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Pavement Surface Texture and Friction to Improve Highway Safety

64th Illinois Bituminous Paving Conference

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Rutting
Cracking

Debonding

Fatigue Cracking

Skid Resistance

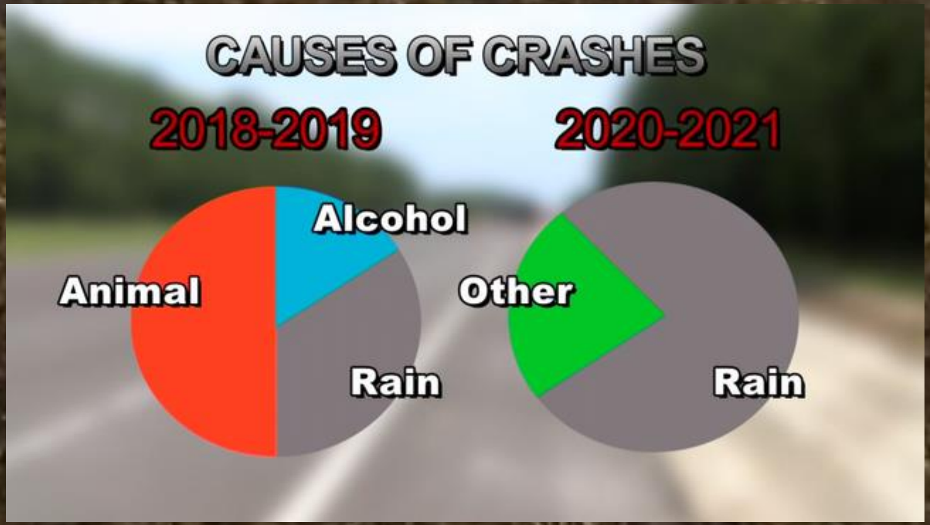
Noise

Rutting

Thermal Cracking

"I don't want to point any fingers," Gray said, "but it is coincidental that it all started in or around when they did the paving."

"It seems to be a strange coincidence that the uptick started in August of 2020." Hussey said. "That's when NCDOT paved that specific area, there have been questions raised as to whether the new pavement is to blame."



Source: Hussey and Basden, WCTI12, 2021

Outline

- How does friction and texture contribute to wet crashes and how do we measure this impact?
- What compositional factors contribute to better or worse friction and texture performance?
- How might limits on friction and texture contribute to improved safety?

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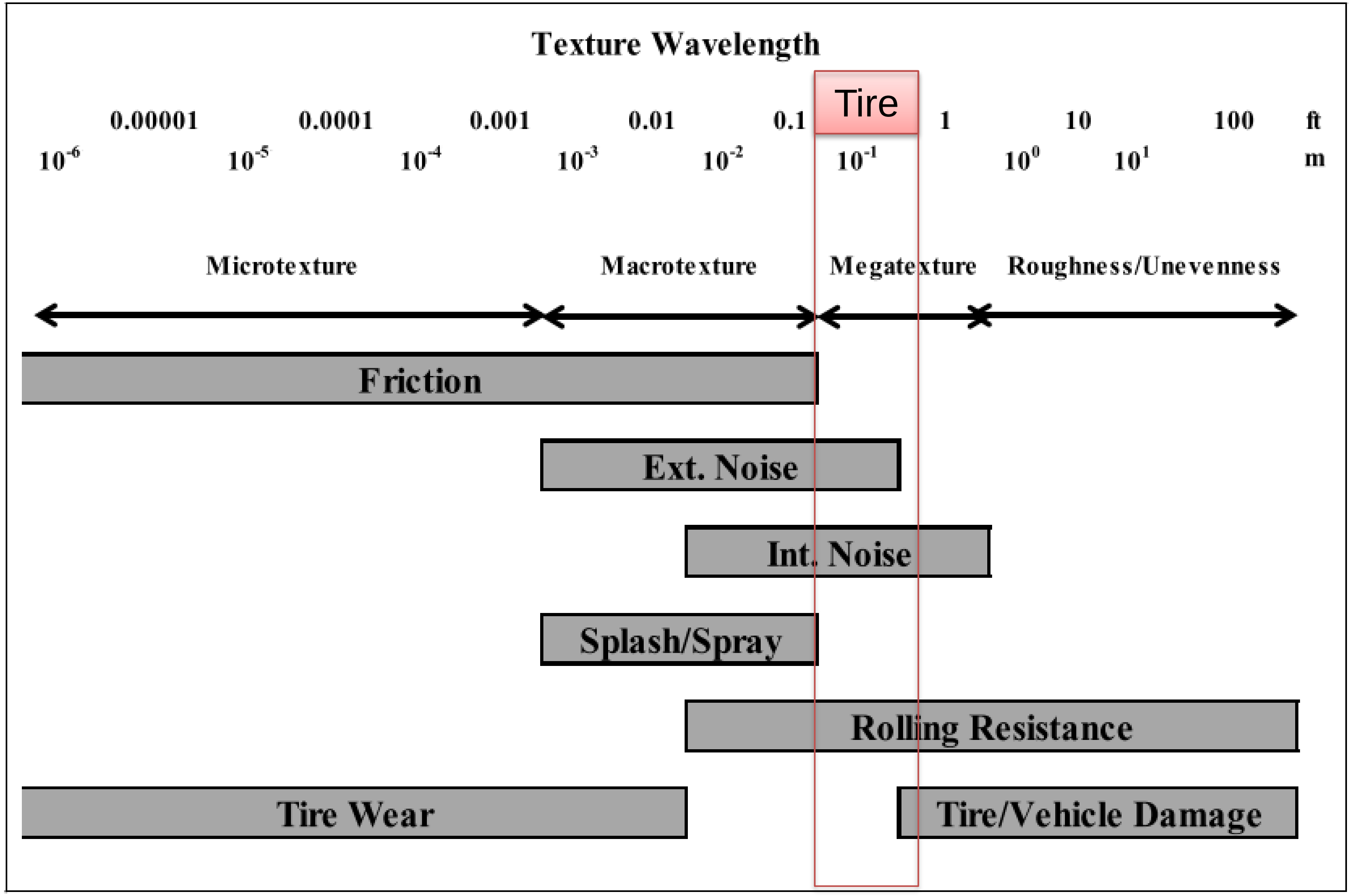
Texture

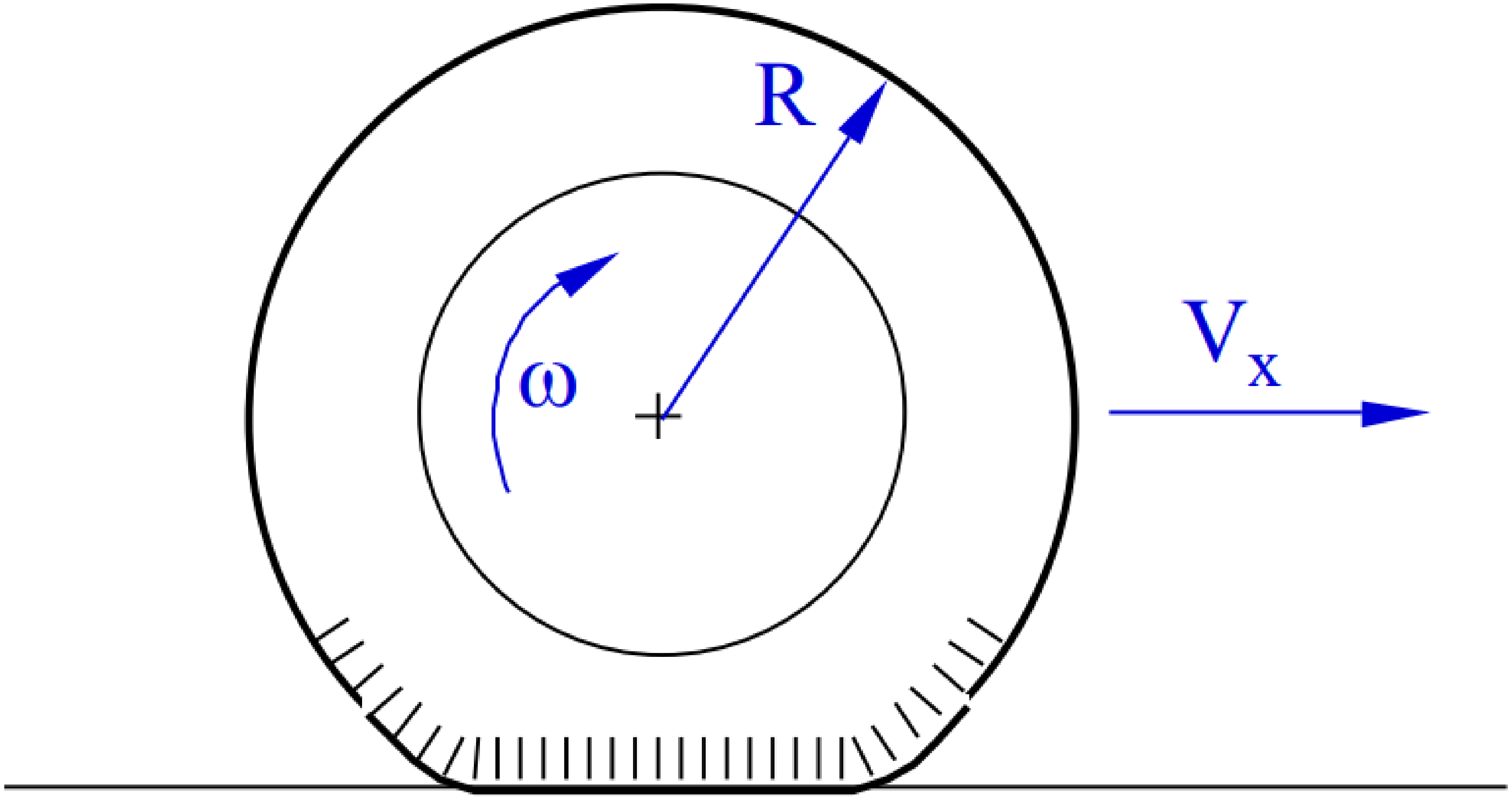


Flintsch, Mcghee, Izeppi, Najafi 2012

The Little Book of Tire Pavement Friction

Source: Schleppi 2020, RPUG

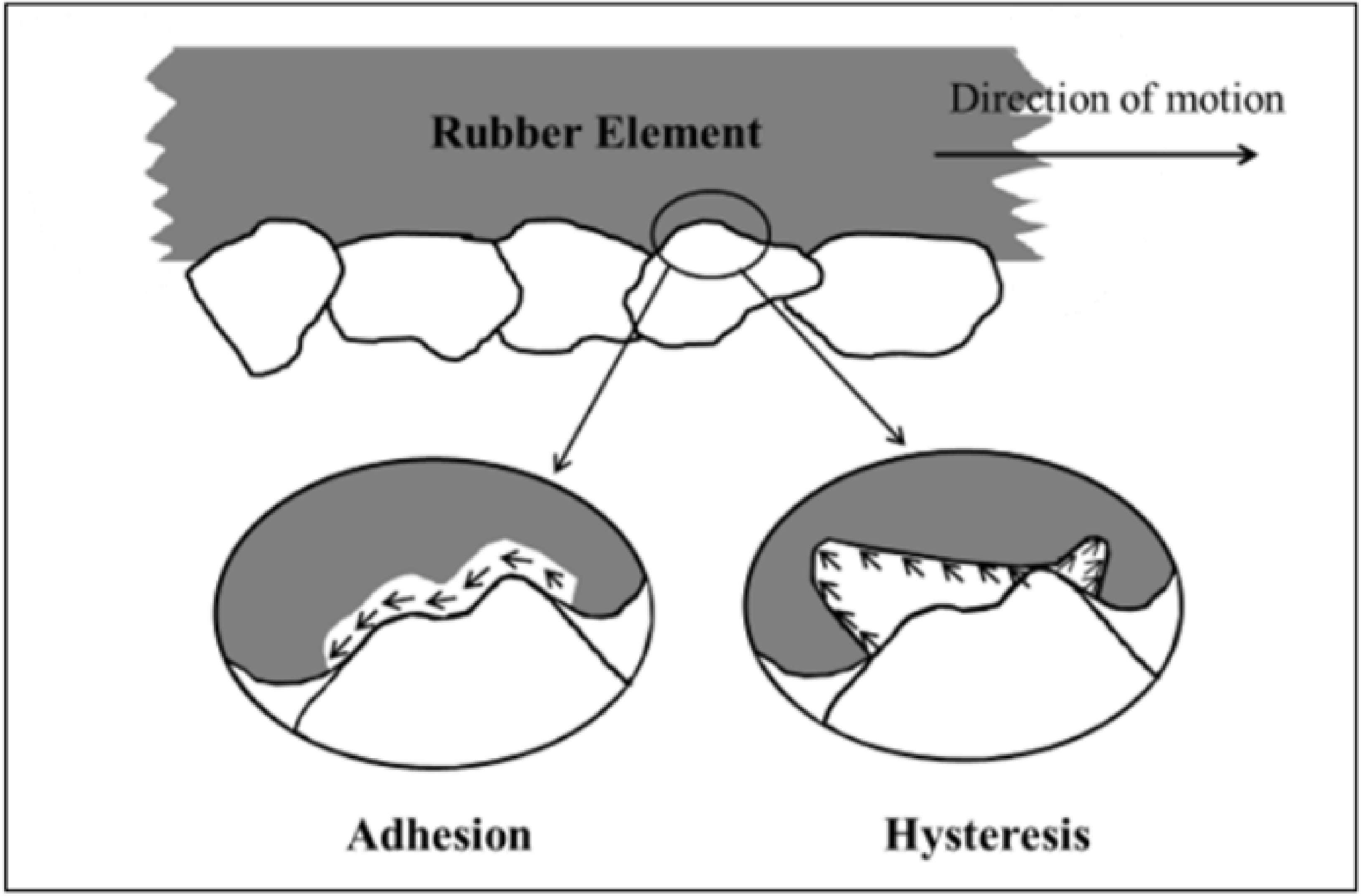
Friction and Texture



Source: Steve Karamihas
UMTRI

Source: Schleppi 2020, RPUG

Friction and Texture



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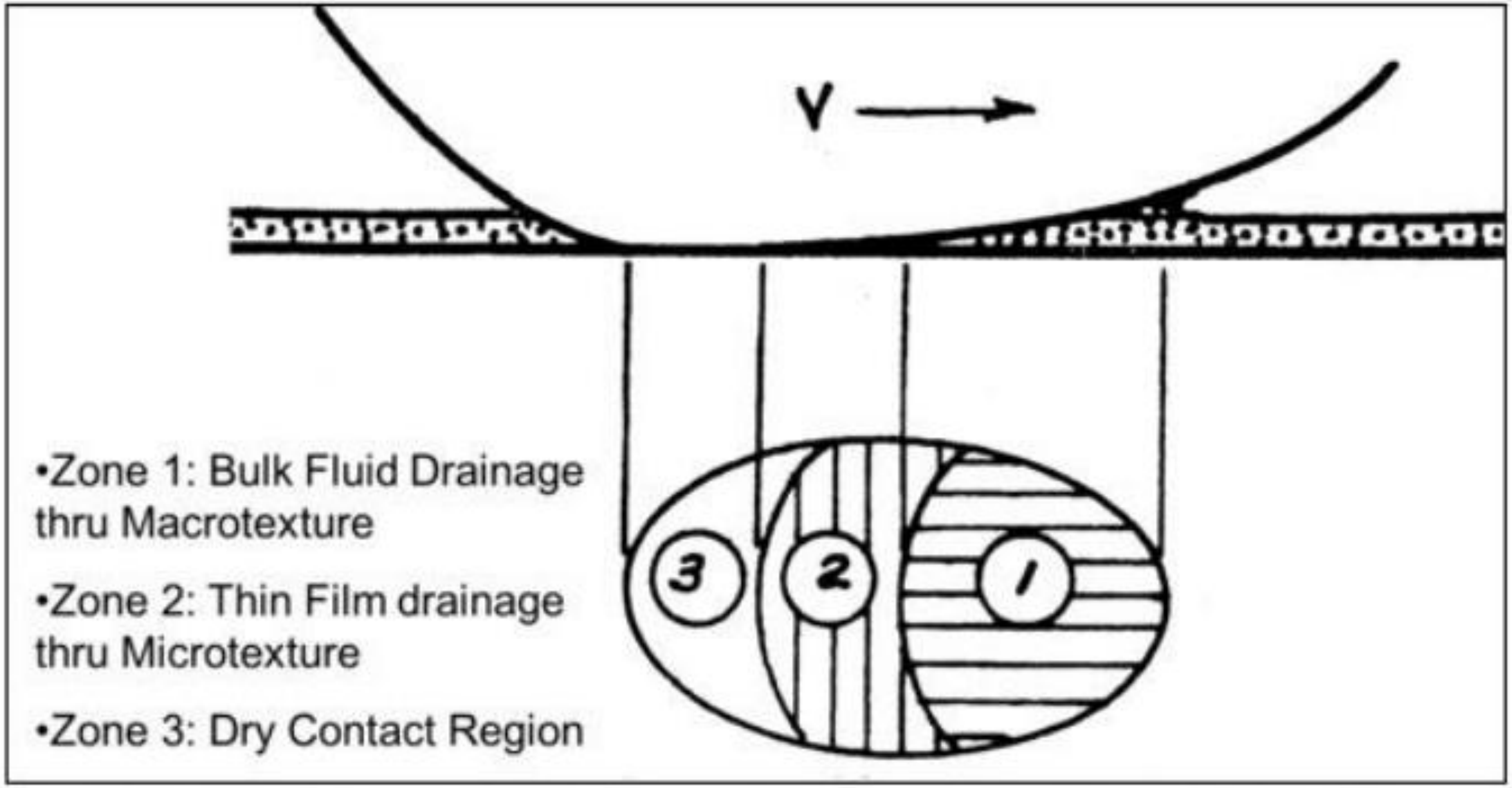
Friction and Texture



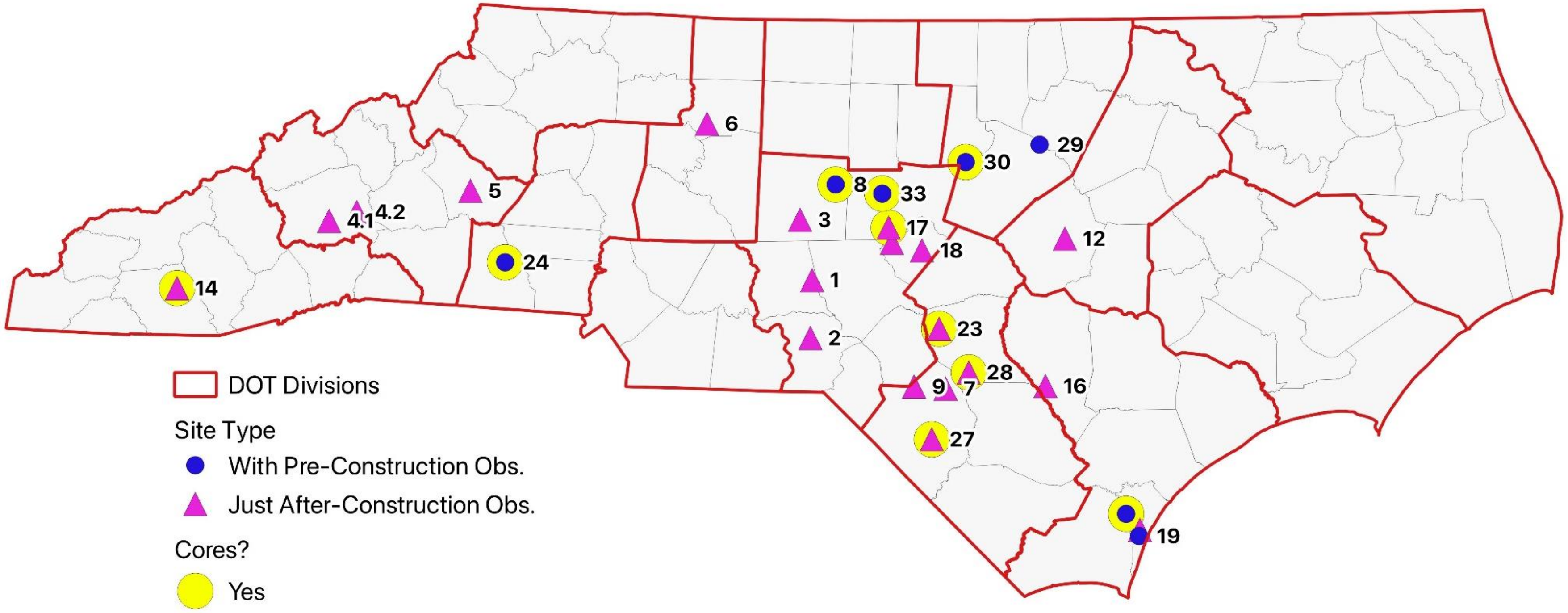
Flintsch, Mcghee, Izeppi, Najafi 2012
The Little Book of Tire Pavement Friction

Source: Schleppi 2020, RPUG

Friction and Texture Measurements

Measurements

- Core Acquisition and Lab Measurements
- Continuous Friction Measurement Equipment (CFME)
- High-Speed Laser Profiler



- Seven sites with Pre and After construction measurements.
- Field cores collected in 10 sites.

Measurements

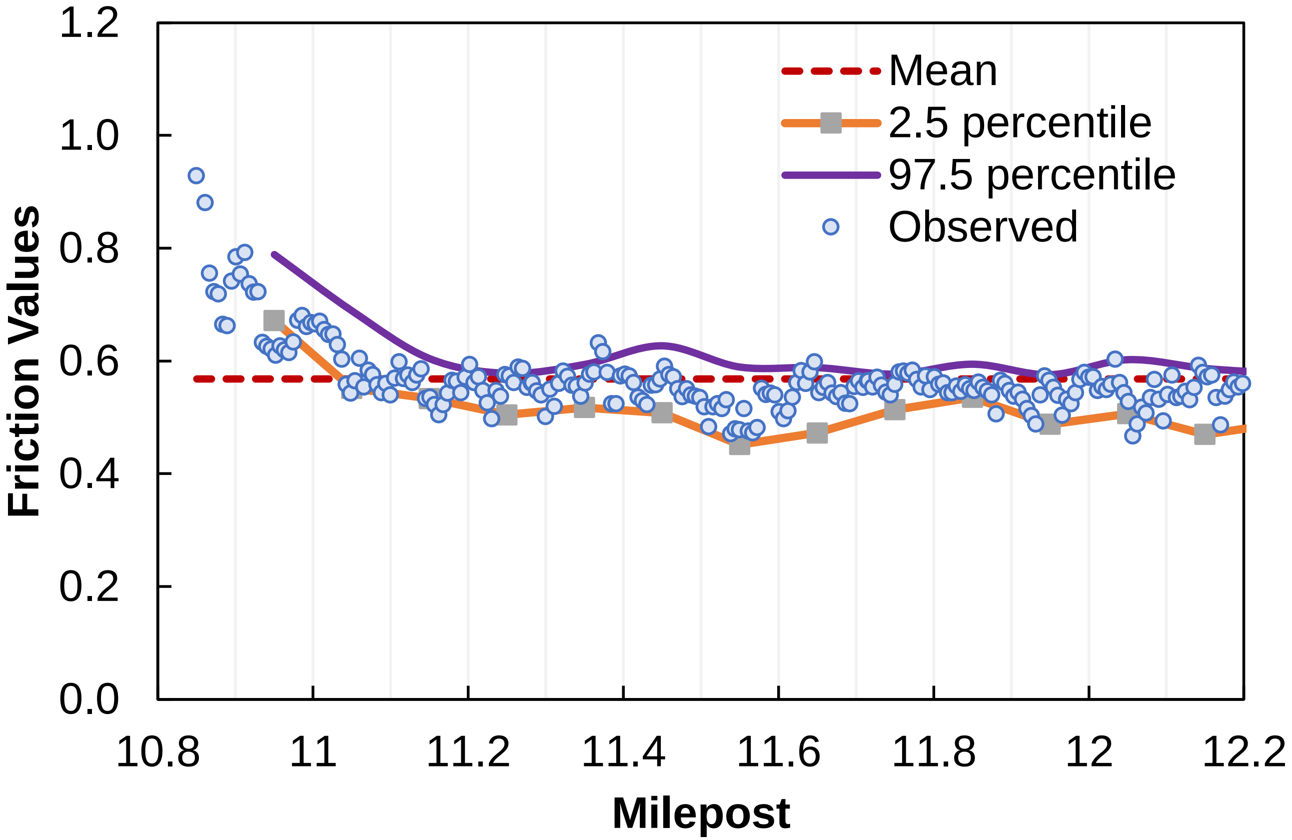
Continuous Observations

	Device	Speed	Location	Parameter
Friction (CFME)	Moventor Skyddometer BV-11	• 60-mph (all sites) • 40-mph (some sites)	• Outer most lane • Right wheel path (RWP) • Center of the lane (CL)	Friction value reported every 3 m (9.8 ft)
Texture	AMES Engineering HSIP (spot laser)	Posted speed limit		Texture indices reported every 3 m (9.8 ft) • MPD • Skewness • Kurtosis

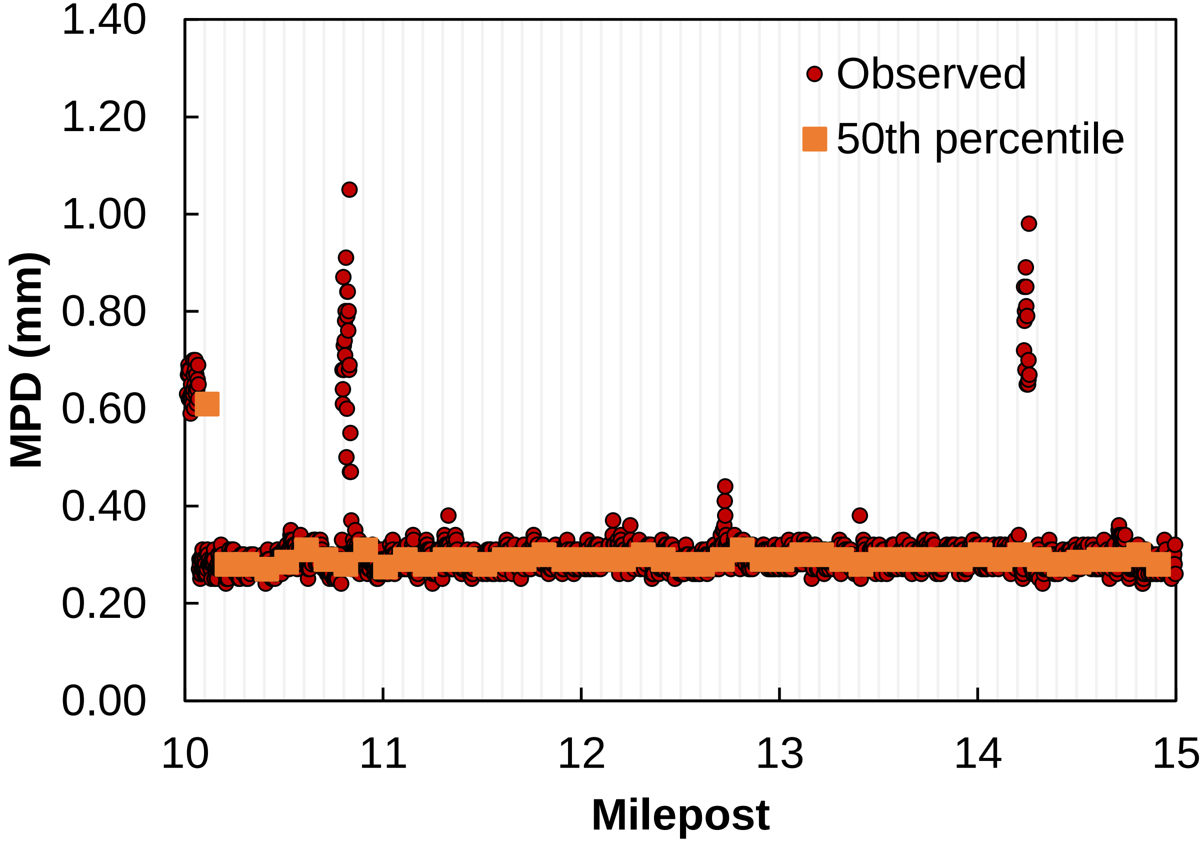
CFME: Continuous Friction Measurement Equipment

Measurement Processing

CFME



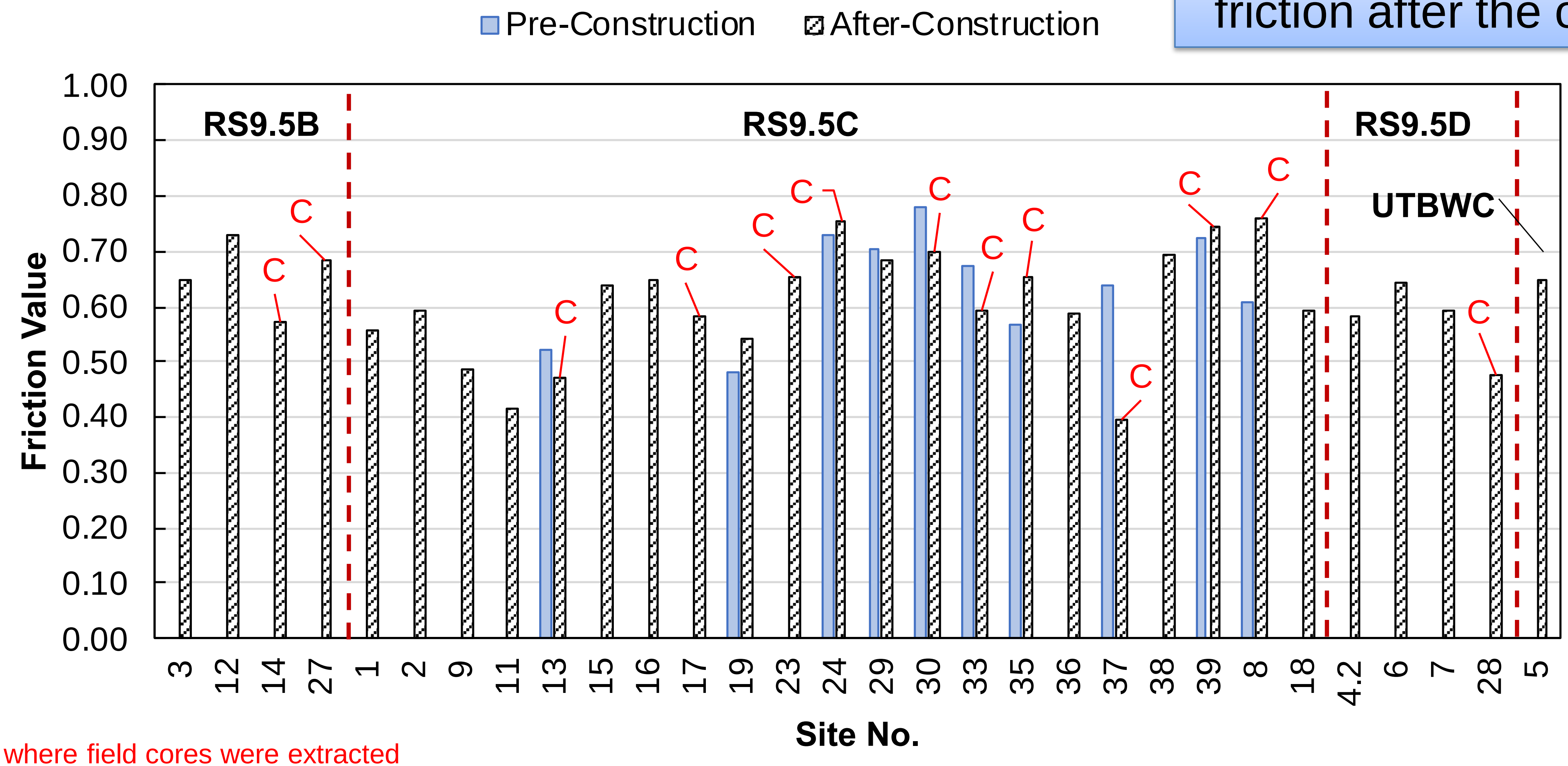
Texture



Results

Field Friction After an Overlay

5 out 10 sites with lower friction after the overlay

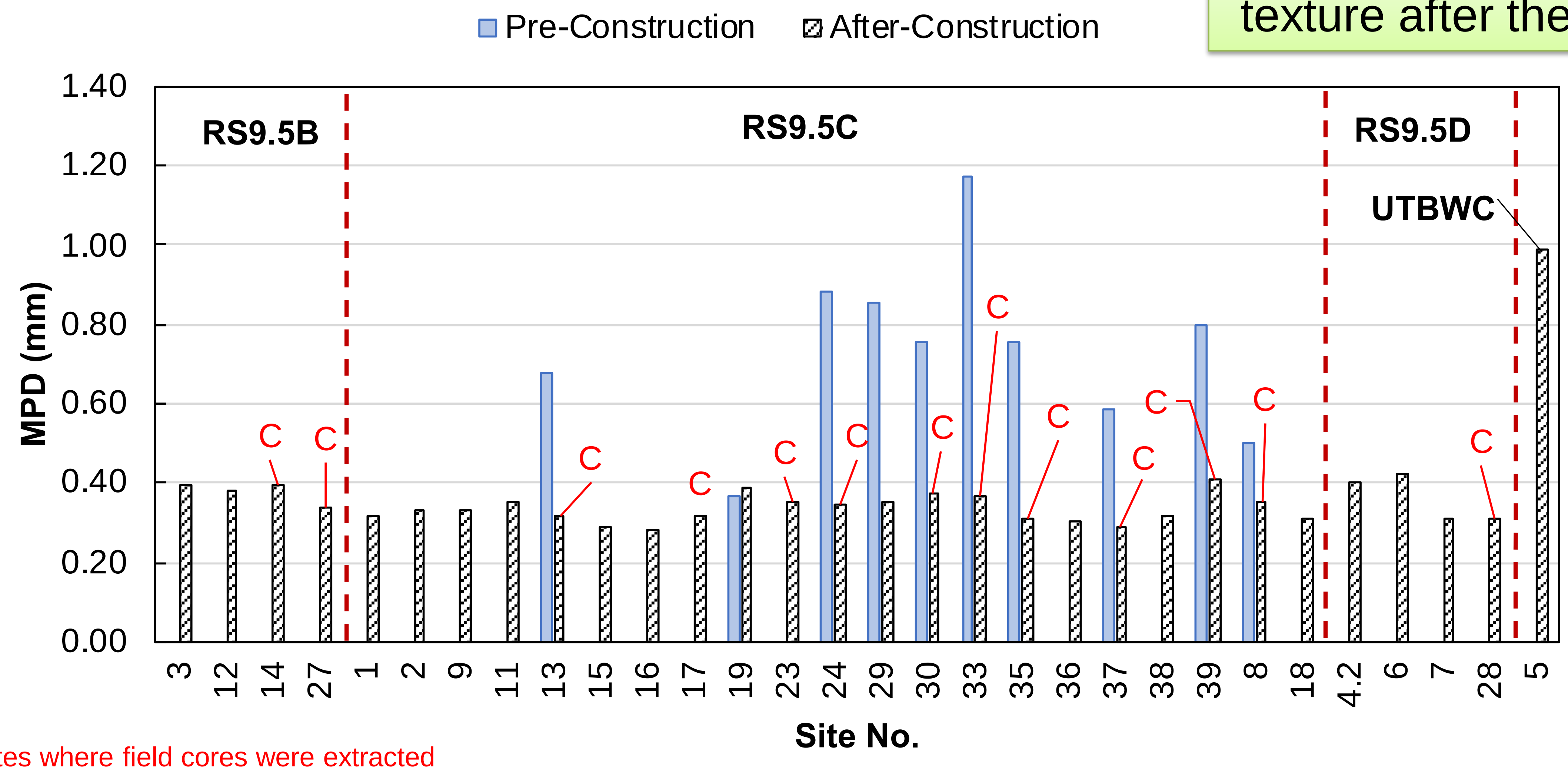


C: Sites where field cores were extracted

Results

Field Texture After an Overlay

9 out 10 sites with lower texture after the overlay.



C: Sites where field cores were extracted

What do these results mean to wet crash rates?

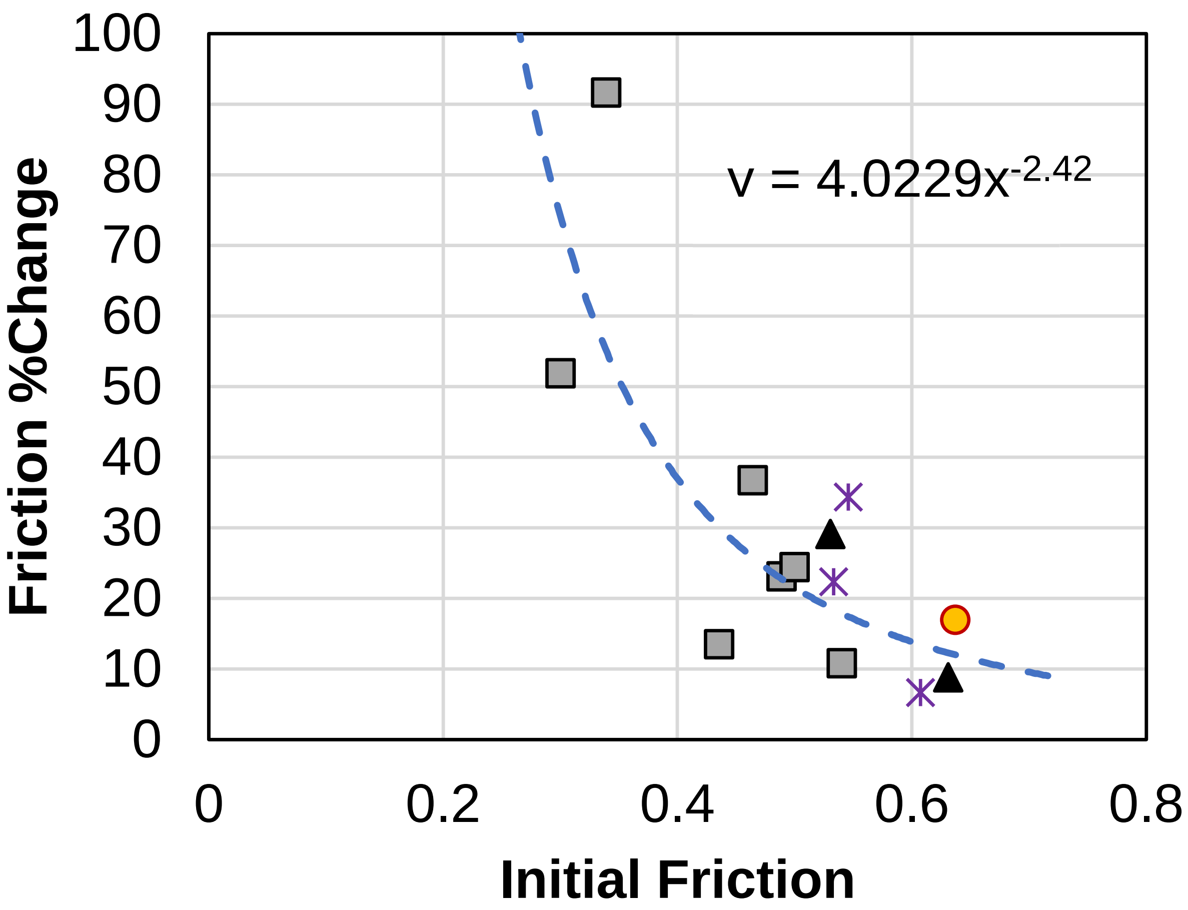
- The crash rates and the average vehicle speeds 'before' and 'after' an overlay were compared.
  - Number of crashes per month after the overlay was placed were generally higher for dense graded mixtures.
  - The UTBWC/OGFC seems to provide better safety performance.

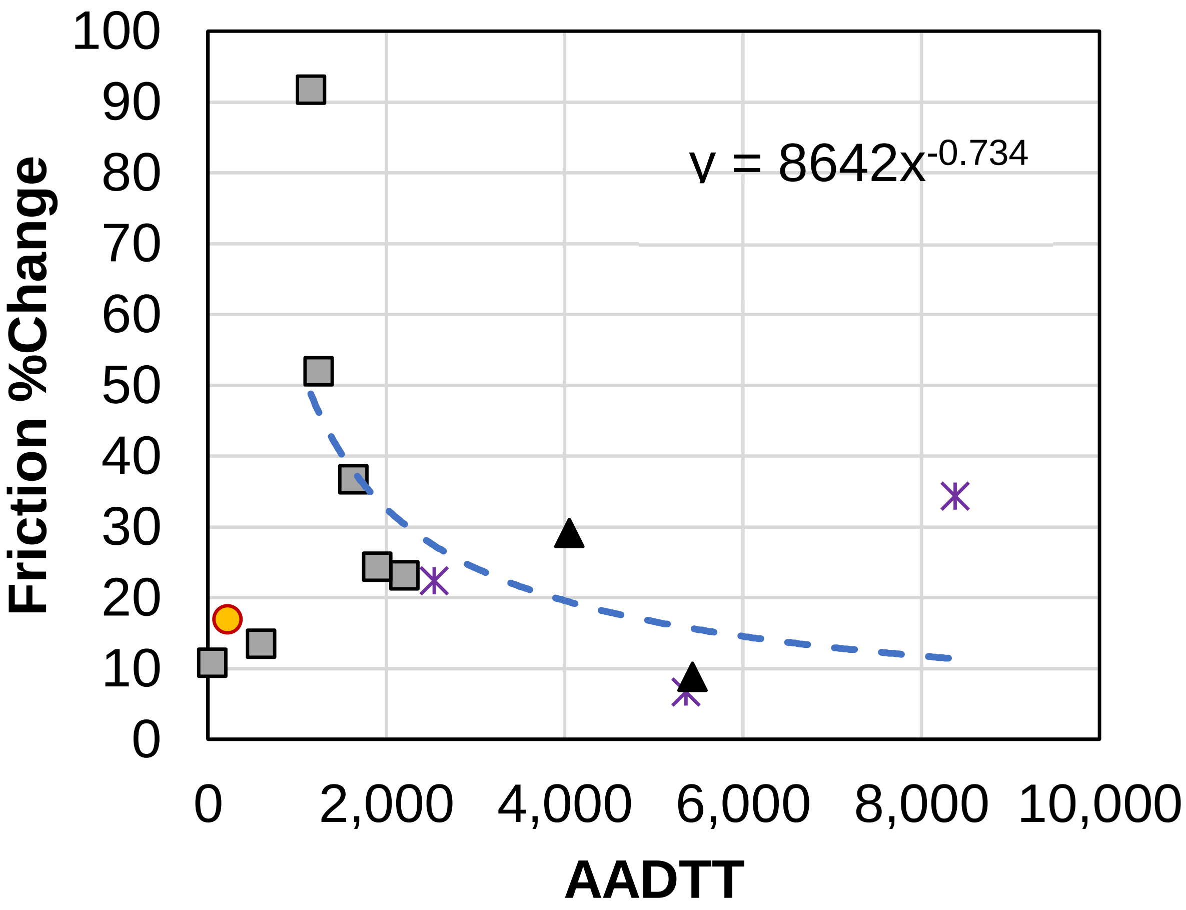
Lane Configuration	Total	Total Wet	Lane Departure	Lane Departure Wet
2-Lane	-77.08	-100.00	-54.17	-100.00
2-Lane	68.06	-100.00	-8.33	-100.00
2-Lane	71.88	-[a]	450.00	-
2-Lane	57.14	1550.00	340.00	-
2-Lane	21.32	175.00	140.63	450.00
2-Lane	22.69	480.00	45.00	45.00
2-Lane	-43.75	-3.13	29.17	55.00
4-Lane Divided Highway	118.18	196.97	129.09	281.82
4-Lane Divided Highway	118.57	440.00	-	-
4-Lane Divided Highway	59.56	481.25	232.14	2225.00
4-Lane Divided Highway	5.77	175.00	-8.33	312.50
4-Lane Divided Highway	7.18	78.18	56.01	256.36
4-Lane Divided Highway	-18.24	-3.33	-13.78	45.00
4-Lane Freeway	29.08	30.63	14.58	22.22
4-Lane Freeway	112.50	175.00	113.89	243.75
4-Lane Freeway	-12.33	64.38	60.00	155.32
4-Lane Divided Highway	13.77	126.21	66.55	266.67
4-Lane Freeway	75.08	455.56	137.04	733.33
6-Lane Freeway	-74.26	-100.00	-100.00	-100.00
6-Lane Freeway	30.95	-1.79	42.24	22.22
4-Lane Freeway	-7.75	-14.06	-42.92	-42.71
4-Lane Freeway	-14.43	-51.67	-0.16	-30.00
4-Lane Freeway	-18.06	-19.40	17.86	-14.06

What compositional factors contribute to better or worse friction and texture performance?

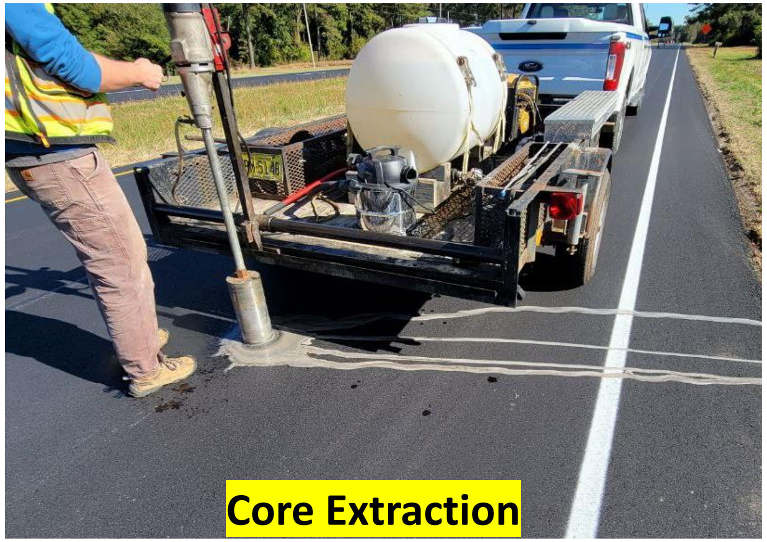
Source: TTI 2021

Friction Evolution

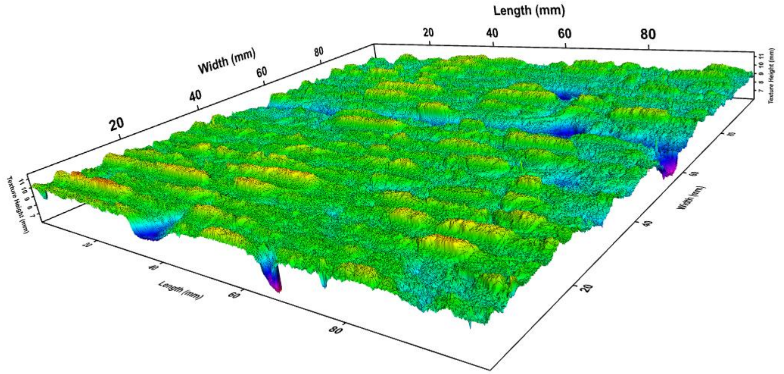


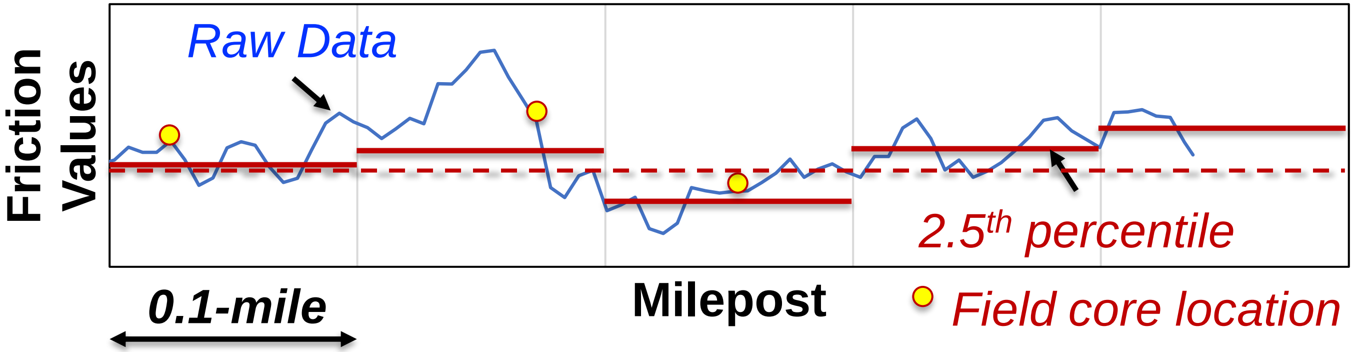


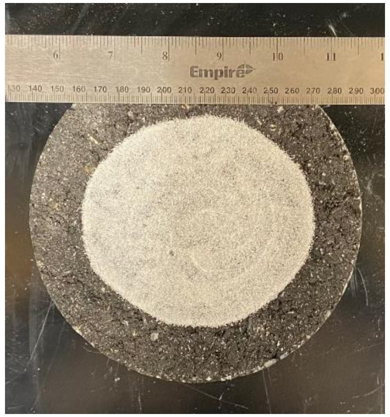
Understanding Volumetric Relationships Affecting Friction and Texture



3D Surface

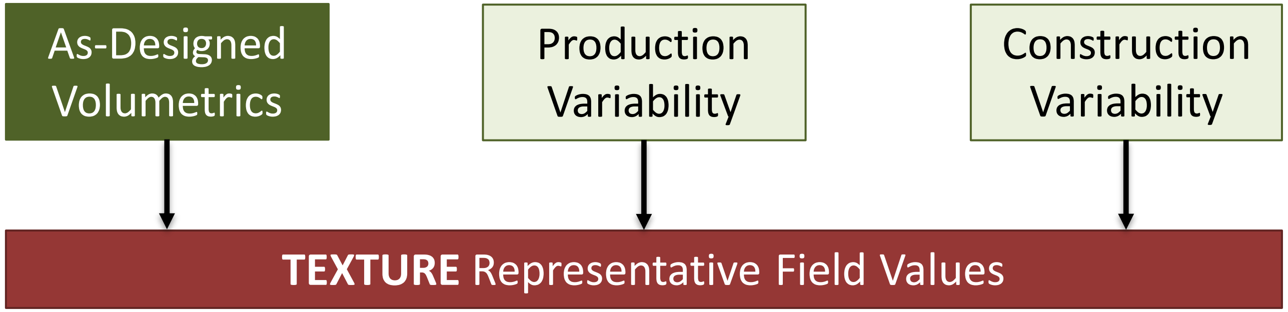




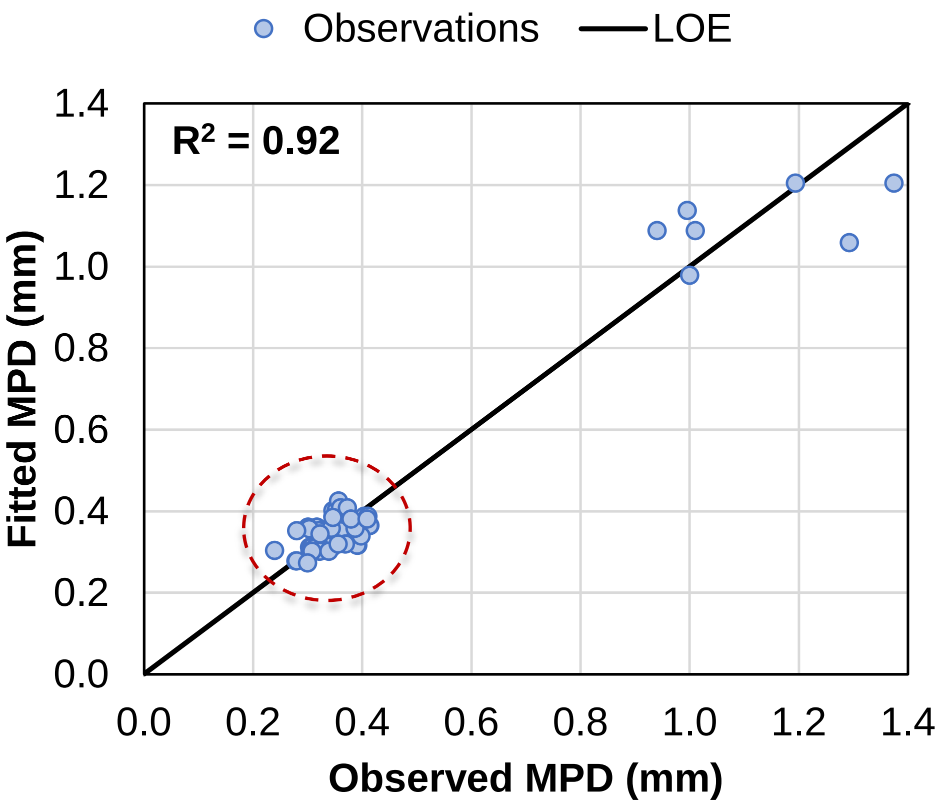


Effect of Volumetric Composition on Field Texture

- A model that relates the **as-designed** mixture composition with the **representative field** friction and texture is proposed.



$$MPD_{representative} = 1.22 - 0.009 \times VFA + 0.087 \times Cc - 0.046 \times \left(AC\% \cdot Dense \right)$$

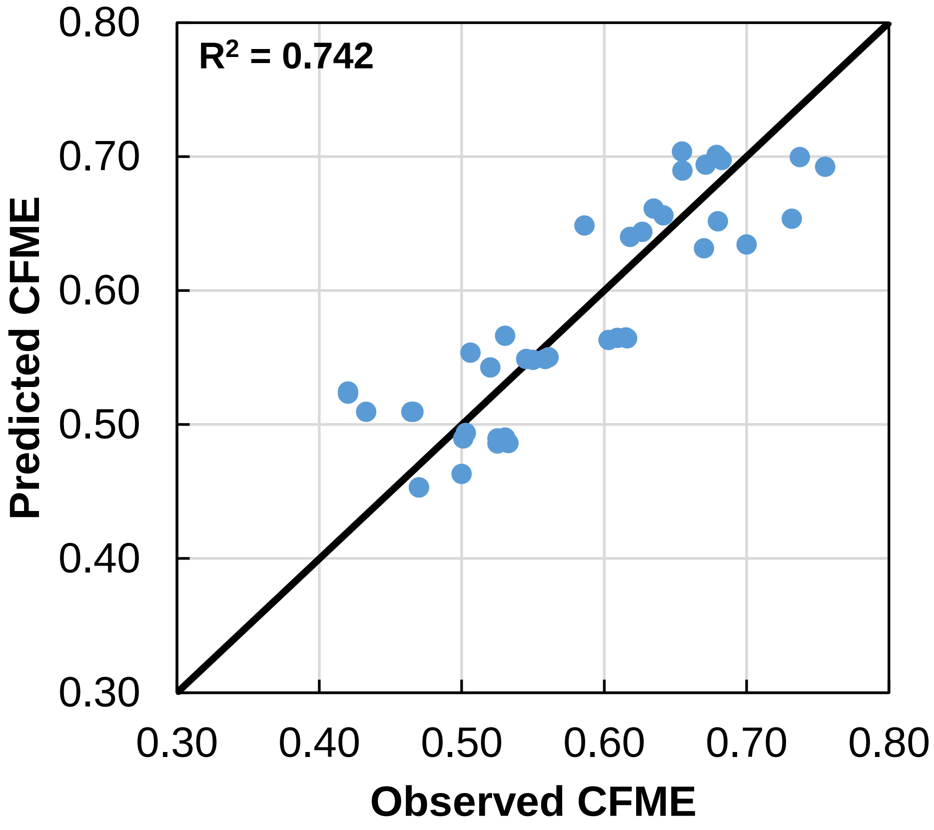


Effect of Volumetric Composition on Field Friction

- A model that relates the **as constructed** mixture composition and **surface parameters**, with the **representative field** friction and texture is proposed.

$$Friction_{field} = 0.619 + 0.172 \times (Cc + Peak + Valley) - 0.0060 \times (AC \times P_{200})$$

$Friction_{field}$	= Avg friction (CFME) in 0.1-mile length,
Cc	= gradation coefficient of curvature,
Peak	= average peak height (positive texture elevation), in mm,
Valley	= average valley depth (negative texture elevation), in mm,
AC%	= binder content in %, and
P_{200}	= percent passing sieve No. 200.



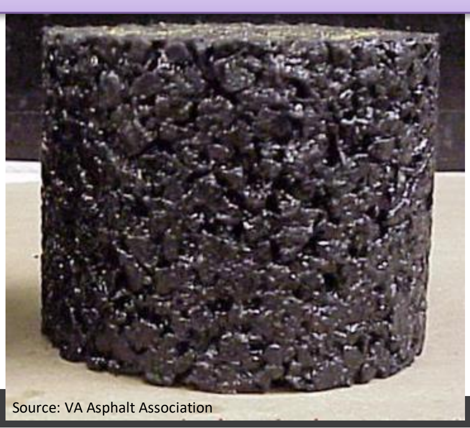
Important Volumetric Factors

Fine Gradation

Source: VA Asphalt Association

VS

Coarse Gradation



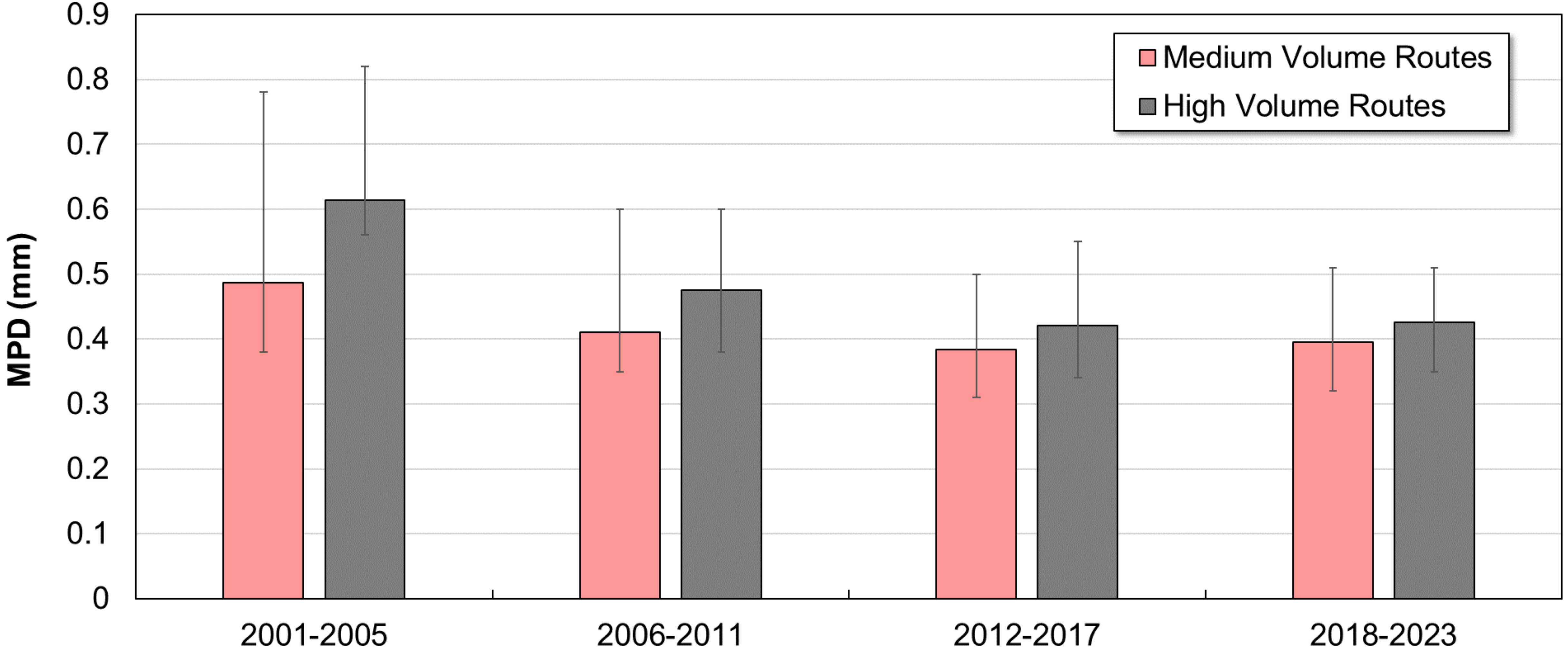
Source: VA Asphalt Association

Asphalt Binder Content

Source: VA Asphalt Association

Filler Content

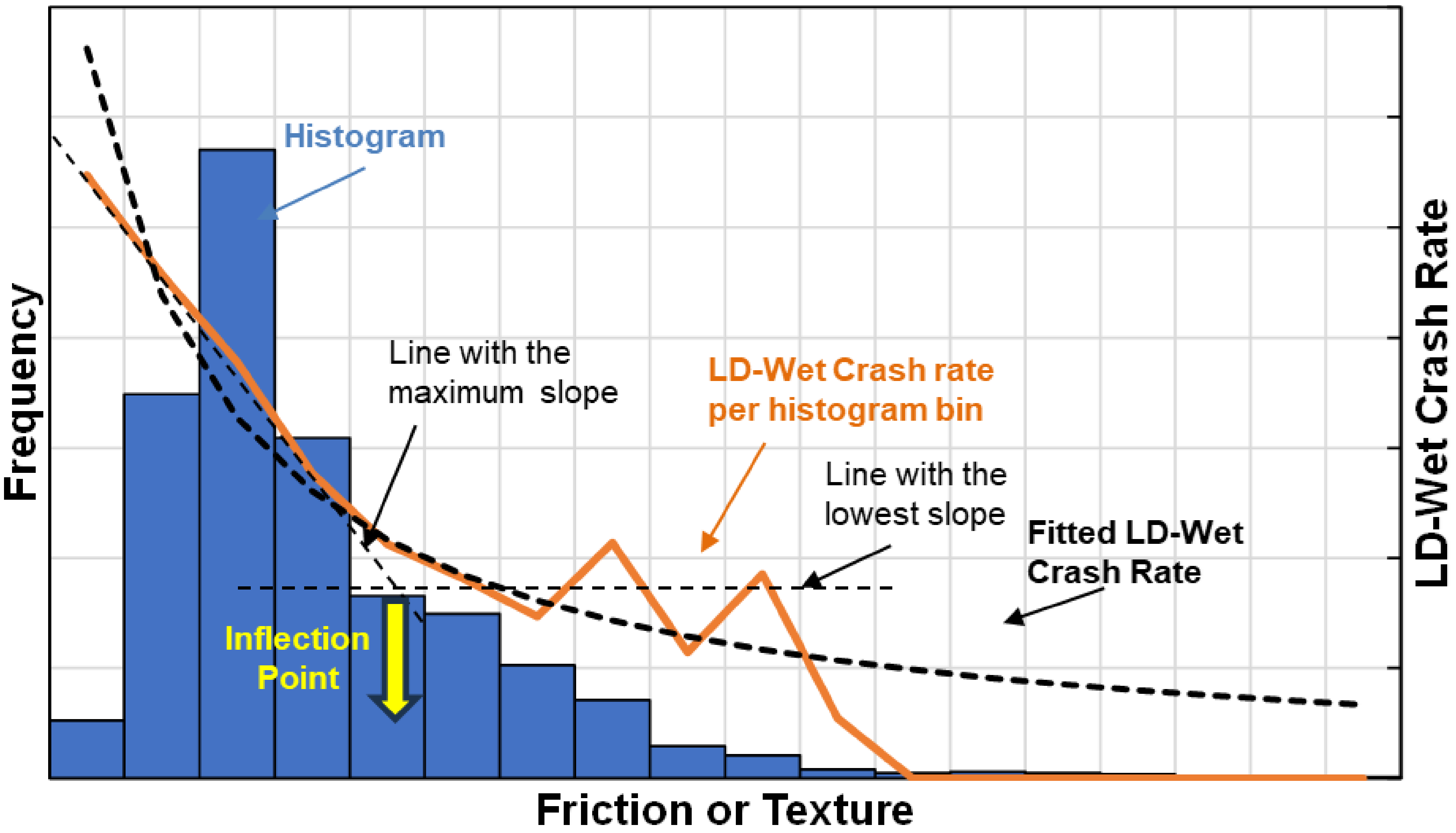
How have mixture composition decisions affected dense mix texture over time?



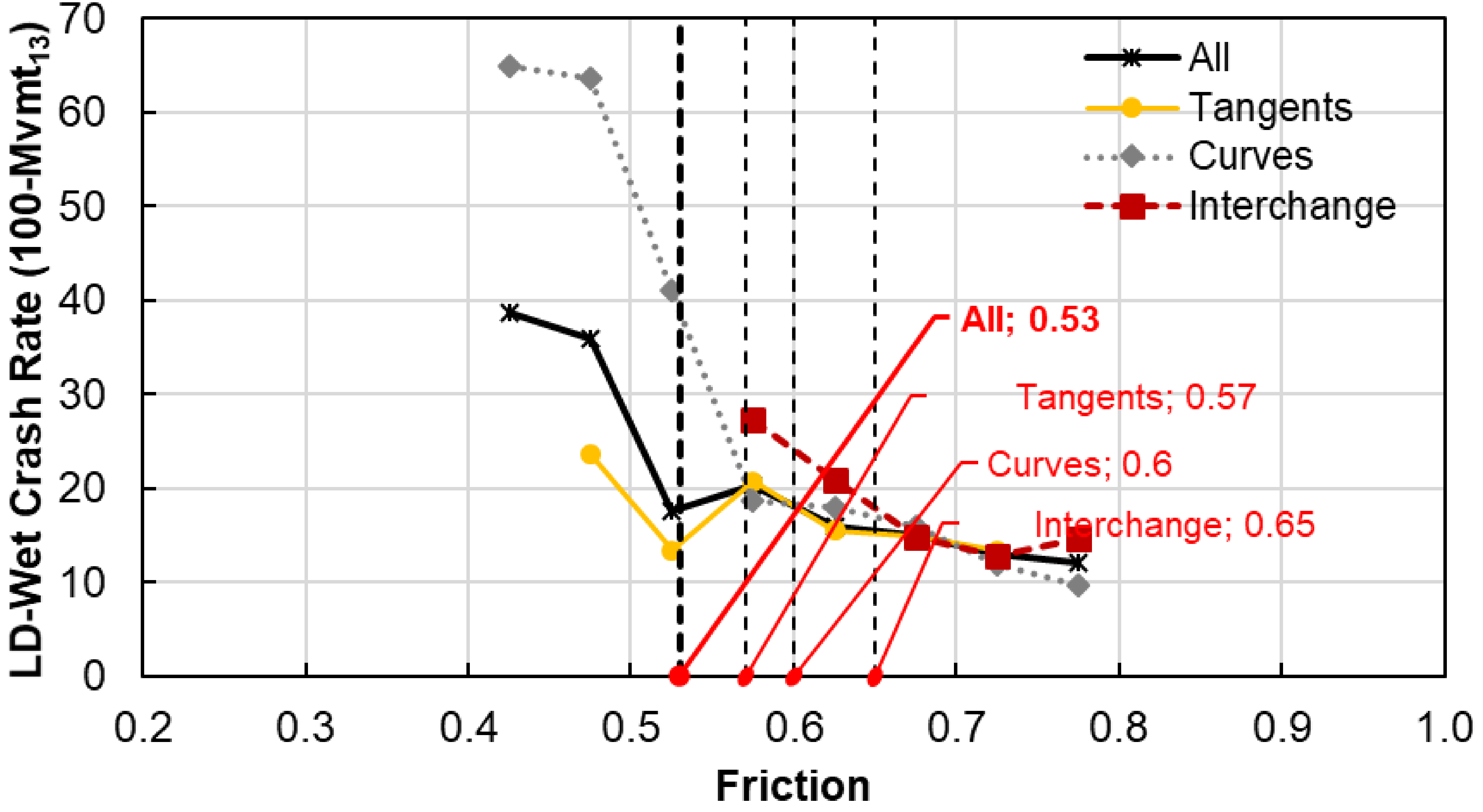
How might limits on friction and texture contribute to improved safety?

Safety Implications of Texture and Friction

Crashes, traffic, and length get aggregated and crash rate implications can be estimated.



Safety Implications of Texture and Friction



Safety Implications of Texture and Friction

Cost-Benefit Analysis

Friction/texture prediction (Do nothing vs. Intervene)

→

Step 2. Estimation of Number of Crashes and Intervention Costs

→

Step 3. Conduct an Benefit-Cost Analysis

Safety Implications of Texture and Friction

Cost-Benefit Analysis

Input	Value
Pavement Age	• Dense mix: 12 years • OGFC: 5-10 years (Note 1) • UTBWC: 7-10 years (Note 2)
Intervention Thresholds	• Friction: 0.53 • MPD: 0.5, 0.6, 0.7-mm • Risk, $P(R<10)$: 45%, 55%, 65%
Maintenance Costs	• The cost of treatment per 0.1-mile-lane segment is: $7,500 for asphalt overlay $3,700 for OGFC $3,400 for UTBWC $2,100 for Skidabrader • An asphalt overlay is applied before an OGFC/UTBWC.
Crash Cost	• $218,000 USD (Lane departure crashes)
Safety Treatments	• UTBWC: Western Divisions: 11 to 14 • OGFC: Eastern Divisions: 1 to 10
Discount Rate	• 3, 5, and 7%
Analysis Period	• 40 years, starting at 2022

- The Group-3 sites were used to demonstrate the proposed PFMP framework.
- A relationship between SCRIM and BV-11/AMES HSTP was established.

Business-As-Usual (S1)

A treatment is triggered based on a maximum service life.

Maintenance-With-Safety (S2)

In addition to age, a treatment is triggered either by texture or friction.

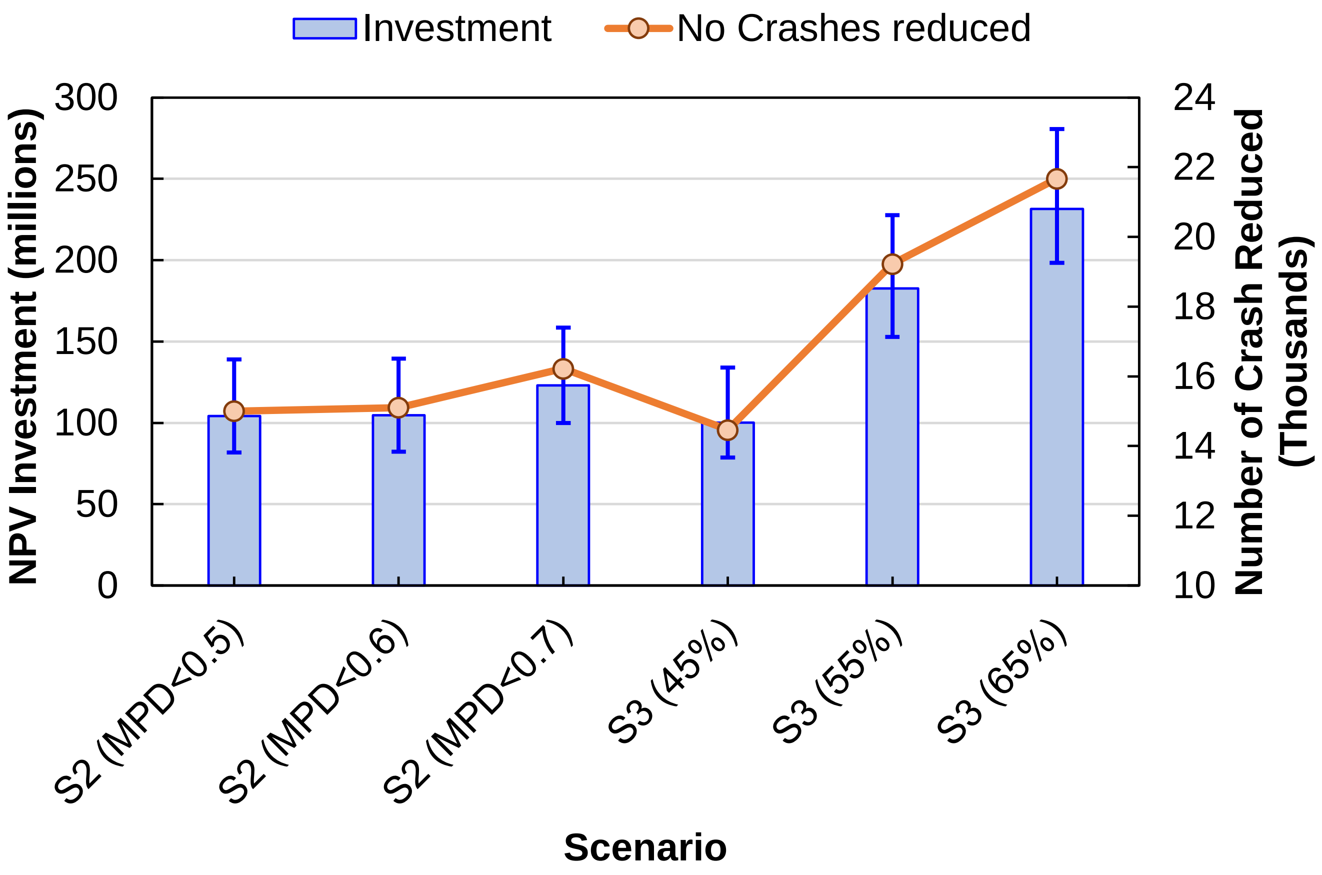
Safety-Risk-Balance (S3)

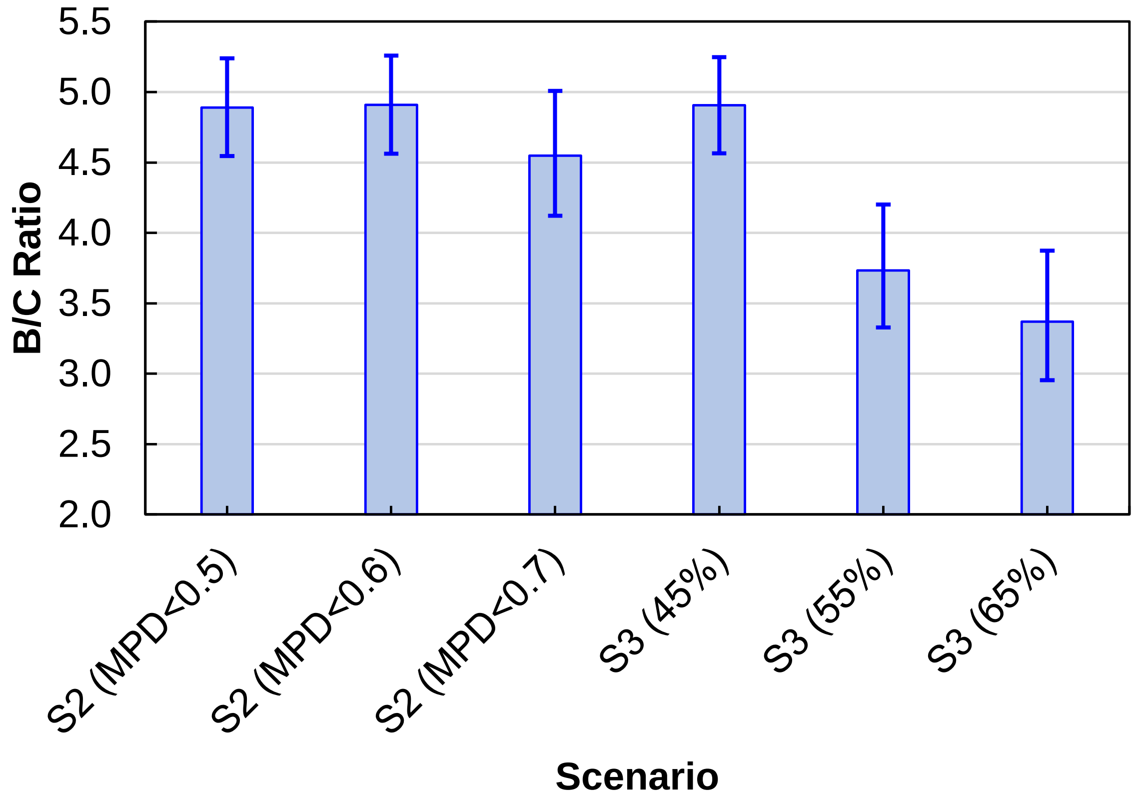
In addition to age, a treatment is triggered based on the concept of allowable risk.

Note 1: Three possible OGFC treatment variations evaluated.
Note 2: Two possible UTBWC treatment variations evaluated.

Safety Implications of Texture and Friction

Cost-Benefit Analysis






Slippery when wet


WHAC
A-
Performance on multiple fronts


Mix design factors


Costs and benefits

Acknowledgements

- NCSU Graduate research assistants: Boris Goenaga and Benson Munywoki
- NCSU colleague: Cassie Castorena
- KPR Engineering: Paul Rogers
- North Carolina Department of Transportation

NC STATE UNIVERSITY

Thank you!

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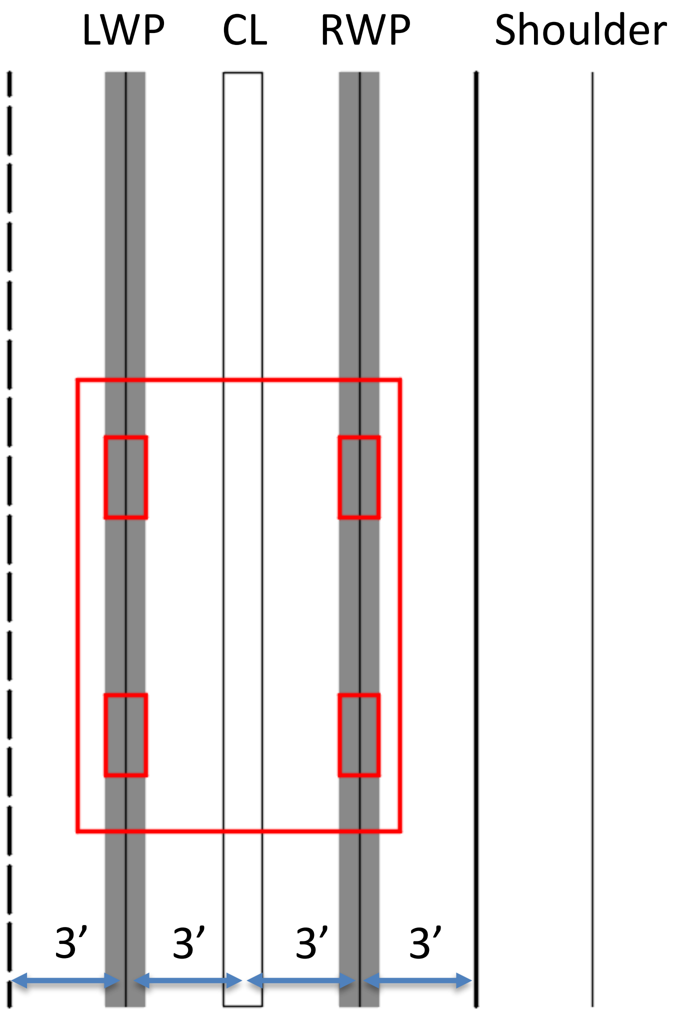
Measurements

Wheel Path Selection

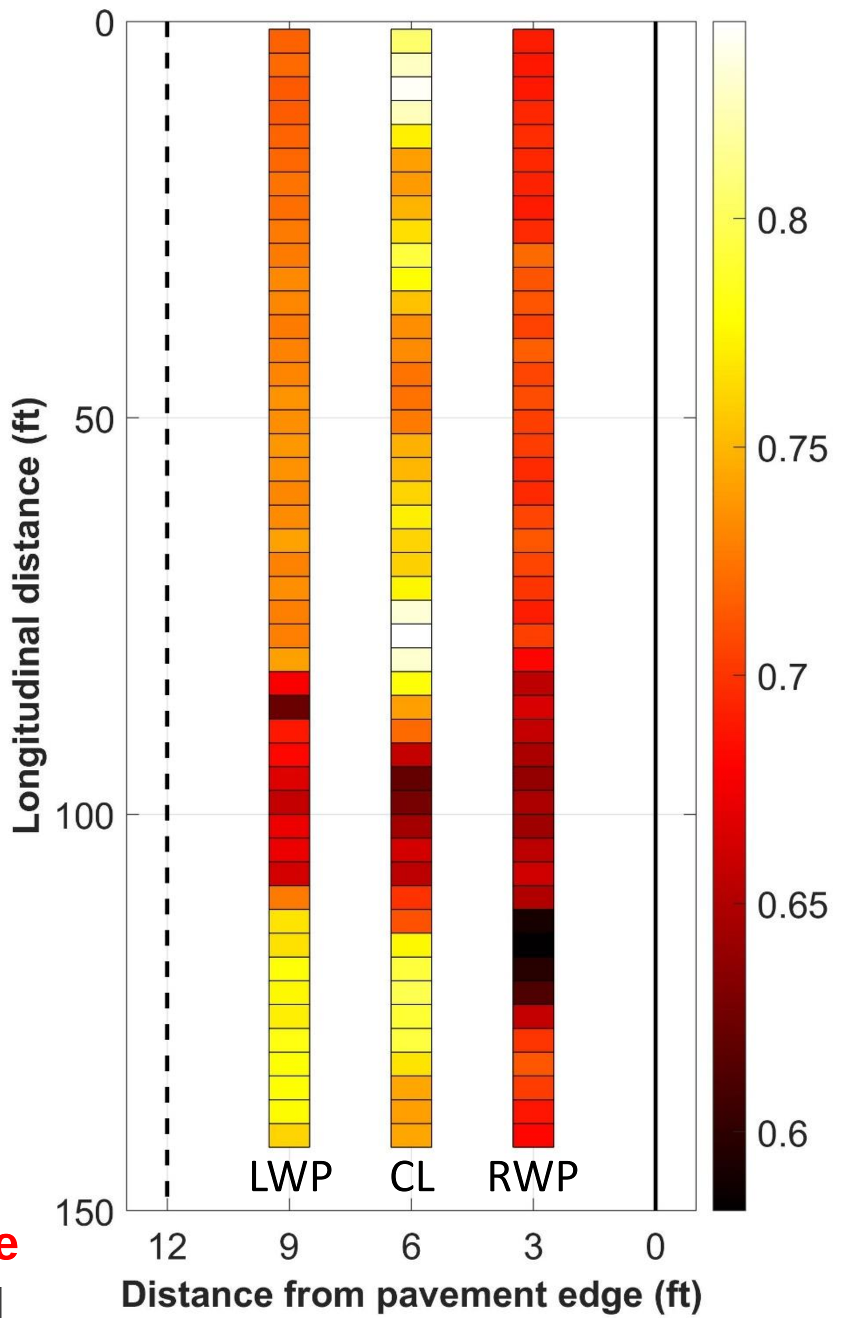
- Friction should be measured in the lane/wheel path with the highest traffic exposure.
- According to the FHWA circular advisory (T 5040.38), the left wheel path in the outer most lane is generally considered to have the most traffic.
- Based on experience from historical measurements, the LWP does not seem to be the critical one, at least in North Carolina.



Measurements

Wheel Path Selection

- It was found that friction and texture, most of the time, are the lowest in the outer most lane.
- Also, within the outer most lane, the right wheel path is the one that shows the lowest friction and texture values more often.
- In general, testing in the RWP gives the best chance to locate potential texture and friction problems and reduce wet weather crashes.



DGAC Site

Measurements

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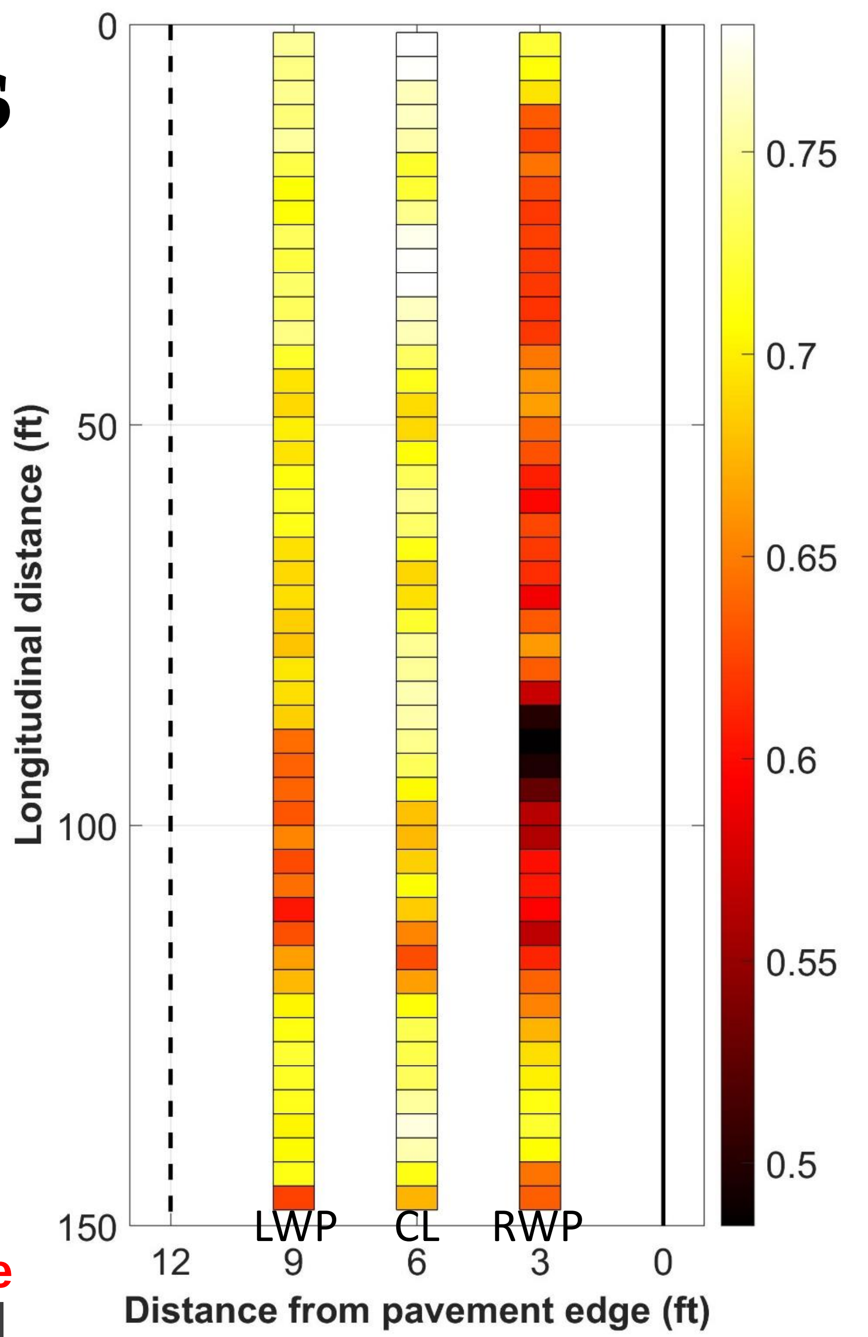

Microsurface