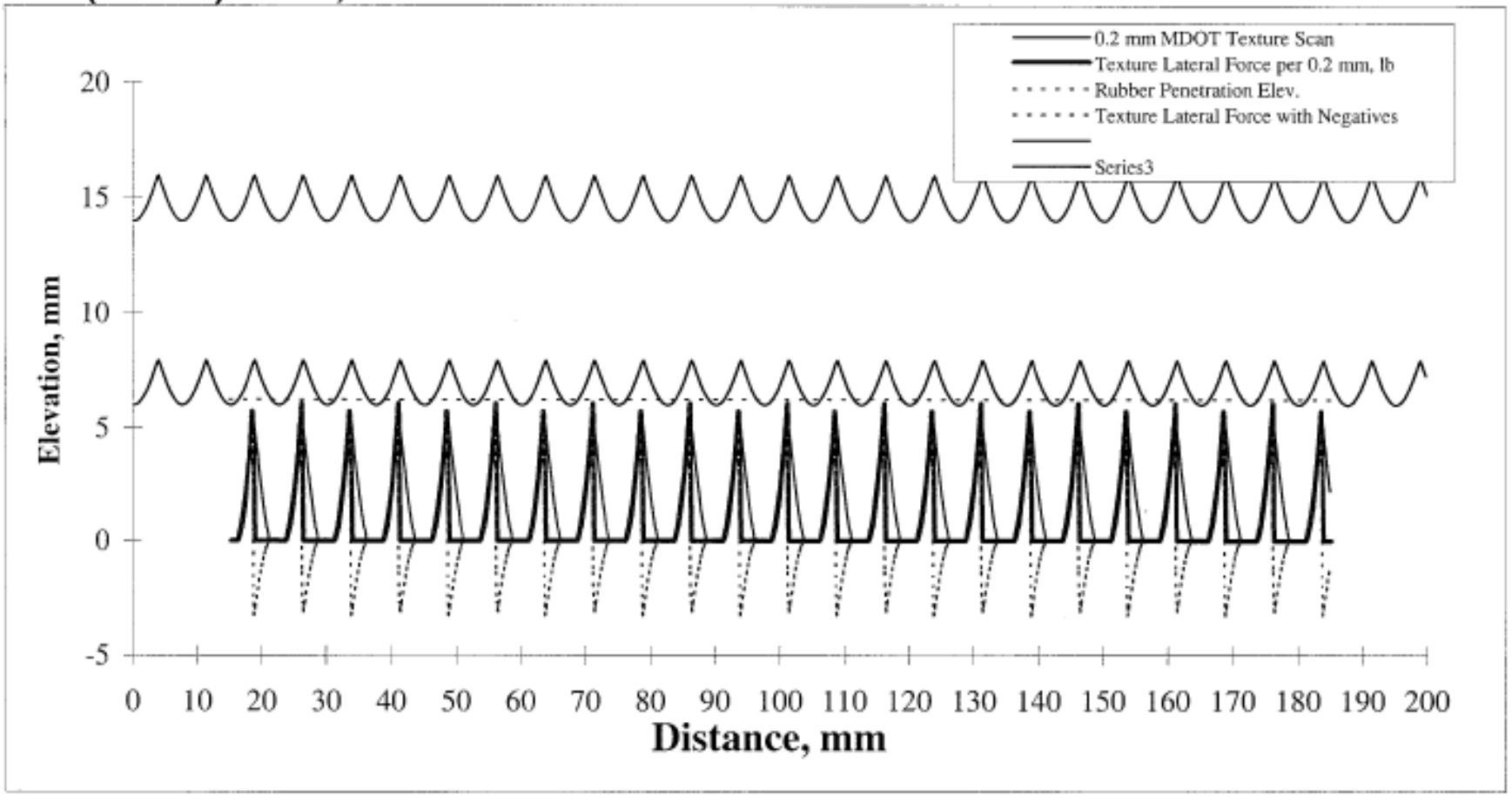


		with	*without*	*negatives*	*% Contact*
Sliding Resistance Index, lb/lb =		**0.598**	**0.62**		**69%**
Fundamental Microtex-Rubber Friction =	0.45			7" Wide Contact Length, in =	6.70
Tire Pressure, psi =	32			Total Up Force, lb =	1500
Tire Load, lb =	1500			Average psi =	32.0
Tire k-value, psi/inch =	1500			Tire Bottom Elev., mm =	-0.073

Macro Shape gives 33% Increase in Micro-Friction Value

-abs(Cosine)-->A=2, L=15 mm

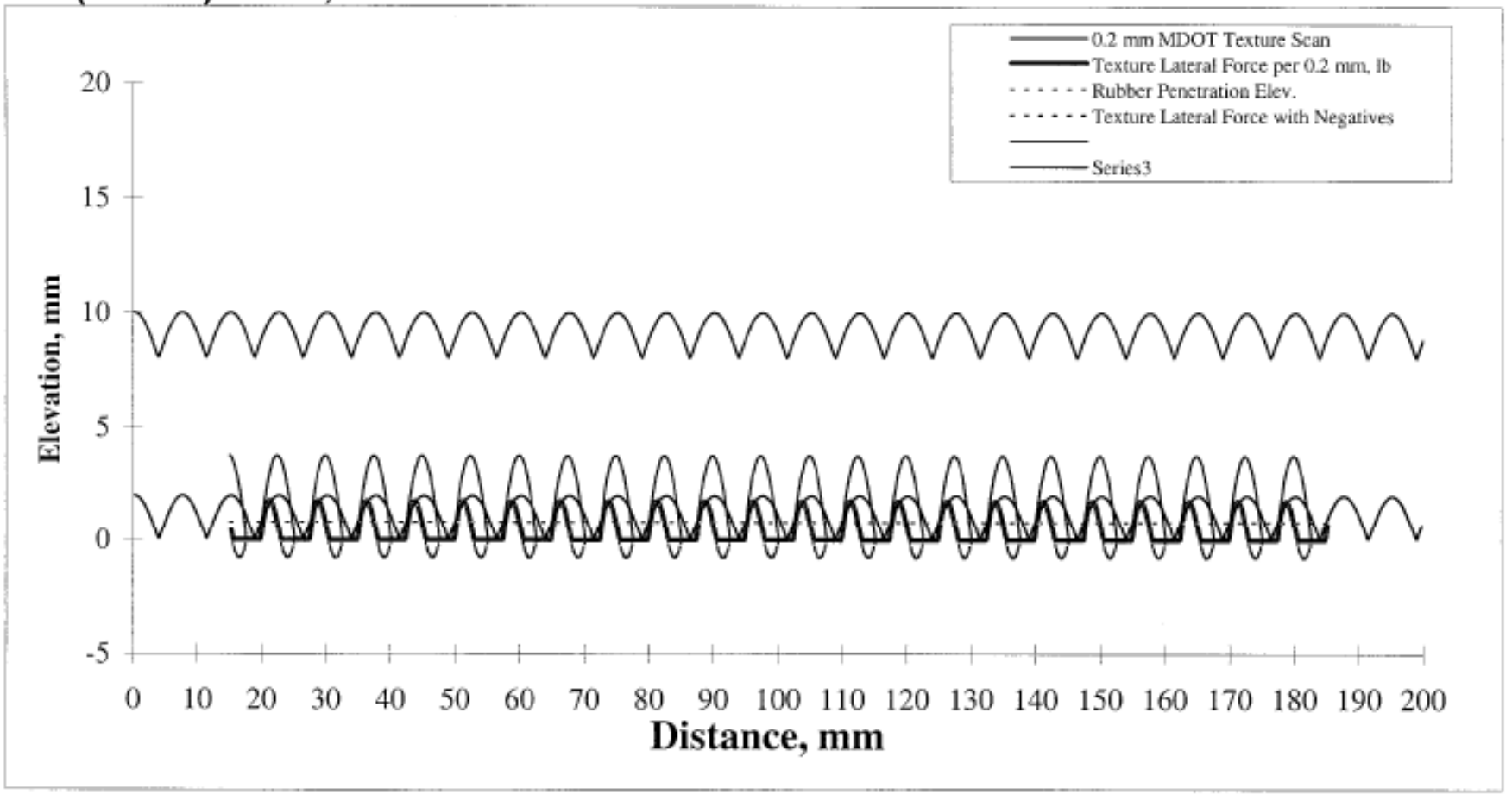


	with	without negatives
Sliding Resistance Index, lb/lb =	**0.238**	**0.50**

Fundamental Rubber Coeff of Friction =	0.15	7" Wide Contact Length, in =	6.70
Tire Pressure, psi =	32	Total Up Force, lb =	1500
Tire Load, lb =	1500	Average psi =	32.0
Tire k-value, psi/inch =	1500	Tire Bottom Elev., mm =	6.241

From 0.15 to 0.238 = 58.6% Enhancement of Micro-Friction

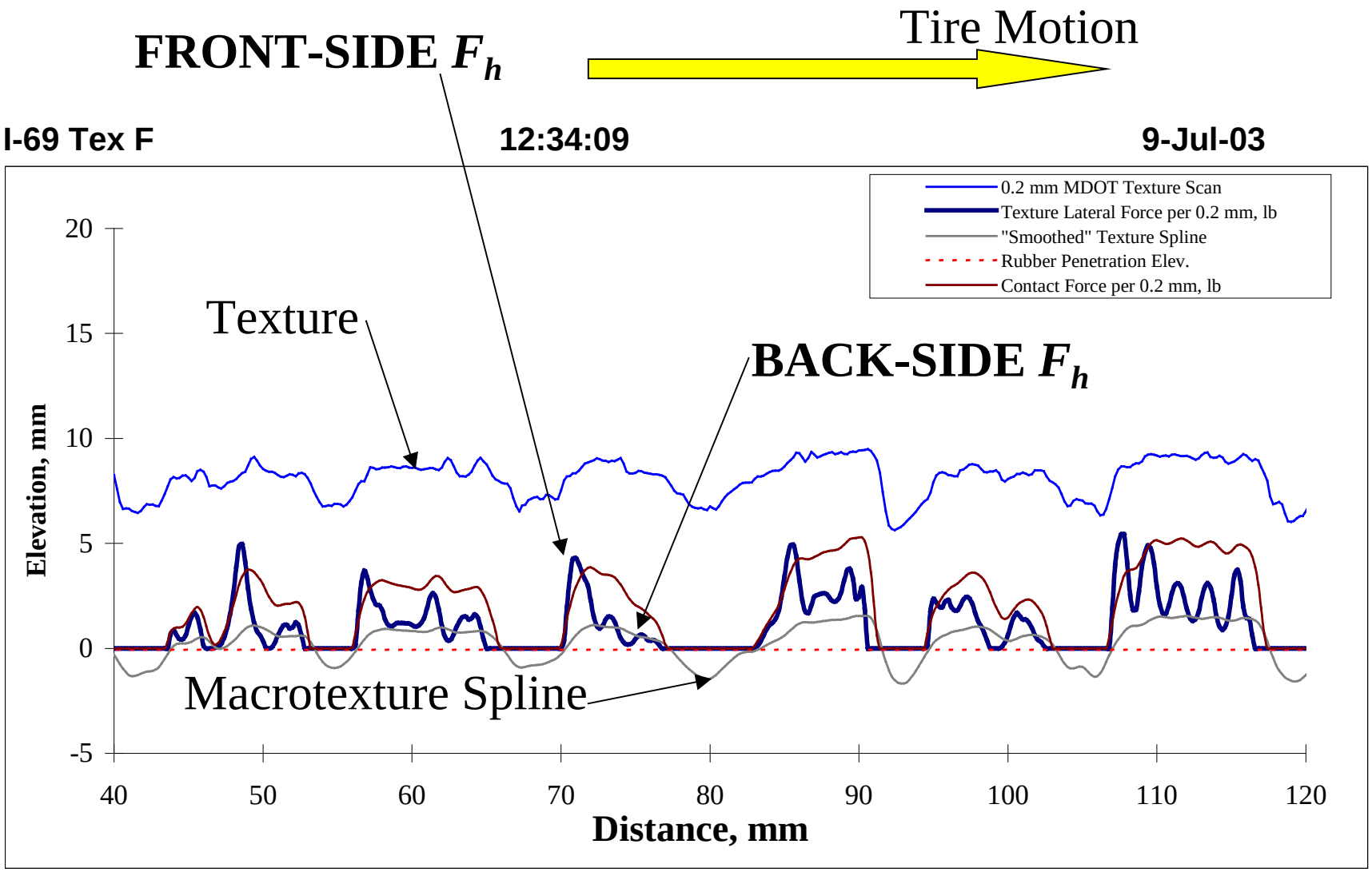
abs(Cosine)-->A=2, L=15 mm



	with	without negatives
Sliding Resistance Index, lb/lb =	**0.166**	**0.26**

Fundamental Rubber Coeff of Friction =	0.15	7" Wide Contact Length, in =	6.70
Tire Pressure, psi =	32	Total Up Force, lb =	1500
Tire Load, lb =	1500	Average psi =	32.0
Tire k-value, psi/inch =	1500	Tire Bottom Elev., mm =	0.841

From 0.15 to 0.166 = 10.7% Enhancement of Micro-Friction



Simulating hard breaking and dry friction $f = 0.45$

Evolution of Friction Demand

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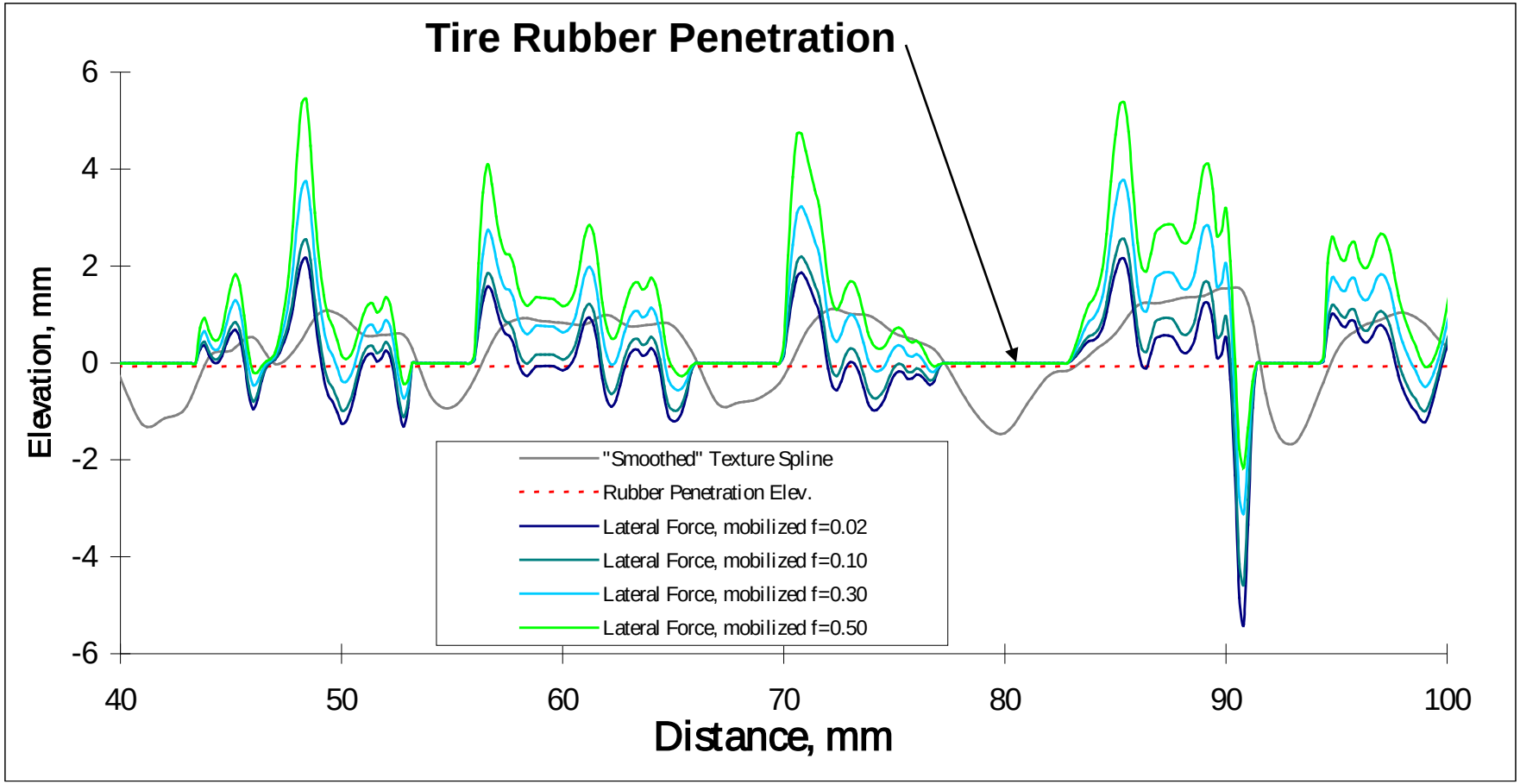
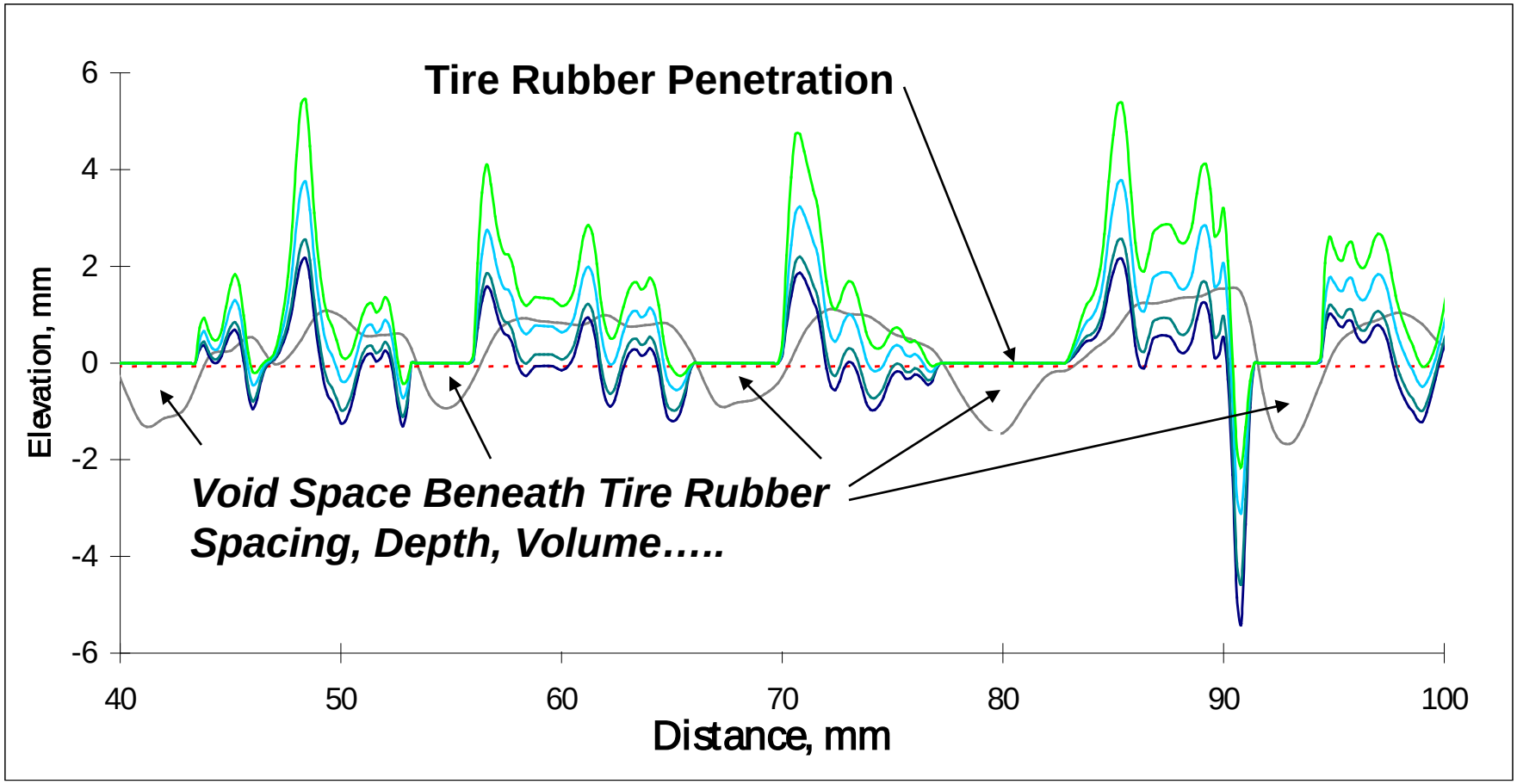
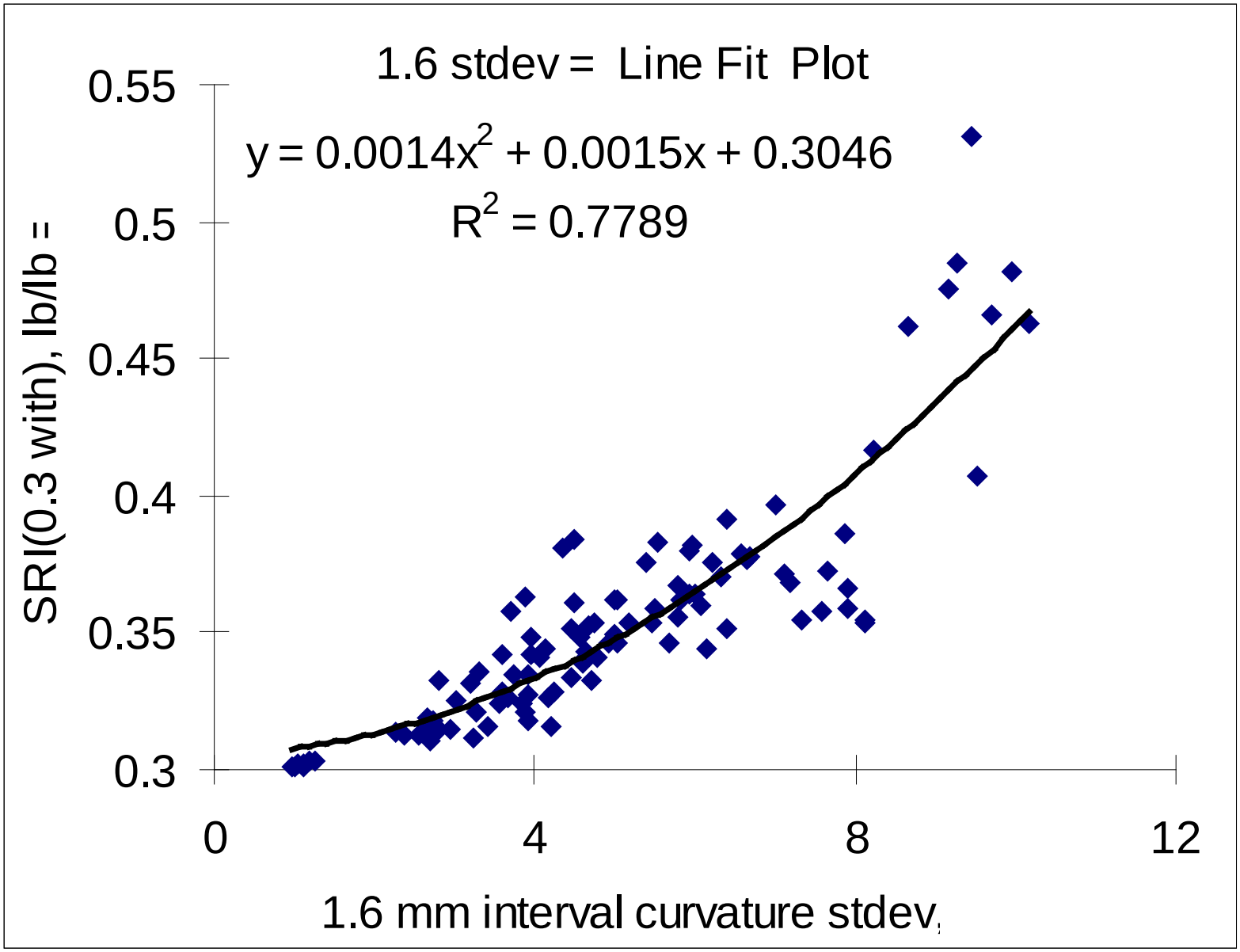
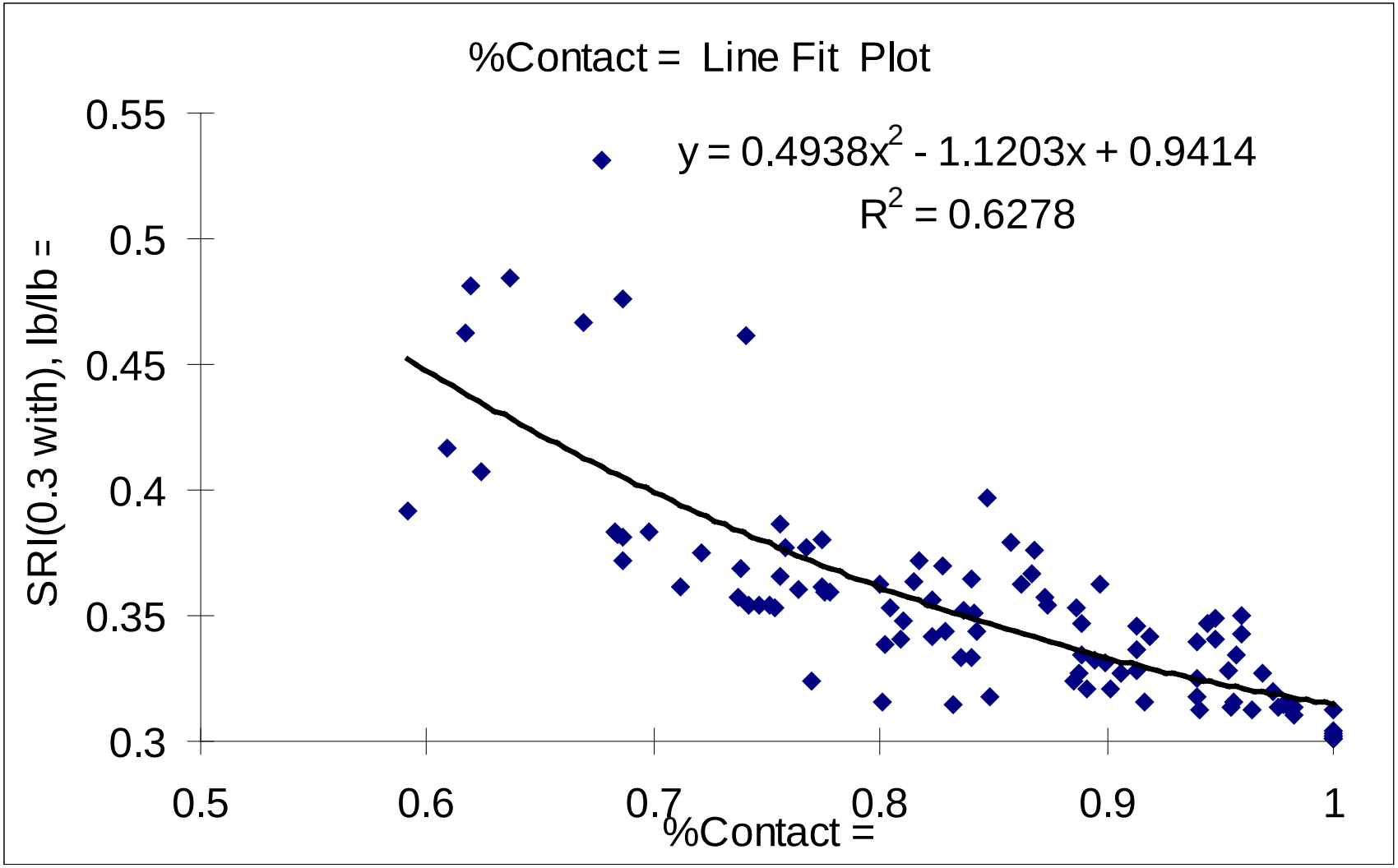
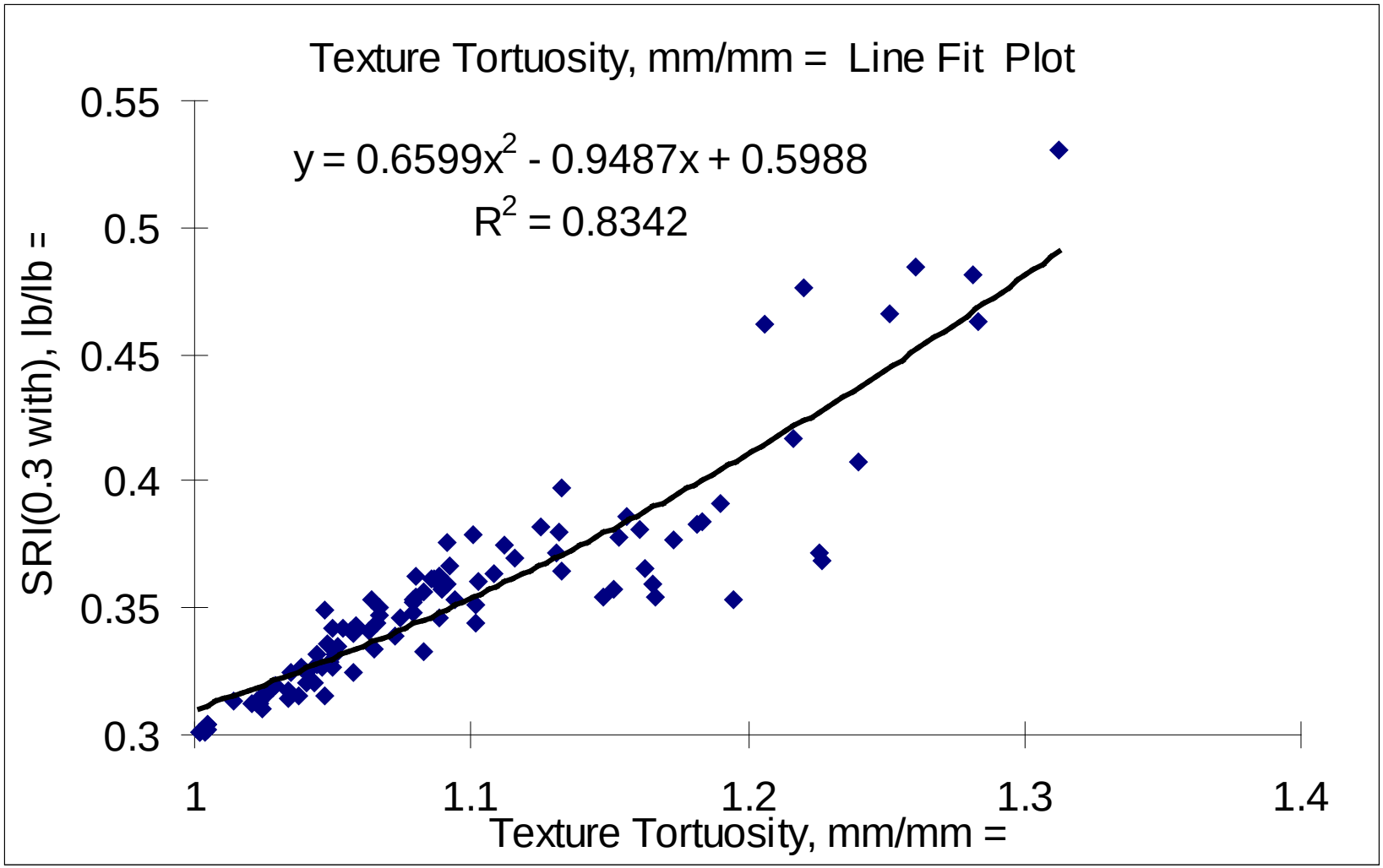


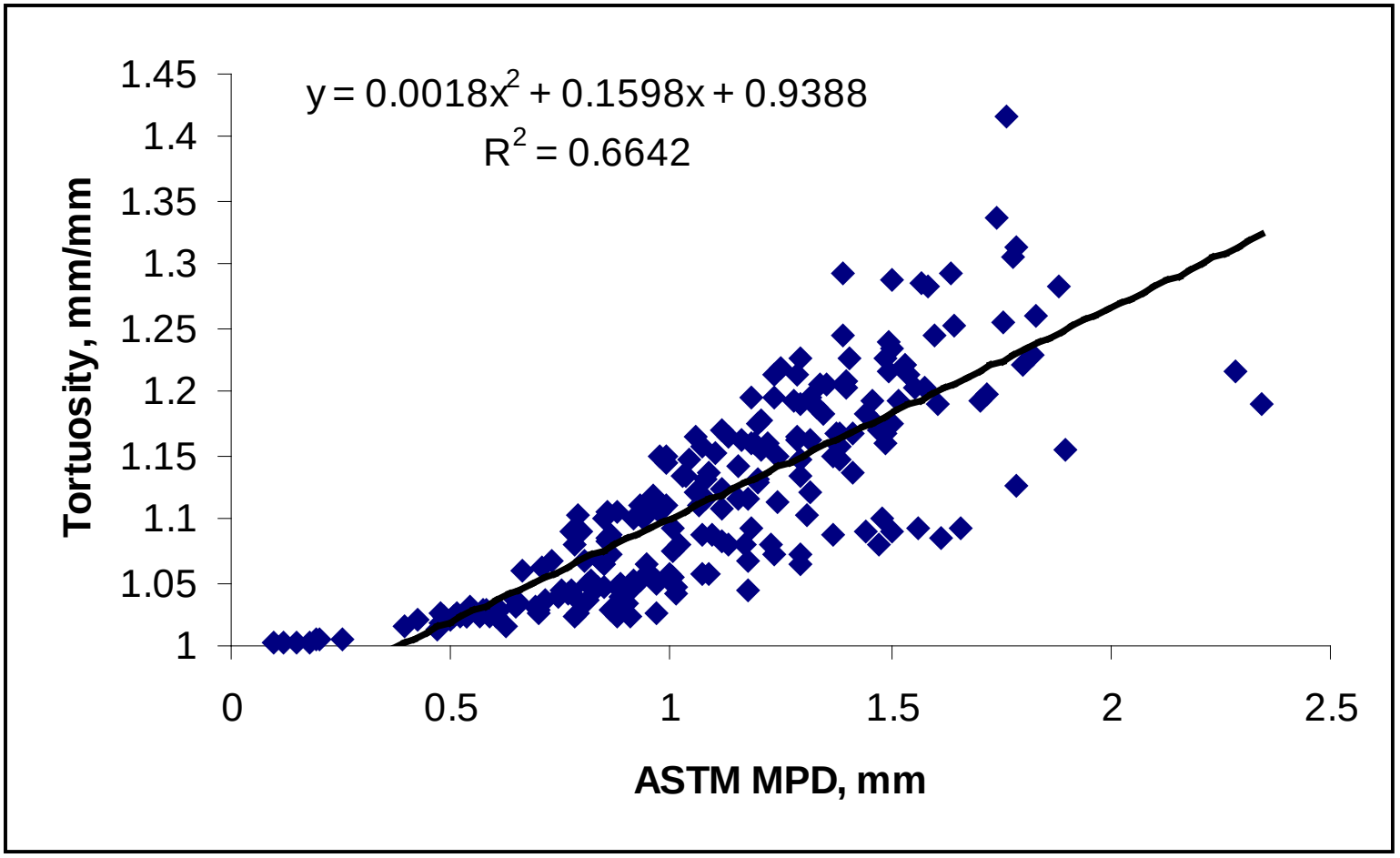
I-69 Tex F 12:34:09 9-Jul-03



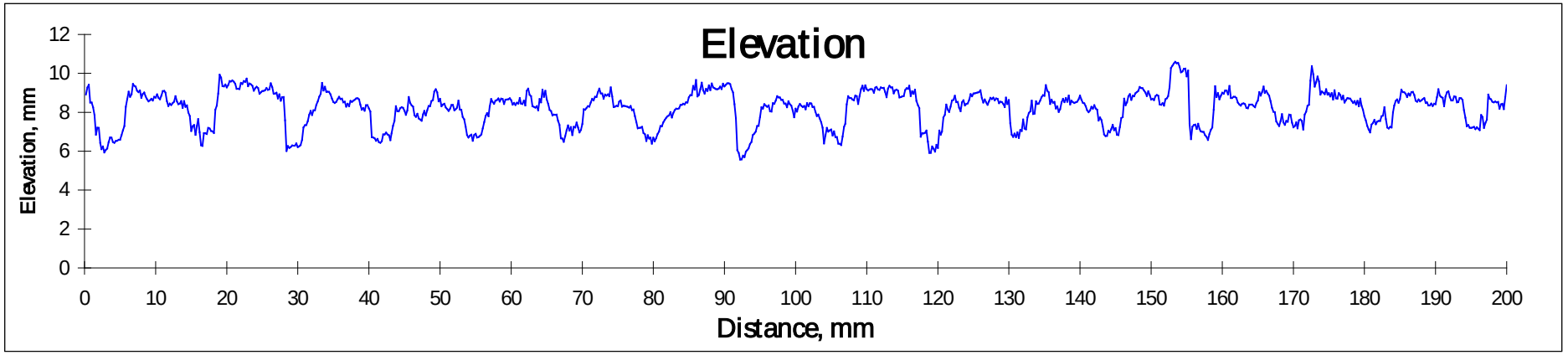

1.6 stdev = Line Fit Plot
y = 0.0014x2 + 0.0015x + 0.3046
R2 = 0.7789
SRI(0.3 with), lb/lb =
0.55
0.5
0.45
0.4
0.35
0.3
0
4
8
12
1.6 mm interval curvature stdev

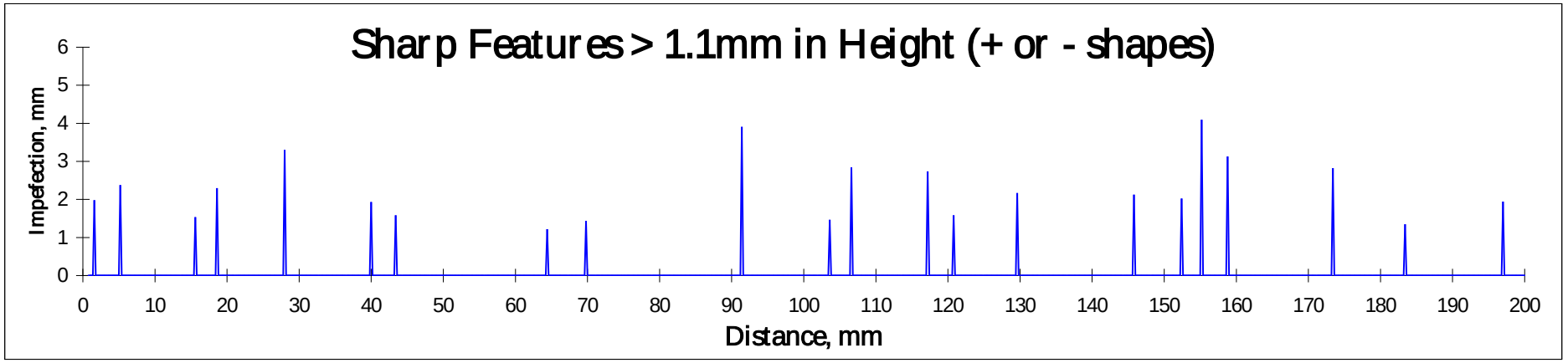

%Contact = Line Fit Plot
y = 0.4938x2 - 1.1203x + 0.9414
R2 = 0.6278
SRI(0.3 with), lb/lb =
0.55
0.5
0.45
0.4
0.35
0.3
0.5
0.6
0.7
0.8
0.9
1
%Contact =


Texture Tortuosity, mm/mm = Line Fit Plot
y = 0.6599x2 - 0.9487x + 0.5988
R2 = 0.8342
SRI(0.3 with), lb/lb =
0.55
0.5
0.45
0.4
0.35
0.3
1
1.1
1.2
1.3
1.4
Texture Tortuosity, mm/mm =

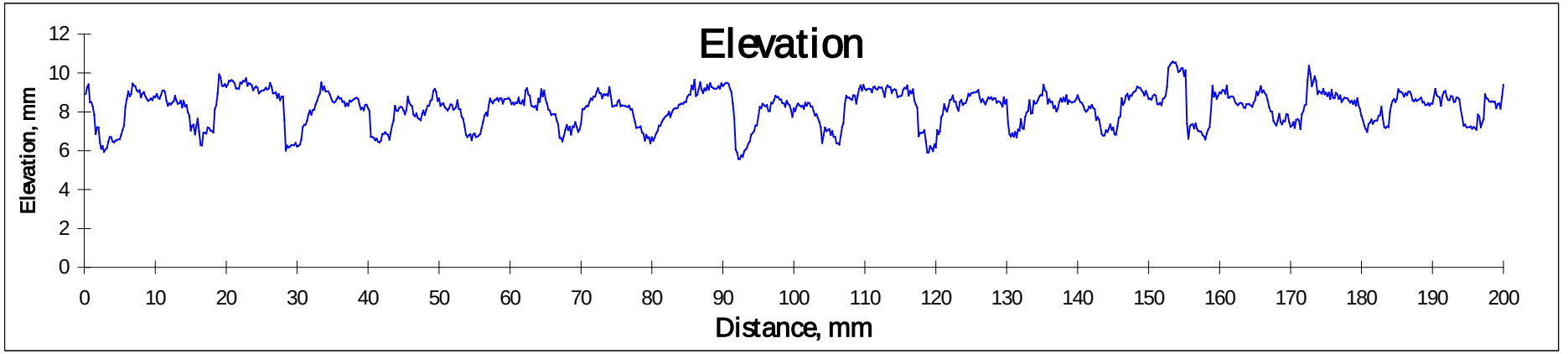

y = 0.0018x2 + 0.1598x + 0.9388
R2 = 0.6642
Tortuosity, mm/mm
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0
0.5
1
1.5
2
2.5
ASTM MPD, mm

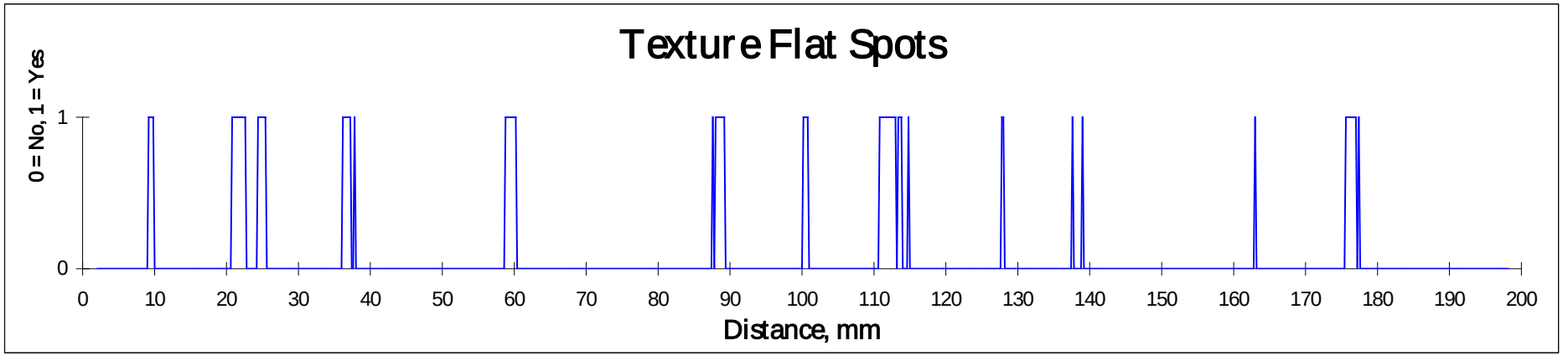
I-69 Tex F **9-Jul-03** **12:34:09**

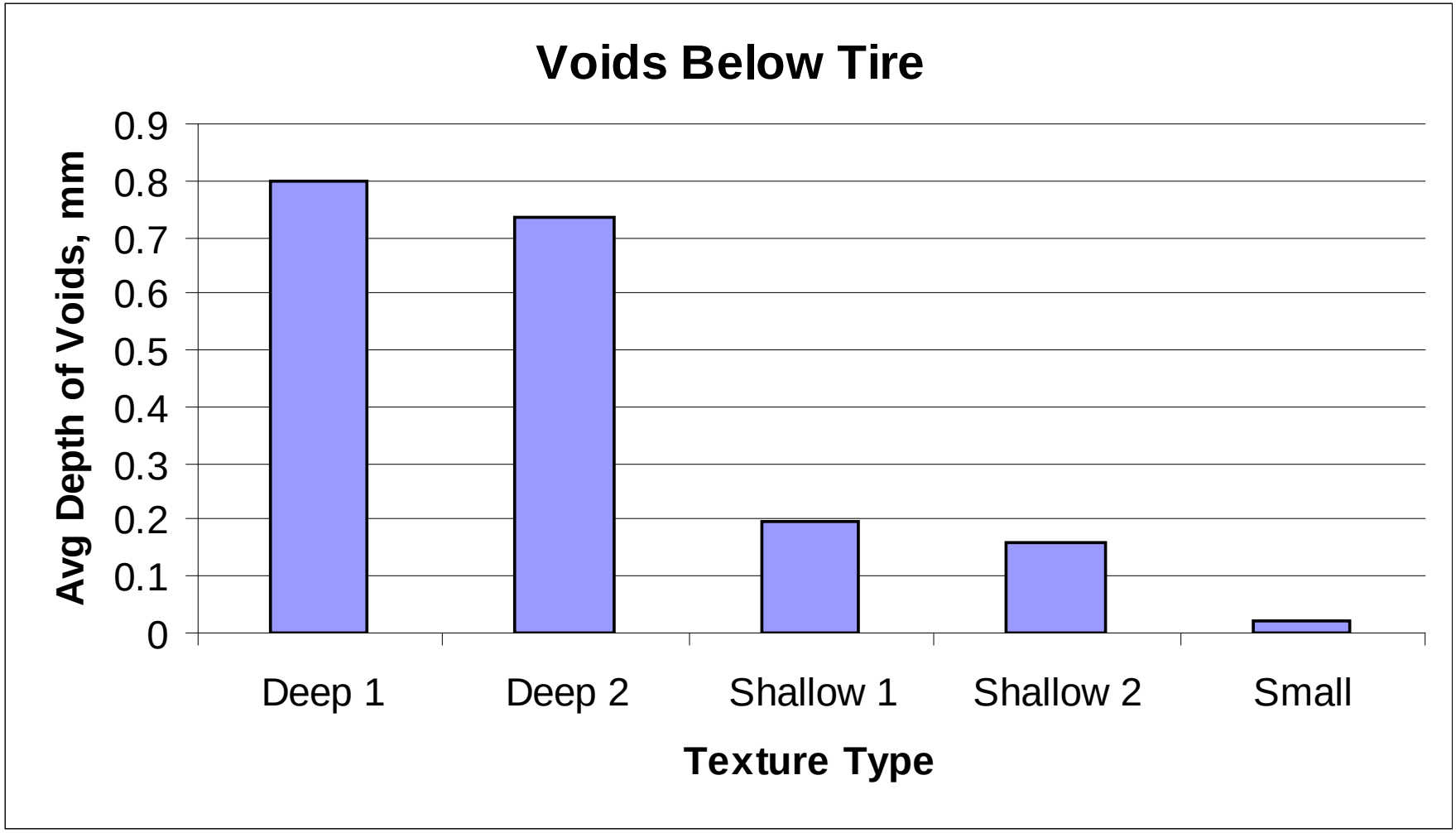


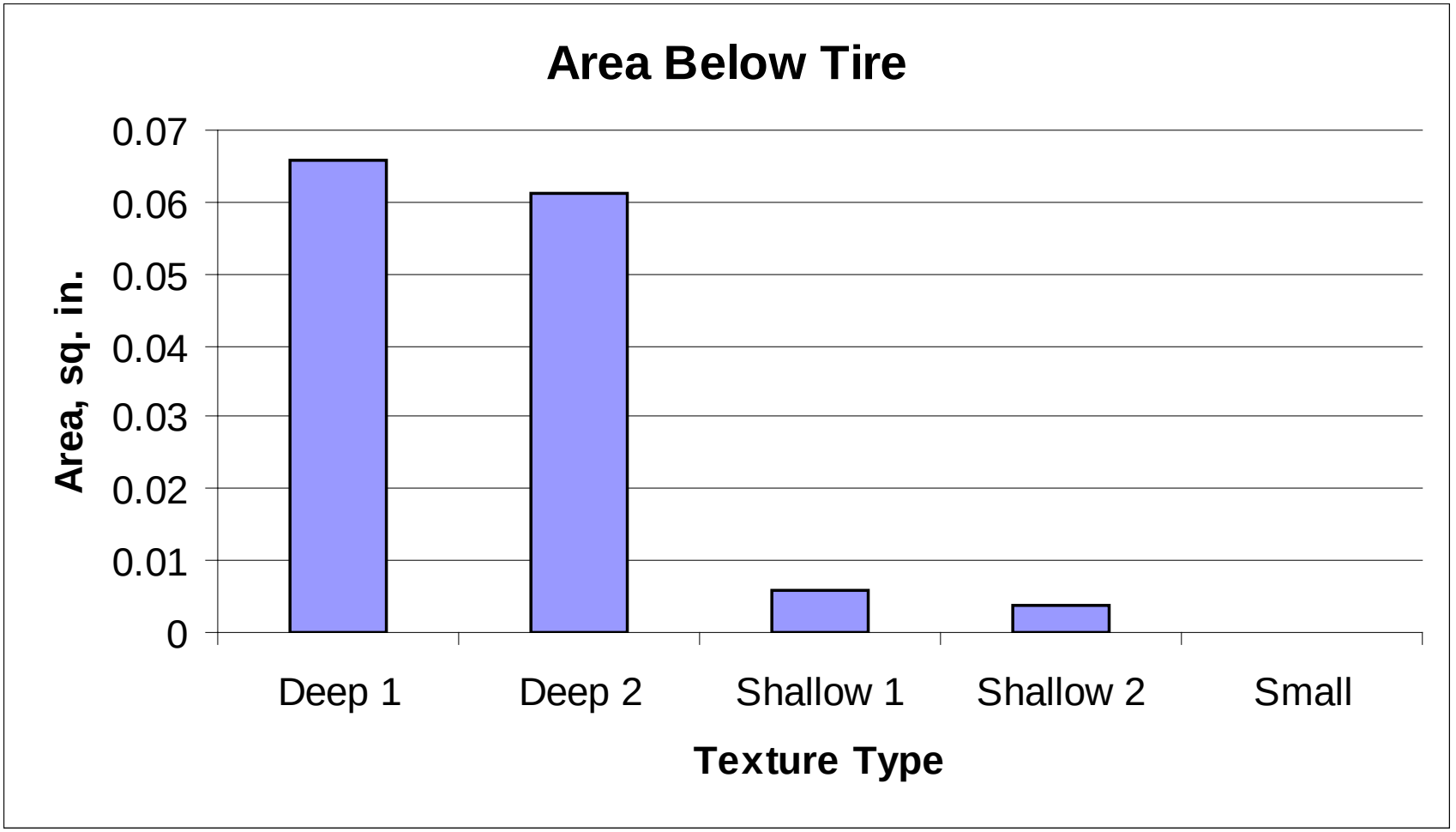


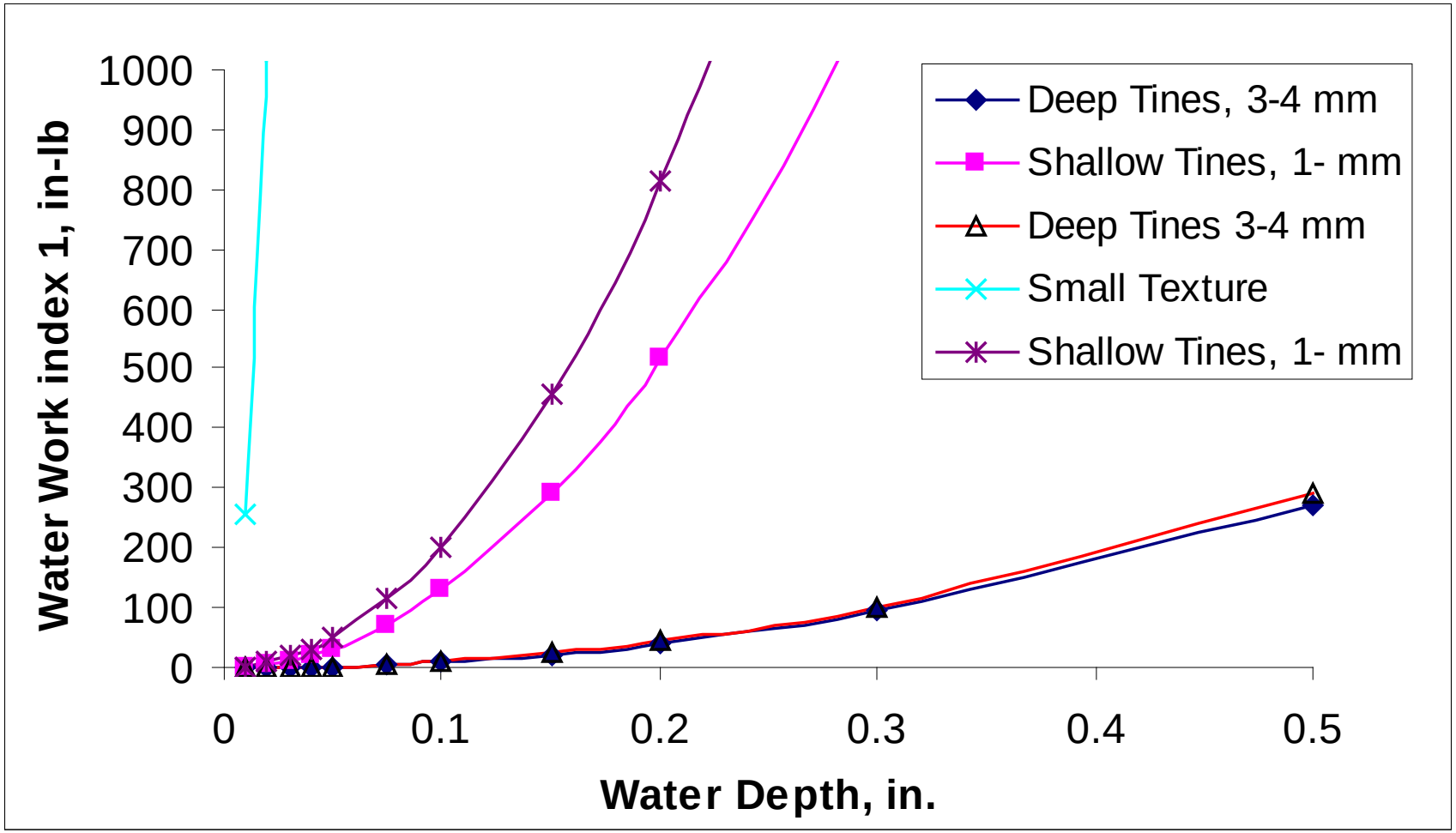
I-69 Tex F **9-Jul-03** **12:34:09**






Voids Below Tire
Avg Depth of Voids, mm
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Deep 1
Deep 2
Shallow 1
Shallow 2
Small
Texture Type


Area Below Tire
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Area, sq. in.
Deep 1
Deep 2
Shallow 1
Shallow 2
Small
Texture Type



Pounds of water displaced times total void path length

Summary

MDOT Texture Scanning Laser reports texture height values almost always within 0.10 mm, and usually within 0.05 mm of true.

Device sample spacing is adjustable and 0.20 mm spacing was selected for various analyses.

A maximum of 0.20 to 0.25 mm elevation sample spacing should be used when macro texture ***shape*** is of interest, so you can capture wavelengths 1 mm and longer.

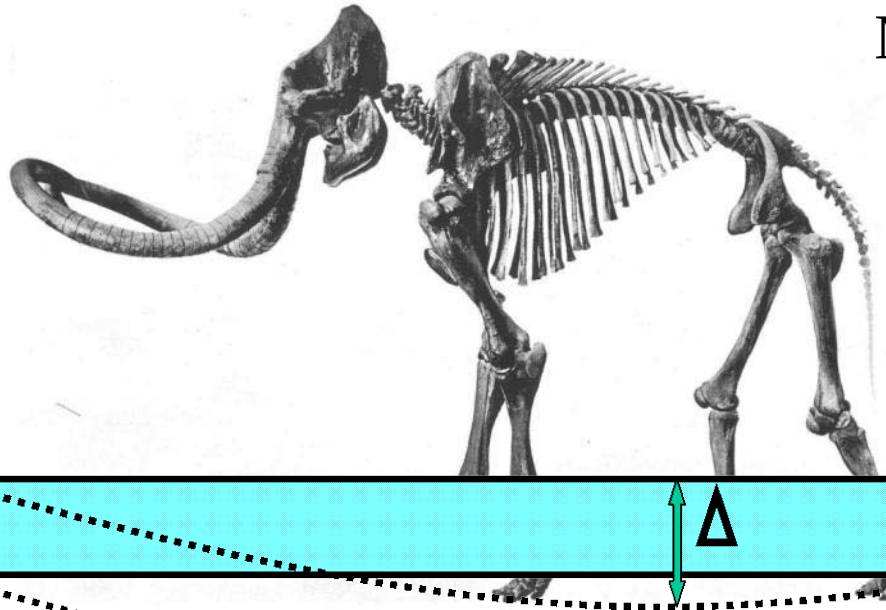
(**Sample Spacing less than 1/5 wavelength of interest**).

Summary

The raw texture scan data goes in, and many texture shape and size related index values are generated and placed in a row-structured database format that can easily be used for statistical analysis comparisons with noise, IRI, Skid testing……. whatever other surface parameter is of interest and correlated to the texture scans.

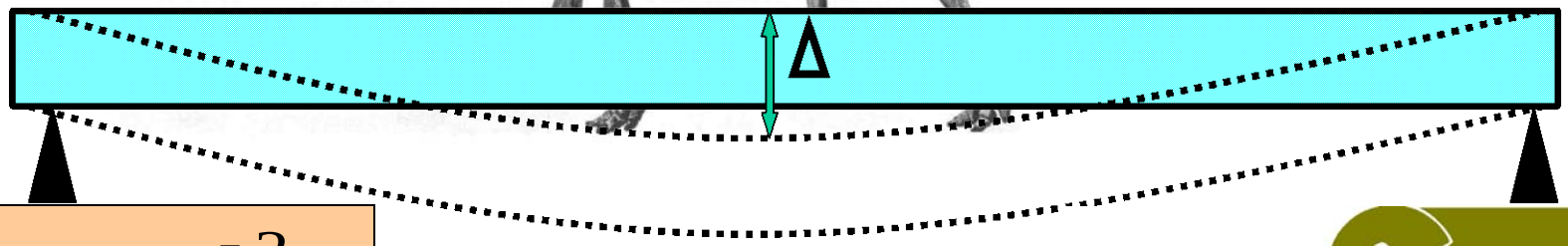
For PSD analyses, take the average PSD of many scans of a given texture as the “Representative PSD”

From Michigan, Good Luck

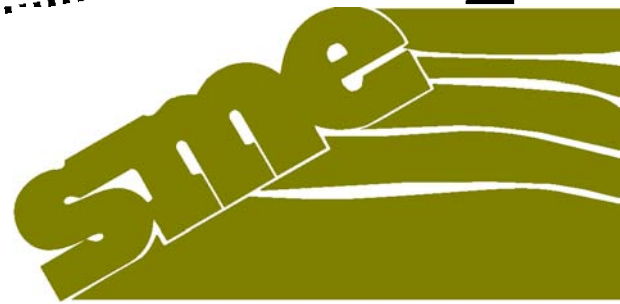


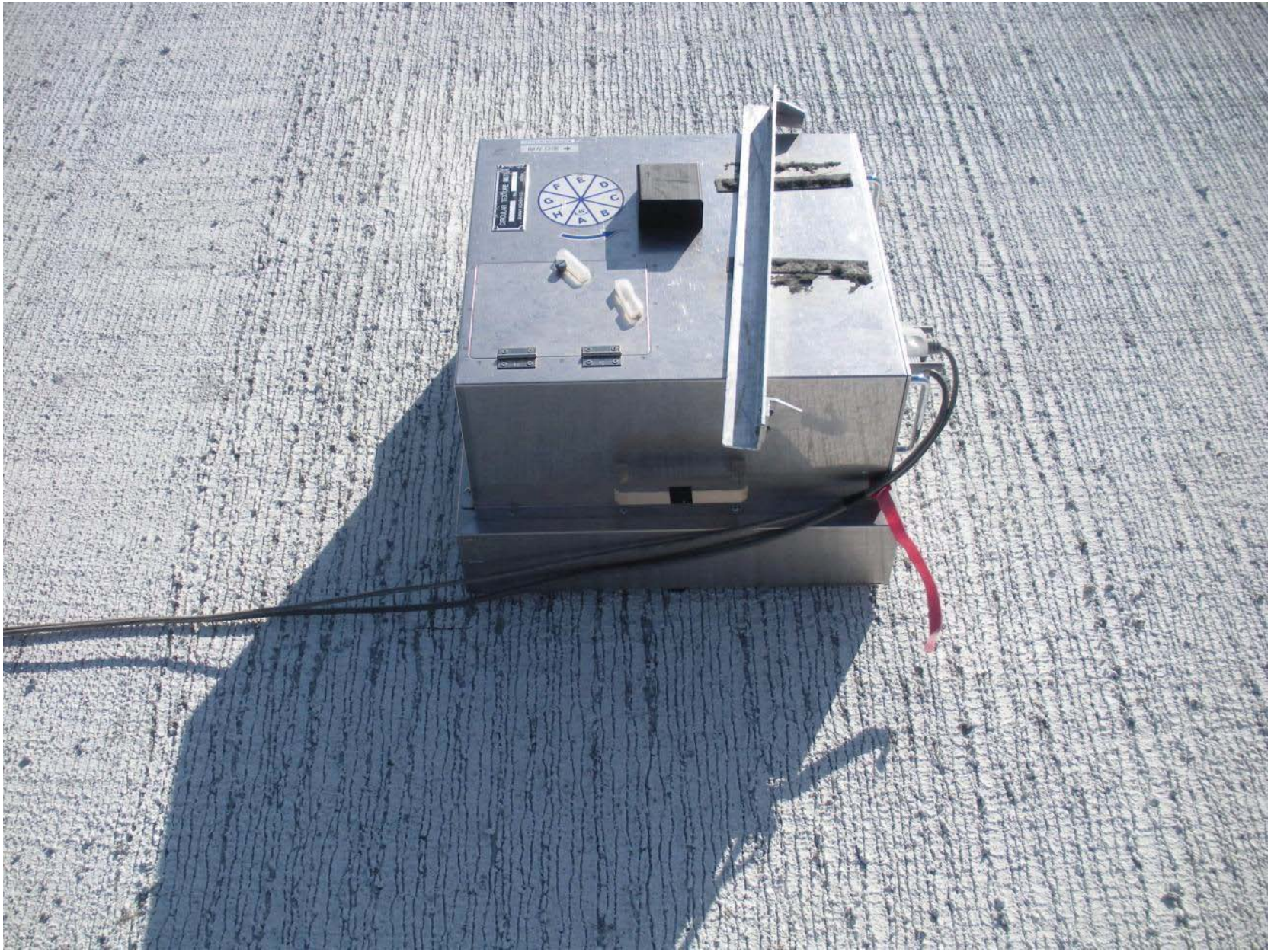
Michigan's State Fossil:

Mastodon



$$M = EI\frac{d^2z}{dx^2}$$






ASTM E1911-98
FRAGILE


ASTM:E1911-98
CAUTION