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Emulsion Task Force - Friction Surface Treatments

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Acronyms

- AASHTO: American Association of State Highway and Transportation Officials
- AADT: Annual Average Daily Traffic
- ADT: Average Daily Traffic
- ASTM: American Society for Testing and Materials
- CFME: Continuous Friction Measurement Equipment
- CFR: Code of Federal Regulations
- CMF: Crash Modification Factor
- DOT: Department of Transportation
- FHWA: Federal Highway Administration
- HFST: High Friction Surface Treatment
- HFT: Highway Friction Tester
- HSM: Highway Safety Manual
- KYTC: Kentucky Transportation Cabinet
- LWST: Locked Wheel Skid Tester
- MPD: Mean Profile Depth
- MSC: Mean SCRIM Coefficient
- NCHRP: National Cooperative Highway Research Program
- RSA: Road Safety Audit
- SCRIM: Sideway-force Coefficient Routine Investigation Machine
- SPF: Safety Performance Function
- SR: Continuous Friction Measurement Test Result
- VaTech, VTTI: Virginia Tech Transportation Institute
- UK: United Kingdom

Agenda

- Friction and Safety
- Continuous Friction Measurement Data to Support Safety Analysis
- Continuous Friction Measurement Data

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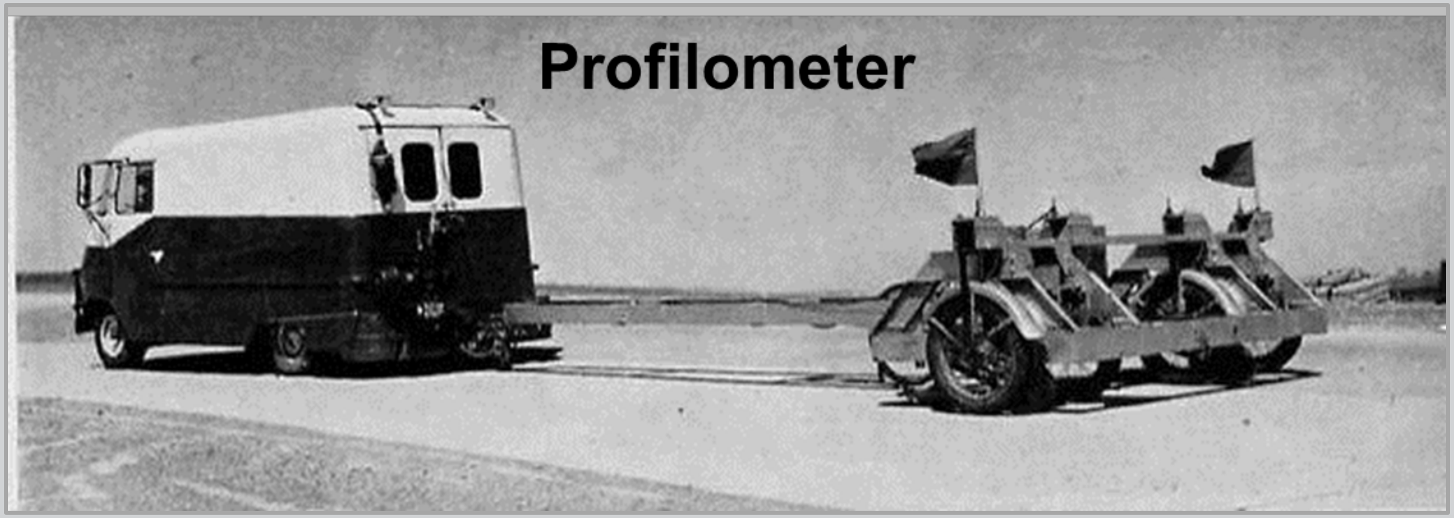
Friction and Safety

AASHO Road Test – 1950's

Major Federal Road Research

- Pavement and Safety
- Large Vehicle Damage Assessment – Taxes



Highway Friction Testing – 1950s to 1960s

- 1st International Skid Prevention Conference held in the United States, 1958
  - Correlation study of locked wheel skid trailers in 1962
- American Society for Testing and Materials (ASTM) committee E-17 on Skid Resistance formed in 1960

Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

Pavement Policy

Federal Regulation, 23 CFR 626.3 – Policy

- "…Pavement shall be designed to accommodate current and predicted traffic needs in a **safe**, durable, and cost effective manner."

National Friction Guidance and Practices (continued)

NCHRP Report 37, 1967:

- Vehicle speeds increased, younger drivers
- "…Because the intensity of the polishing process increases markedly with tread element slip, all other factors being equal, the lowest friction levels are found on high-speed roads, curves, and approaches to intersections; in short, in locations at which high friction values are needed most."

Kentucky HFST Program – Crash Reductions

- Crash reduction percent; % (138 locations: 107 curves, 30 ramps, 1 int.)
- Nationwide, very few HFST installations were from sites identified by network friction testing.

(As of 10/29/2018)

Annual	All	Ramps
Wet Average	91%	90%
Dry Average	53%	31%

Source: Kentucky Transportation Cabinet (KYTC).

2020 Initiated largest continuous friction measurement project in US. Annually collecting approximately 15,100 lane miles.

The Safe System Approach: 6 Core Principles

- Death/Serious Injury is Unacceptable
- Humans Make Mistakes
- Humans are Vulnerable
- Responsibility is Shared
- Safety is Proactive
- Redundancy is Crucial

Source: FHWA

5 Inter-Related Elements

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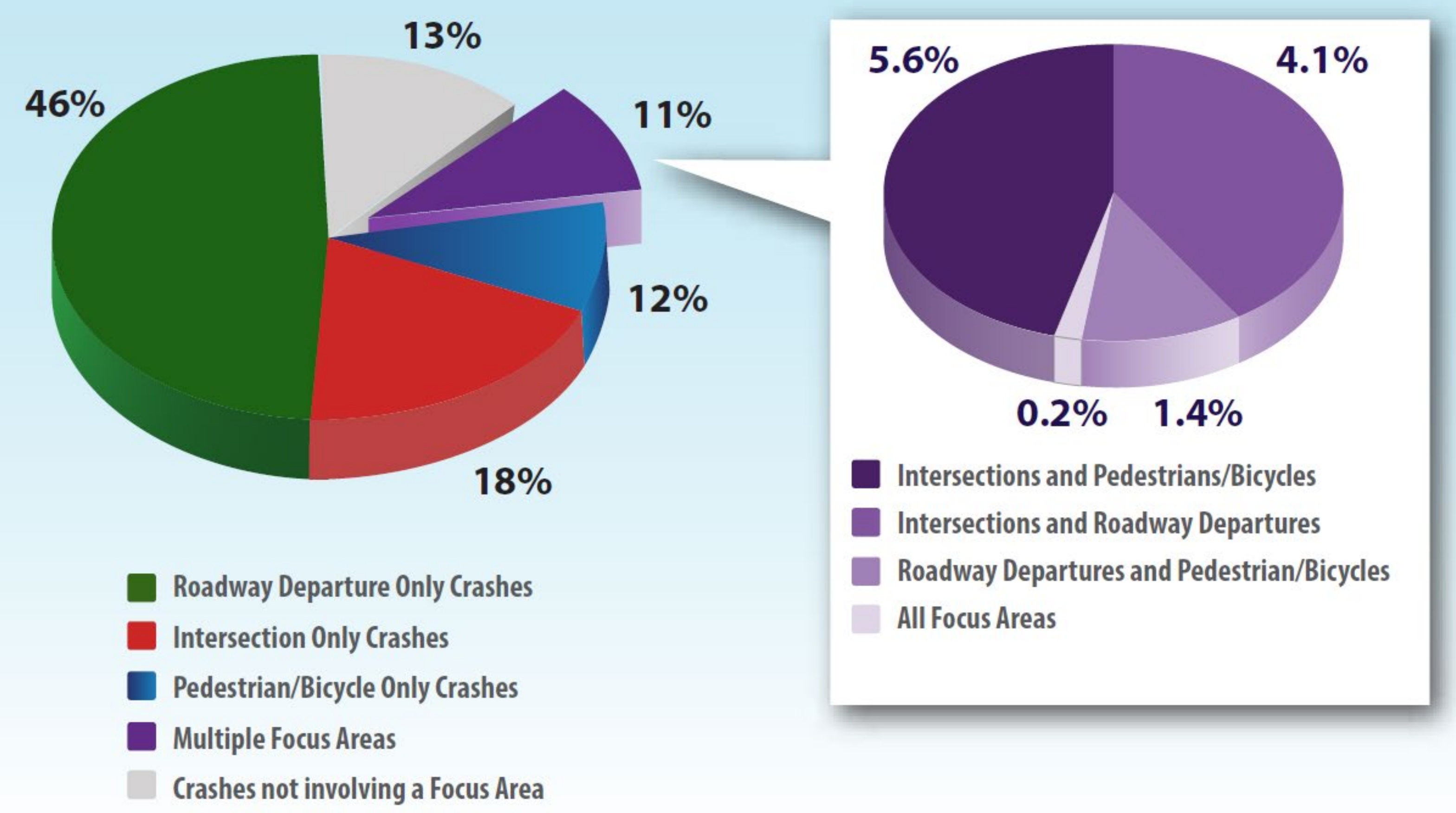
ZERO IS OUR GOAL
A SAFE SYSTEM IS HOW WE GET THERE

United States Fatalities by FHWA Focus Area Average 2016-2018



SOURCE: FARS

FHWA definitions available at safety.fhwa.dot.gov/fas

NOTE: The total in the secondary pie chart does not exactly add up to 11% due to rounding.

Safety Analysis

Safety Performance Functions (SPF), relate crashes to several factors

- X1, X2, …, X n
  - Explanatory variables
    - P: Number of crashes on segment L
    - AADT: Traffic count
    - Xi: Friction, Texture, Curvature, cross-slope, grade, etc.

$$P = L \times e^{\beta_o + \ln(AADT)\beta_1 + X_{1+i}\beta_{1+j}}$$

Friction demand – level of friction (micro- and macrotexture) needed to safely perform braking, steering, and acceleration maneuvers.

AASHTO Highway Safety Manual (2010)

Design Elements Covered in the HSM1 Predictive methods

Design Elements Directly Covered by the HSM Chapters 10-12,18, 19	Design Elements Indirectly Covered by the HSM Chapters 10-12,18, 19	Design Elements NOT Covered by the HSM1 Predictive Method There may be a Crash Modification Factor (CMF) that covers this Design Element for your specific need and context.	Updated 08/01/16

Rural Two-Lane Highways (Chapter 10 of HSM1)	3r	5r	1r	2r	Roadway				10r	6r	10r	11r		Bridges 1r	2r	
Roadway Segments	Horiz. Align. Curve Radius & Superelevation. Not Super Tra 4r tions	Vert. Align. (Grade. Not Vertical curves)	Lane Width	Shldr Width & Surface Type	Lane Tran-sition	Median Width	Cross Slope Lane	Cross Slope Shldr	Fill/ Ditch Slopes (Roadside Hazard Rating)	Access (Driveway Density)	Clear Zone (Roadside Hazard Rating)	Sign, Del. & Illumin. (Illumin. only)	Bike & Ped.	Lane Width	Shldr Width	Structural Capacity
Intersections												Sign, Del. & Illumin. (Illumin. only)	Bike & Ped.			

Rural Two-Lane Highways (Chapter 10 of HSM1)	Intersections			Barri	10r	10r	Other Elements C 7r red	Limitations	Designs Not Covered
Roadway Segments				Term & Trans. Section	Std. Run (Roadside Hazard Rating)	Bridge Rail (Roadside Hazard Rating)	- Shoulder Surface Type - Centerline Rumble Strips (8r) - Passing Lanes (9r) - Two-Way Left-Turn Lane - Auto Speed Enforcement (12r)	• Shoulder Rumble Strips not Included	Auxiliary Lanes
Intersections	Turn Radii	Angle (Skew from 90°)	I/S Sight Distanc e				Intersection Control Types + 3ST - 3 Leg Side Street Stop Controlled + 4ST - 4 Leg 2-Way Stop Controlled + 4SG - 4 Leg Signal Controlled - Left Turn Lanes - Right Turn Lanes	• I/S Sight Distance not included	• Roundabouts: A CMF is available on the WSDOT CMF short list (Intranet: Sustainable Safety) • 4-way Stop Intersections

annual traffic; segment length

$$N_{spr\,rf} = (AADT) * (L) * (365 * 10^{-6}) * (e^{-0.312}) * (CMF_n)$$

Base Equation for Rural Two-Lane Segments

(CMF_{1r}) (CMF_{5r}) (CMF_{9r})
(CMF_{2r}) (CMF_{6r}) (CMF_{10r})
(CMF_{3r}) (CMF_{7r}) (CMF_{11r})
(CMF_{4r}) (CMF_{8r}) (CMF_{12r})

Example Analysis: Rural Two-Lane Segment

Lane Width - base condition is 12'

- Segment has 12' lanes, the CMF is 1.00.
- Segment has 11' lanes, if ADT is <400 CMF is 1.01 (increase in crash risk by 1%)
- Segment has 11' lanes, if ADT is > 2000 CMF is 1.05

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Continuous Friction Measurement Data to Support Safety Analysis

Standard of Practice

- Locked-Wheel Skid Trailer (LWST)
- Wet weather-related crashes (Skid Accident Reduction Program (SKARP))

Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

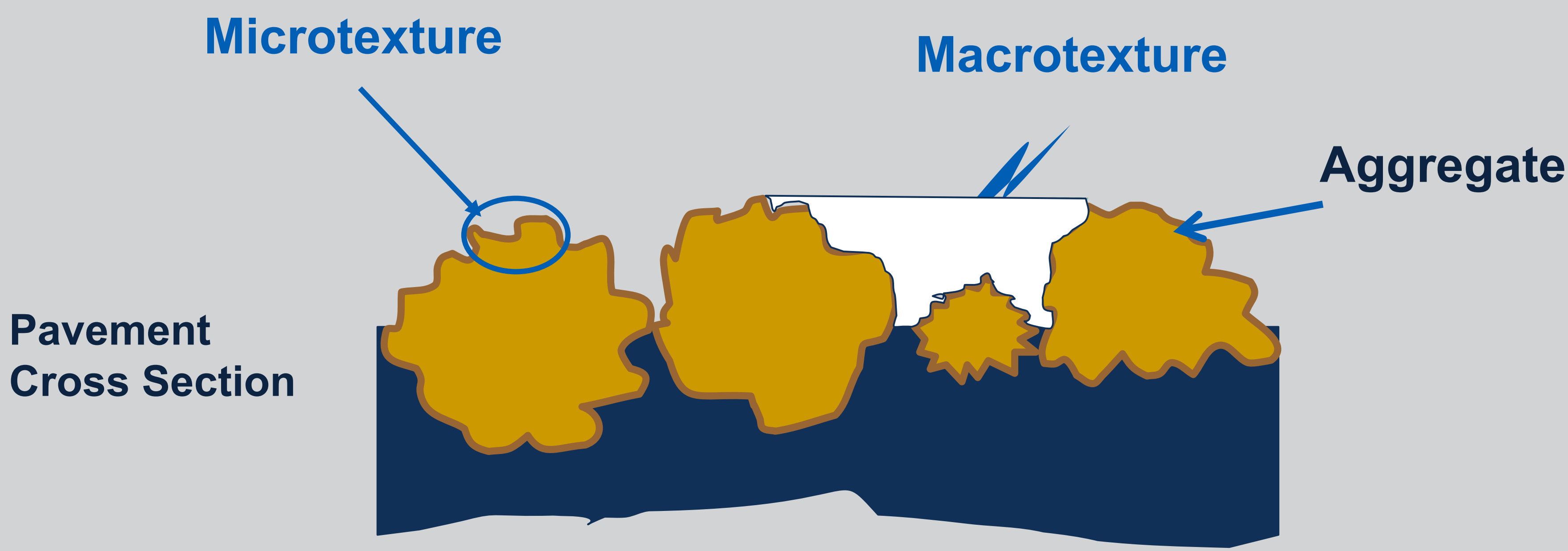
Continuous vs. Sampled Based Pavement Testing

Standard friction testing in the United States is sample based

Do pavement conditions vary markedly as you travel down the road?

- Density (Intelligent Compaction, Infrared Technology, Ground Penetrating Radar (GPR))
- Structural Integrity (Traffic Speed Deflectometer (TSD), GPR)
- Segregation (Texture)
- Ride
- Cracking

What is Texture?



Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

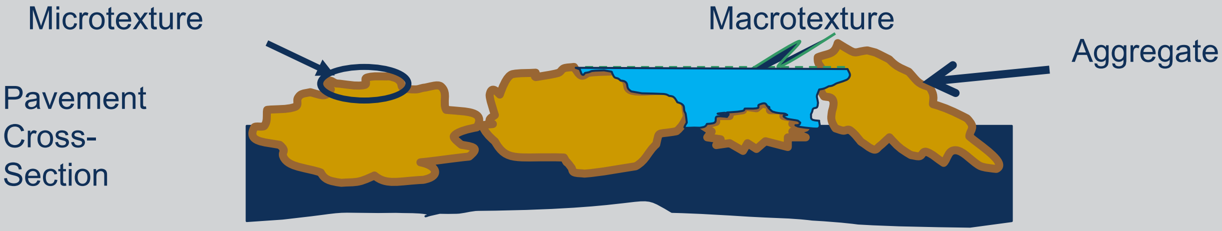
Continuous Friction Measurement

- Rubber Tire test continuously measuring every foot of pavement (study – microtexture)
- Laser based texture measurement system measuring every foot of pavement (macrotexture)

Discrete Macrotexture Test – Sand Patch Test

Circular Track Meter (CTM)

- Changes in Pavement Macrotexture
- Have Been Used to Identify Segregation, Skid Resistance, Pavement Noise
- CTM – Laser-Based Device to Measure Mean Profile Depth (MPD) of a Pavement
- Correlates Well with Sand Patch Test



Ames RLTS 9500

Source: https://amesengineering.com/products/laser-texture-scanner-model-9500/

Scan Area: 100 mm x 100 mm
Vertical Resolution: 0.01 mm
Transverse Res.: 0.415 mm
Longitudinal Res.: 0.496 mm
Scan Time: 90 sec

British Pendulum

Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

Dynamic Friction Tester (DFT)

Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

Grip Tester

Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

Dynatest HFT

Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

Data Collection System – SCRIM

Water Tank: 2,200 Gallons = 8,400 Liters

Source: Center for Sustainable Transportation Infrastructure (CSTI)/ Virginia Tech Transportation Institute (VTTI).

Laser Texture Sensor

Source: WDM® United Kingdom

Friction Demand - Investigatory Levels (UK)

Site category and definition		Investigatory level (50 or 80 km/h)							
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
A	Motorway								
B	Dual carriageway non-event								
C	Single carriageway non-event								
Q	Approaches to and across minor and major junctions, approaches to roundabouts								
K	Approaches to pedestrian crossings and other high risk situations								
R	Roundabout								
G1	Gradient 5-10% longer than 50m								
G2	Gradient >10% longer than 50m								
S1	Bend radius < 500m - dual carriageway								
S2	Bend radius < 500m - single carriageway								

Source: United Kingdom CS 228 Skidding Resistance Revision 0, August 2019.

Initial Texture Depth for UK Trunk Roads/ Motorways

Road Type	Surfacing Type	Average/ 1,000 m	Average/ 10 measures
High Speed Roads > 50 MPH	Thin surface overlay Aggregate size<14mm	MPD 1.4 mm	MPD 1.0 mm
	Surface treatments	MPD 1.6 mm	MPD 1.25 mm
Lower Speed roads <40 MPH	Thin surface overlay Aggregate size<14mm	MPD 1.4 mm	MPD 0.9 mm
	Surface treatments	MPD 1.25 mm	MPD 1.0 mm
Roundabout, high speed >50 MPH	All surfaces	MPD 1.25 mm	MPD 1.0 mm
Roundabout, low speed <40 MPH	All surfaces	MPD 1.0 mm	MPD 0.9 mm

Source: United Kingdom Specification for Highway Works, Volume 1 Series 900, August 2008 Amendment, Table 9-3; British Standard EN 13036-1) using ASTM E1845 eq. MPD = (ETD -0.2)/0.8.

Texture Demand Categories New Zealand Transport Agency (NZTA)

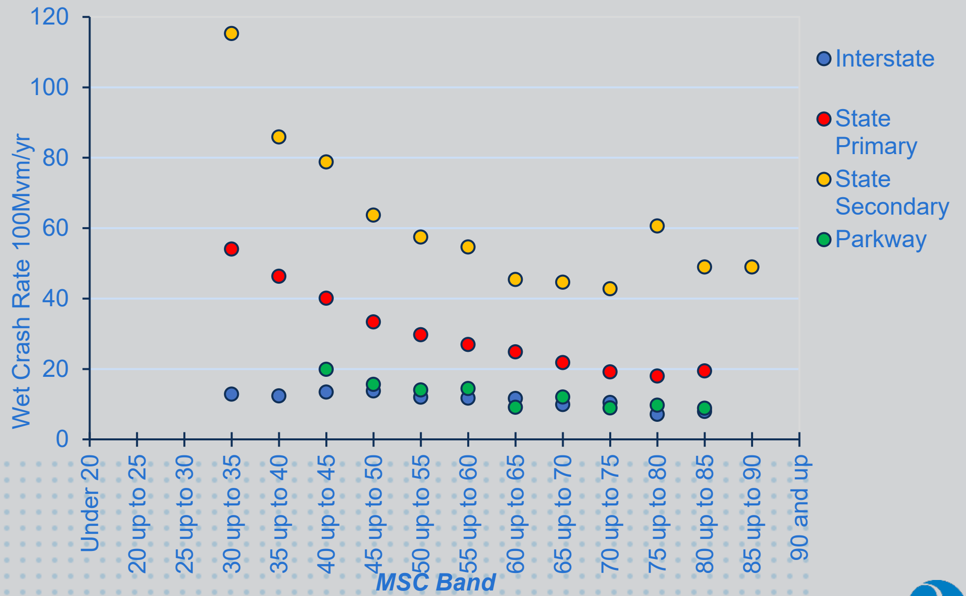
Table 3 Minimum macrotexture requirements

Minimum macrotexture – mean profile depth (MPD mm)						
Permanent speed limit	Chipseal		Asphaltic concrete, ESC ≥ 0.4		Asphaltic concrete, ESC < 0.4	
	ILM	TLM	ILM	TLM	ILM	TLM
50km/h and less	1.0	0.7	0.4	0.3	0.5	0.5
Less than or equal to 70km/h but >50km/h	1.0	0.7	0.4	0.3	0.7	0.5
Greater than 70km/h	1.0	0.7	0.9	0.7	0.9	0.7

Source: NZ Transport Agency T10, 2010.

MSC Crash Rates Differ by Road Classification

- The relationship between MSC and KYTC's wet crash rate is strongest on State Primary and State Secondary roads.
- The wet crash rate on State Secondary roads is 5x the wet crash rate on Parkways (60.4 vs 11.3).
- May reflect how geometric design standards and improved alignments on the Interstate and Parkway networks mitigate crash risk or the predominance of certain segment types on different Road Classifications.



Hierarchy	Year 1 Survey Miles	Wet Crash Rate (per 100Mvm/yr)
Interstate	1,756.1	12.0
Parkway	964.1	11.3
State Primary	3,693.3	29.7
State Secondary	7,375.2	60.4

Source: Kentucky Transportation Cabinet (KYTC).

Data Analysis Results - Statewide

0.1-mile analysis section segmented into 4 subsegments – lowest average friction subsegment used in the analysis.

Site Category	Hierarchy	CMF	% Decrease in Crash Rates for 10 unit increase in MSC
C1	State Secondary	0.9650	**29.96** (23.58, 35.81)
C4	State Secondary	0.9657	**29.44** (26.93, 31.85)
Non-Event	State Secondary	0.9695	**26.64** (25.1, 28.15)
Intersection	State Secondary	0.9700	**26.26** (24.88, 27.62)
C1	State Primary	0.9711	**25.44** (18.61, 31.7)

In this District-level example, the 5 Site Category/Hierarchy combinations that offer the most potential impact (measured as the % decrease in 5-year crash rate if MSC is increased by 10 units).

Source: Kentucky Transportation Cabinet (KYTC).

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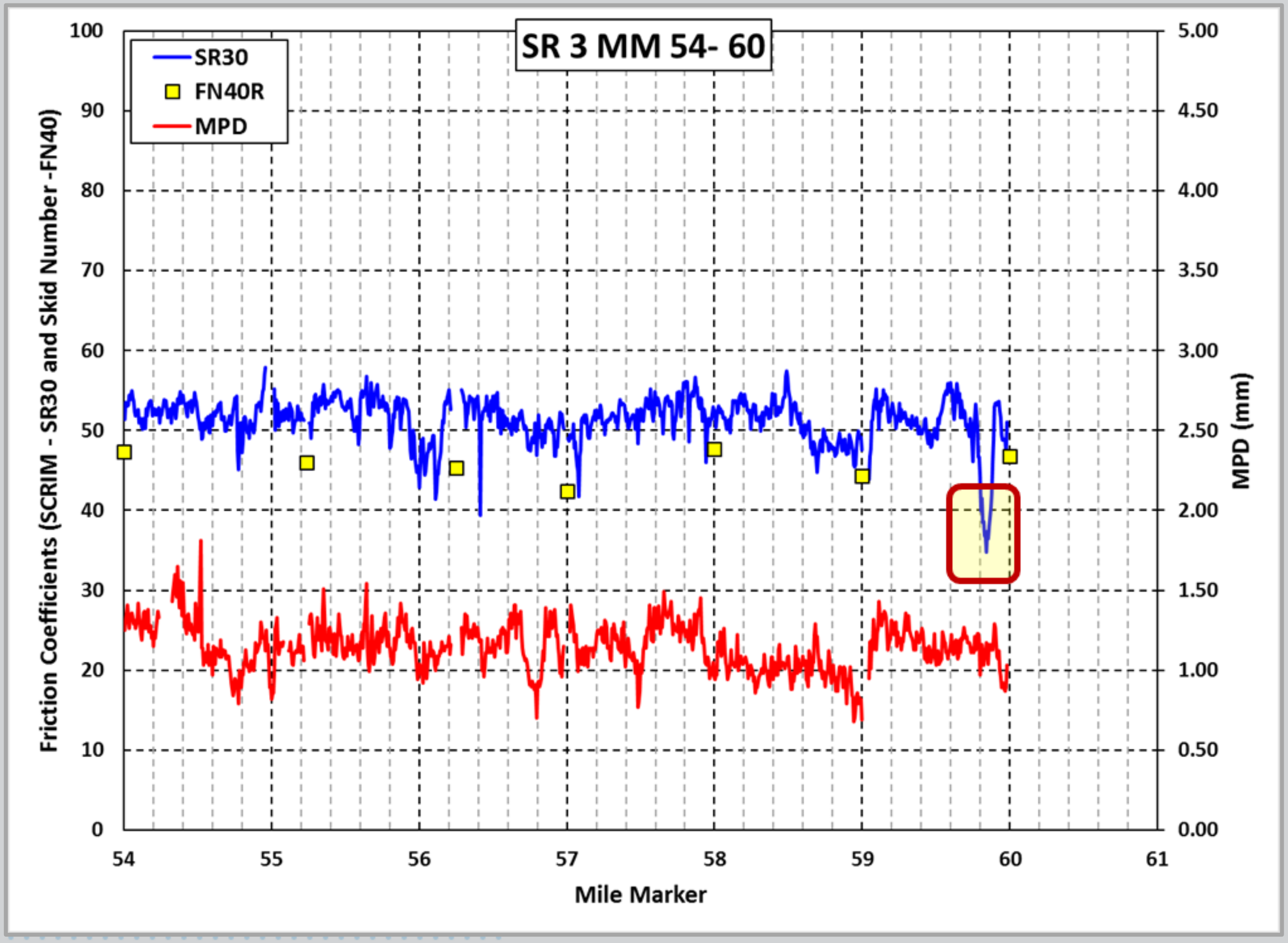
Continuous Friction Measurement Data

Importance of Continuous Measurement

- State Route A
- Comparison Continuous Friction Measurement Equipment (CFME) and texture data collection vs. 1.0-mile Locked Wheel Skid Testing (LWST)

Continuous Friction Test Results



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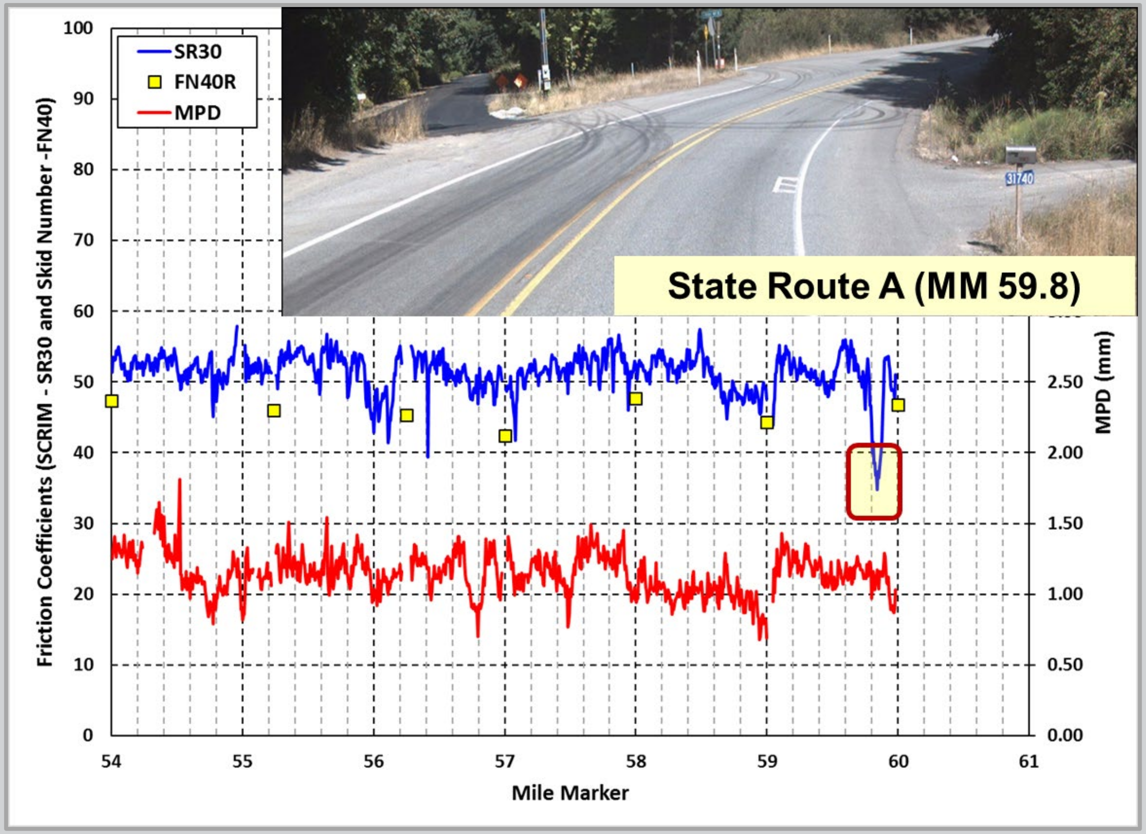
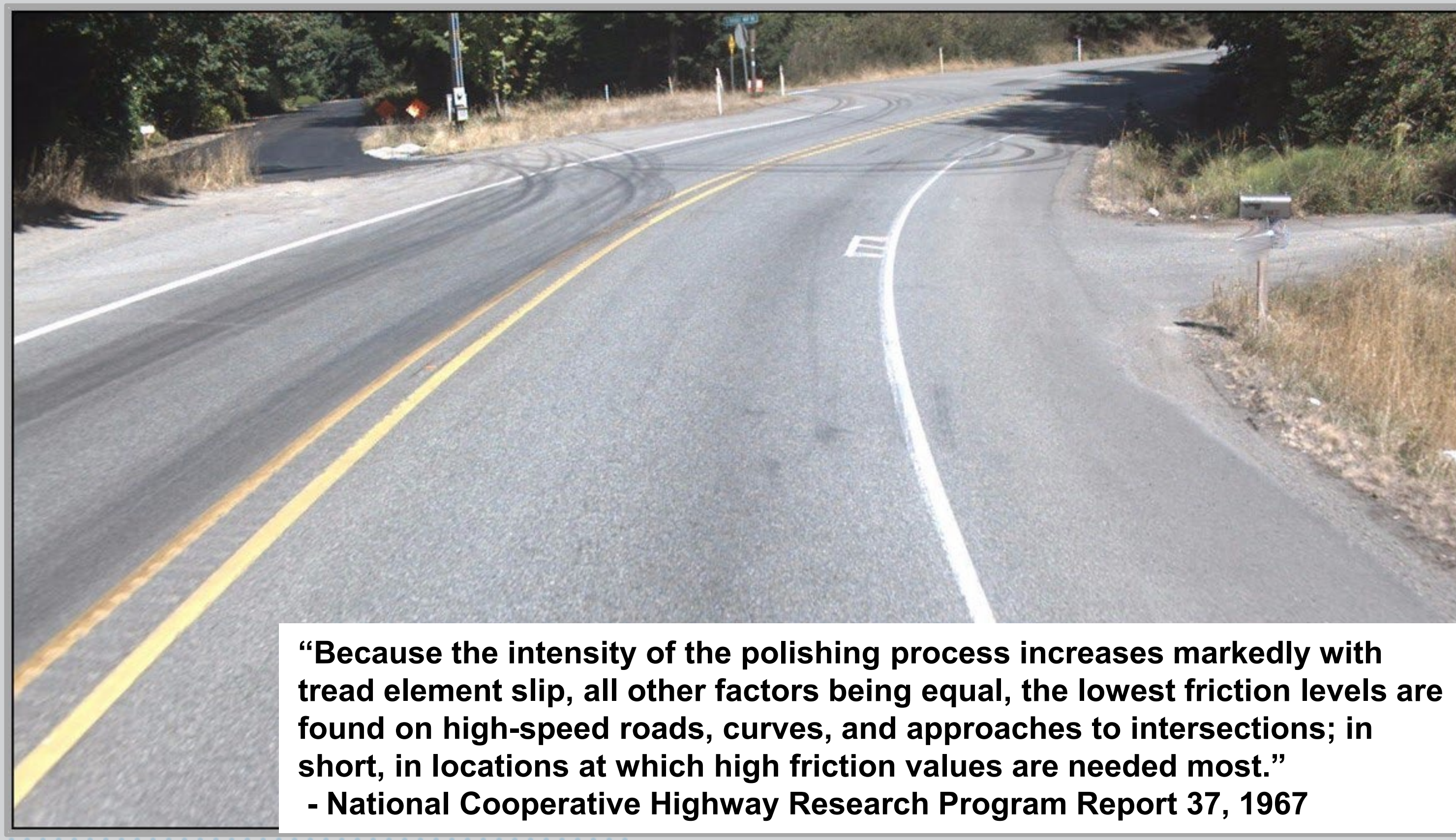
Road Geometrics and Intersection at Low Fiction Location



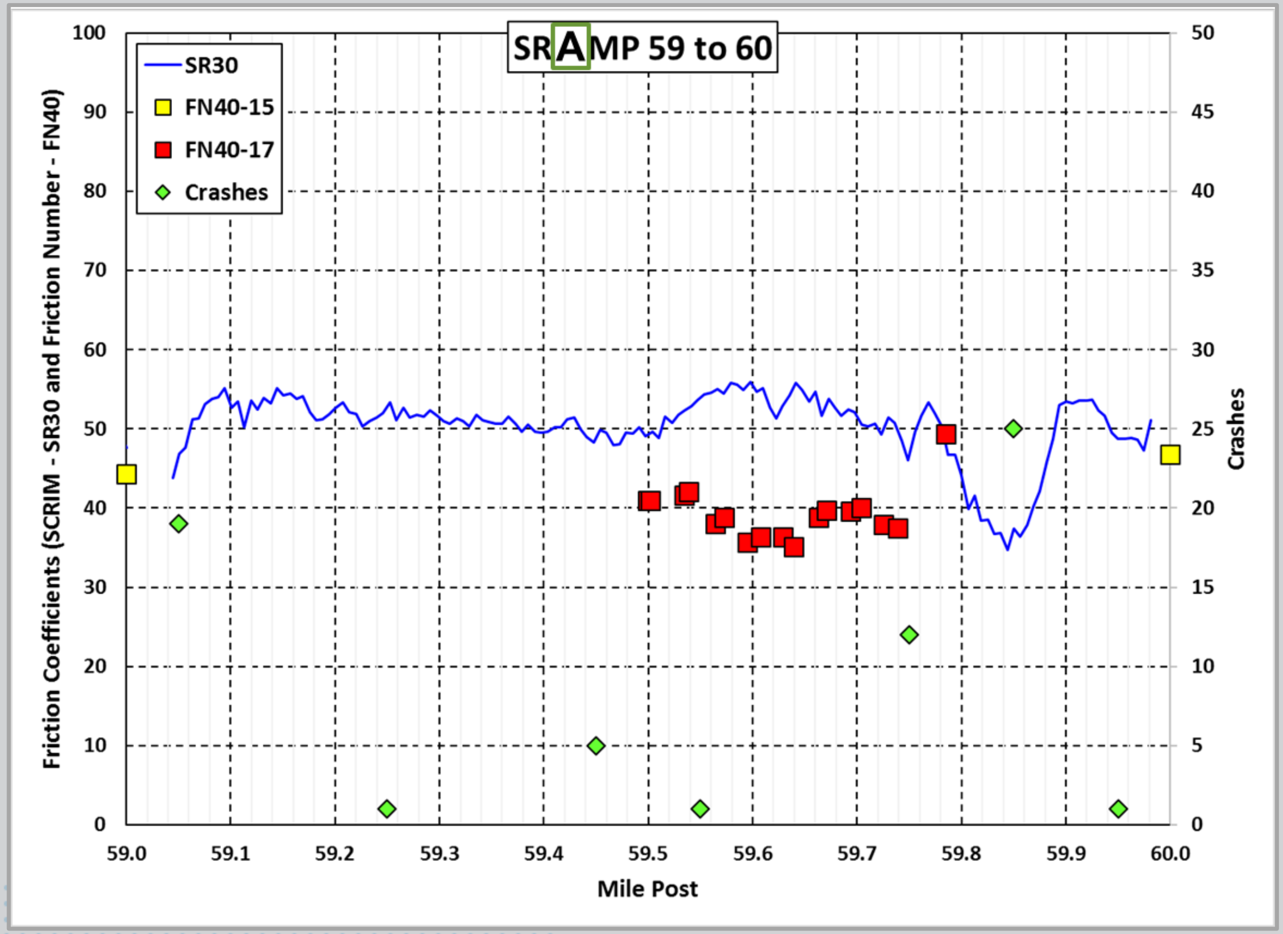
NCHRP Report 37, 1967



“Because the intensity of the polishing process increases markedly with tread element slip, all other factors being equal, the lowest friction levels are found on high-speed roads, curves, and approaches to intersections; in short, in locations at which high friction values are needed most.”

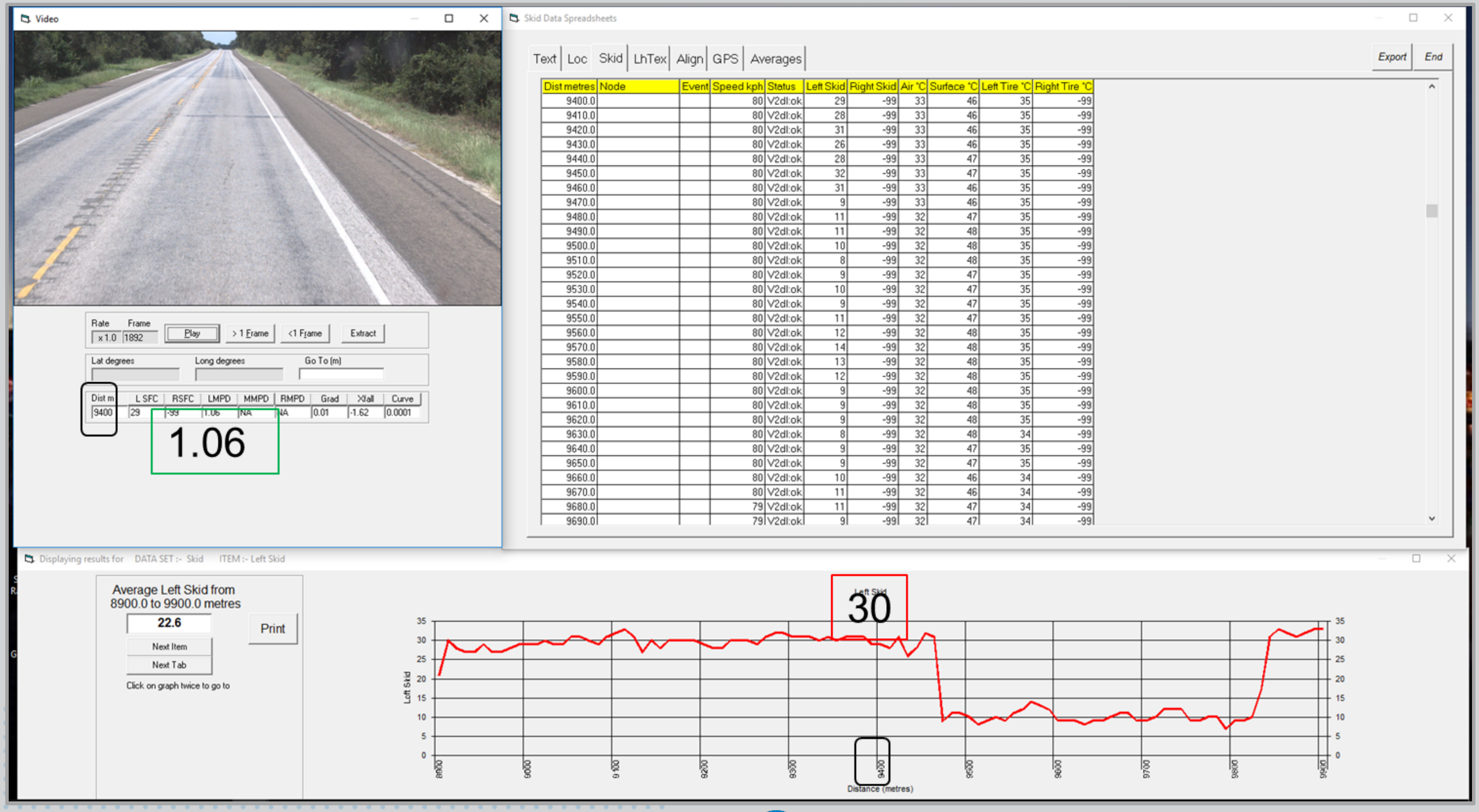
- National Cooperative Highway Research Program Report 37, 1967

16 Tests/Tries to Find Low Friction



Chip Seal

Continuous Friction and Texture data collection on chip sealed roads in hot weather (bleeding?)



Dist metres	Node	Event	Speed kph	Status	Left Skid	Right Skid	Air °C	Surface °C	Left Tire °C	Right Tire °C
9400.0			80	V2dl:ok	29	-99	33	46	35	-99
9410.0			80	V2dl:ok	28	-99	33	46	35	-99
9420.0			80	V2dl:ok	31	-99	33	46	35	-99
9430.0			80	V2dl:ok	26	-99	33	46	35	-99
9440.0			80	V2dl:ok	28	-99	33	47	35	-99
9450.0			80	V2dl:ok	32	-99	33	47	35	-99
9460.0			80	V2dl:ok	31	-99	33	46	35	-99
9470.0			80	V2dl:ok	9	-99	33	46	35	-99
9480.0			80	V2dl:ok	11	-99	32	47	35	-99
9490.0			80	V2dl:ok	11	-99	32	48	35	-99
9500.0			80	V2dl:ok	10	-99	32	48	35	-99
9510.0			80	V2dl:ok	8	-99	32	48	35	-99
9520.0			80	V2dl:ok	9	-99	32	47	35	-99
9530.0			80	V2dl:ok	10	-99	32	47	35	-99
9540.0			80	V2dl:ok	9	-99	32	47	35	-99
9550.0			80	V2dl:ok	11	-99	32	47	35	-99
9560.0			80	V2dl:ok	12	-99	32	48	35	-99
9570.0			80	V2dl:ok	14	-99	32	48	35	-99
9580.0			80	V2dl:ok	13	-99	32	48	35	-99
9590.0			80	V2dl:ok	12	-99	32	48	35	-99
9600.0			80	V2dl:ok	9	-99	32	48	35	-99
9610.0			80	V2dl:ok	9	-99	32	48	35	-99
9620.0			80	V2dl:ok	9	-99	32	48	35	-99
9630.0			80	V2dl:ok	8	-99	32	48	34	-99
9640.0			80	V2dl:ok	9	-99	32	47	35	-99
9650.0			80	V2dl:ok	9	-99	32	47	35	-99
9660.0			80	V2dl:ok	10	-99	32	46	34	-99
9670.0			80	V2dl:ok	11	-99	32	46	34	-99
9680.0			79	V2dl:ok	11	-99	32	47	34	-99
9690.0			79	V2dl:ok	9	-99	32	47	34	-99

Chip Seal

Dist metres	Node	Event	Speed kph	Status	Left Skid	Right Skid	Air °C	Surface °C	Left Tire °C	Right Tire °C
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9750.0			79	V2dl:ok	9	-99	32	47	34	-99
9760.0			79	V2dl:ok	9	-99	32	47	34	-99
9770.0			80	V2dl:ok	10	-99	32	47	34	-99
9780.0			80	V2dl:ok	10	-99	32	46	34	-99
9790.0			80	V2dl:ok	7	-99	32	47	34	-99
9800.0			80	V2dl:ok	9	-99	32	47	34	-99
9810.0			81	V2dl:ok	9	-99	32	46	34	-99
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9830.0			81	V2dl:ok	17	-99	32	46	34	-99
9840.0			81	V2dl:ok	31	-99	32	46	34	-99
9850.0			81	V2dl:ok	33	-99	32	46	34	-99
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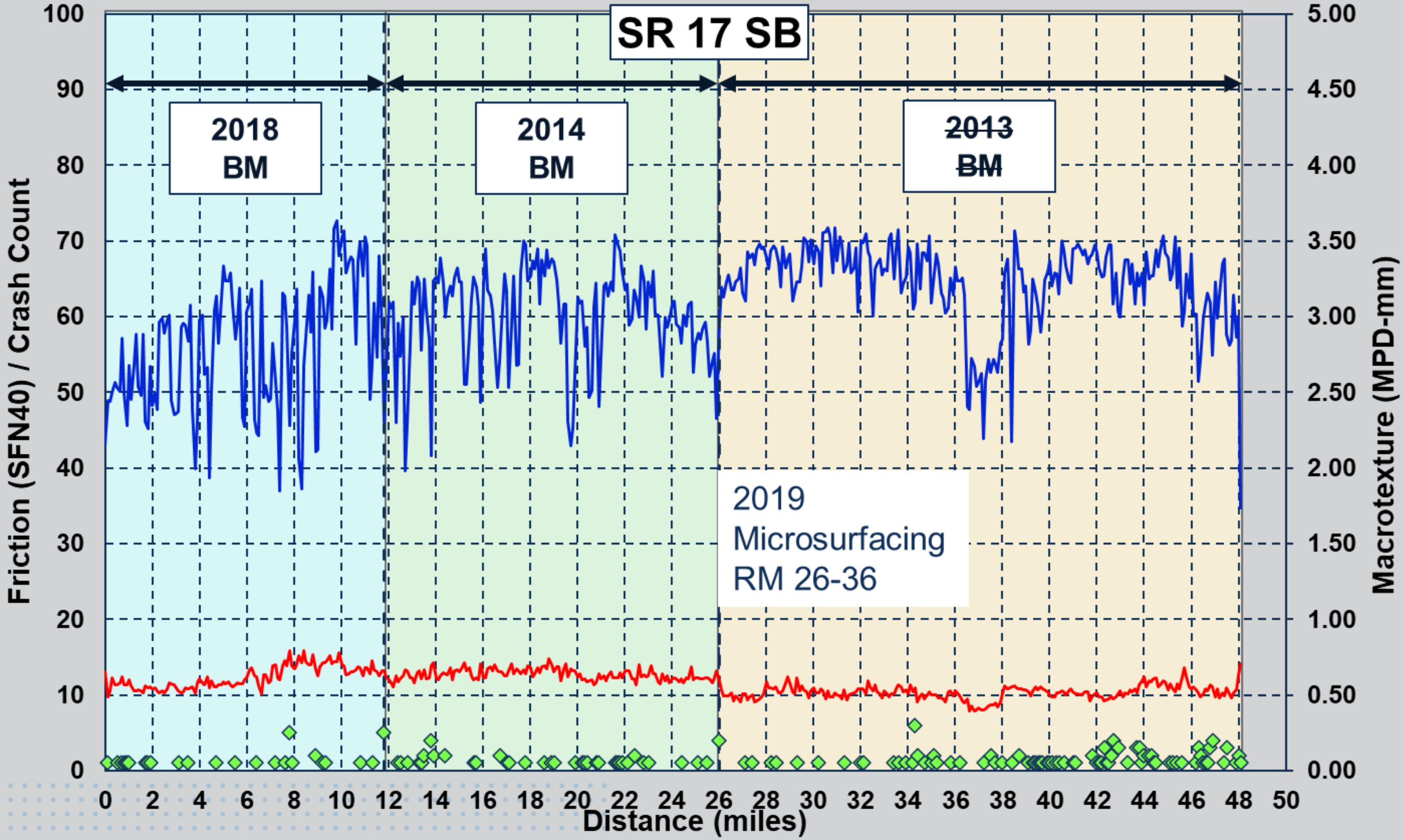
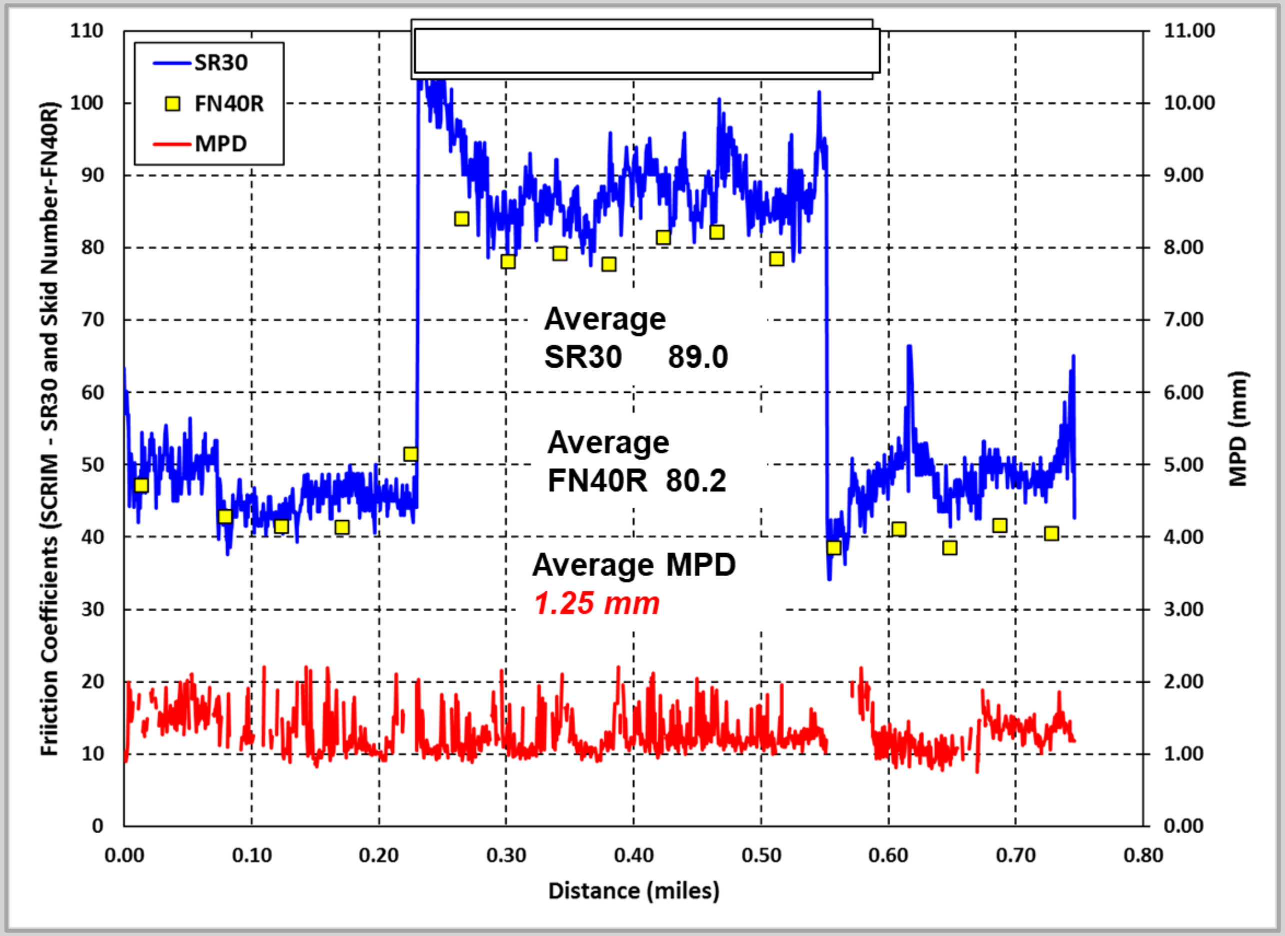
9890.0			81	V2dl:ok	33	-99	32	46	34	-99
9900.0			81	V2dl:ok	33	-99	32	46	34	-99
9910.0			81	V2dl:ok	31	-99	32	46	34	-99
9920.0			81	V2dl:ok	32	-99	32	46	34	-99
9930.0			80	V2dl:ok	32	-99	32	46	34	-99
9940.0			80	V2dl:ok	32	-99	32	46	34	-99
9950.0			80	V2dl:ok	32	-99	32	46	34	-99
9960.0			80	V2dl:ok	29	-99	32	46	34	-99
9970.0			80	V2dl:ok	30	-99	32	46	34	-99
9980.0			80	V2dl:ok	31	-99	32	46	34	-99
9990.0			80	V2dl:ok	32	-99	32	46	34	-99

Microsurfacing



Data Collection in 2021

HFST – Interstate Ramp



Assist in defining HFST installation on termini

Conclusion

- Various road sections have different friction demand.
- Friction demand – level of friction (micro- and macrotexture) needed to safely perform braking, steering, and acceleration maneuvers.
- Different pavement surfaces provide different levels of friction – through the life of the surface.

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Questions?

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