Safer Pavement Surfaces: Friction Characteristics

David K. Merritt, P.E.

THE TRANSTEC GROUP
The World's Pavement Engineering Specialists

NATIONAL PAVEMENT PRESERVATION CONFERENCE
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IMPACTS AND BENEFITS FROM PAVEMENT PRESERVATION

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AASHTO TSP2 PAVEMENT PRESERVATION

ROCKY MOUNTAIN WEST PAVEMENT PRESERVATION PARTNERSHIP
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MIDWESTERN PAVEMENT PRESERVATION PARTNERSHIP
NORTHEAST PAVEMENT PRESERVATION PARTNERSHIP

Presentation Overview

- Importance of Pavement Friction
- Basics of Pavement Friction
- Measurement of Pavement Friction
- How Much Friction is Enough?

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Importance of Pavement Friction

- Pavement friction is related to roadway safety and directly impacts the lives of roadway users.

Importance of Pavement Friction

- In 2019, there were approximately 6.76 million crashes reported in the U.S., accounting for 36,096 fatalities and over 2.74 million injuries (*42,939 fatalities in 2021*).
- 50% of the 2019 fatalities were the result of roadway departure (RwD) crashes and more than 23% were intersection-related.
- ~25% of fatal crashes are associated with horizontal curves (horizontal curves make up only 5% of our Nation's roadways)
- ~76% of curve-related fatal crashes are the result of roadway departure.

(FHWA-SA-21-093)

Importance of Pavement Friction

- Most safety countermeasures focus on reducing driver error or minimizing the consequences of leaving the roadway.
- Pavement friction helps keep vehicles in the lane and helps reduce stopping distance.

Importance of Pavement Friction

- Effect of Low-Cost Surface Treatments on Crashes
  - Most treatments generally increase friction.
  - CMF = Crash Modification Factor
  - Examples:
    - Chip Seal:
      CMF = 0.373 (wet ROR)
    - Diamond Grinding:
      CMF =0.869 (wet road, freeways)
    - Thin Overlay:
      CMF = 1.256 (wet road, two-lane)

Treatment	Wet Road Crashes
Thin HMA Overlay	Two-lane roads
	All other roads
OGFC	All roads
Chip Seal	All roads
Microsurfacing	All roads
Slurry Seal	All roads
UTBWC	All roads
Diamond Grinding	All roads

CMF > 1 CMF < 1

Source: FHWA-HRT-14-065

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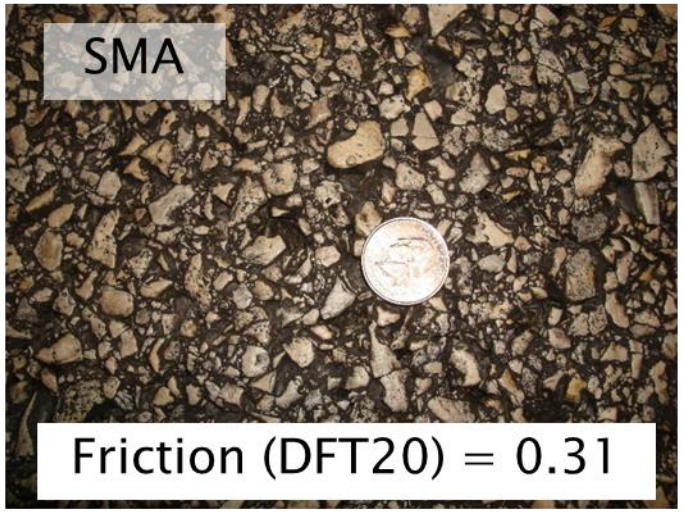
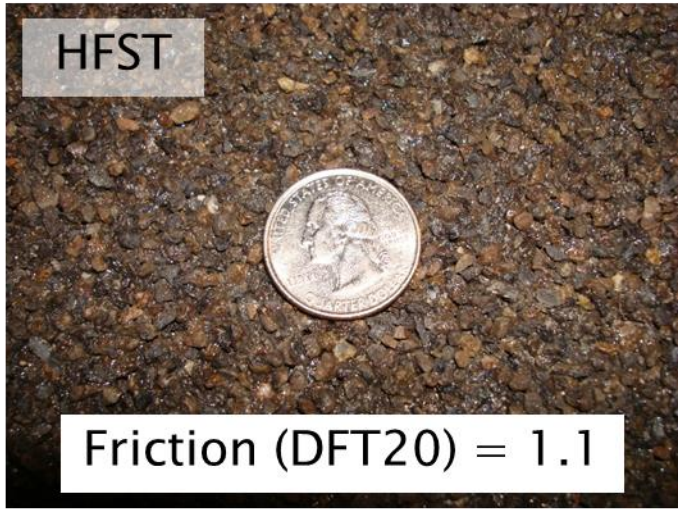
Importance of Pavement Friction

- Effect of Low-Cost Surface Treatments on Crashes (HFST)





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Importance of Pavement Friction

- Relationship between friction and pavement safety performance:

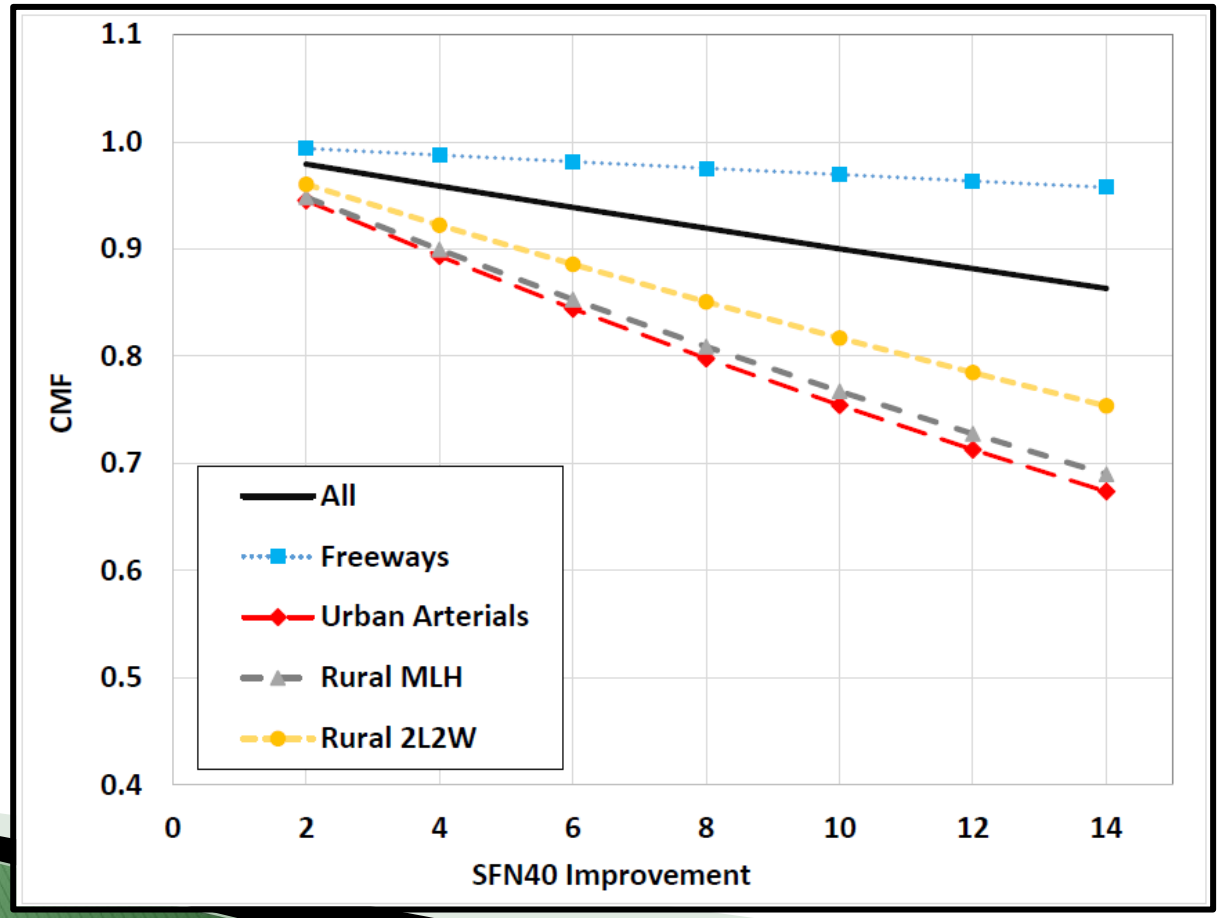
  "The analysis confirmed a strong statistical association between pavement surface frictional properties (friction and macrotexture) and crash rates. Lower crash rates were observed with higher friction (SFN40) and macrotexture (MPD) on all roadway types."

  Source: FHWA-SA-23-006

Importance of Pavement Friction

- Relationship between friction and pavement safety performance

CMFs vs. Friction Improvement



Source: FHWA-SA-23-006

Importance of Pavement Friction

- Myth #1: Friction is only important for wet weather crashes
  - "The results of crash rate analyses showed that both wet- and dry-road crash rates decreased as skid resistance increased."
  - "Wet-road crash rates were found to be significantly higher in curves than on tangents. For dry-road crashes, no differences were found between curves and tangents."

Source: FHWA-SA-23-006

Treatment	Dry Road Crashes
Thin HMA Overlay	Two-lane roads
	All other roads
OGFC	Two-lane and multilane roads
	All other roads
Chip Seal	Multilane roads
	Two-lane roads
Microsurfacing	Two-lane roads
	All other roads
Slurry Seal	Two-lane roads
	All other roads
UTBWC	Two-lane roads
	All other roads
Diamond Grinding	Freeways
	All other roads

CMF > 1 CMF < 1

Source: FHWA-HRT-14-065

Importance of Pavement Friction

- Myth #2: Friction is only important for curves.

- Illinois Interstate 74
  - 77% Roadway Departure Crashes
  - >50% tractor trailer semis
  - >50% wet conditions
  - High crosswinds
- Before Friction Treatment
  - 8 car and 50 semi crashes under 'slick' pavement conditions in 5 years
- After Friction Treatment (HFST)
  - 6 car and 0 semi crashes under 'slick' conditions in 4+ years

Presentation Overview

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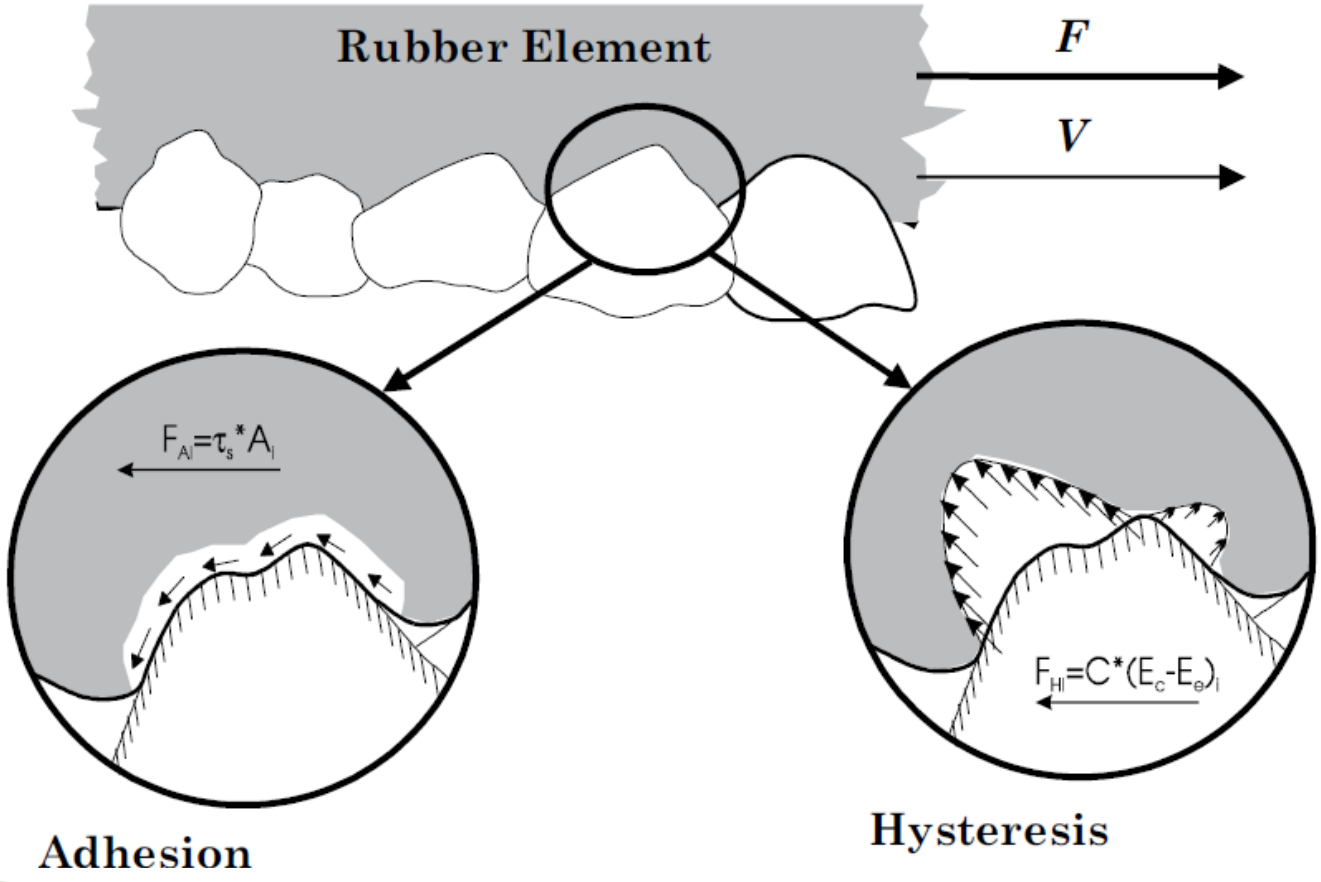
Basics of (Tire-Pavement) Friction

- Tire-pavement interaction is complex

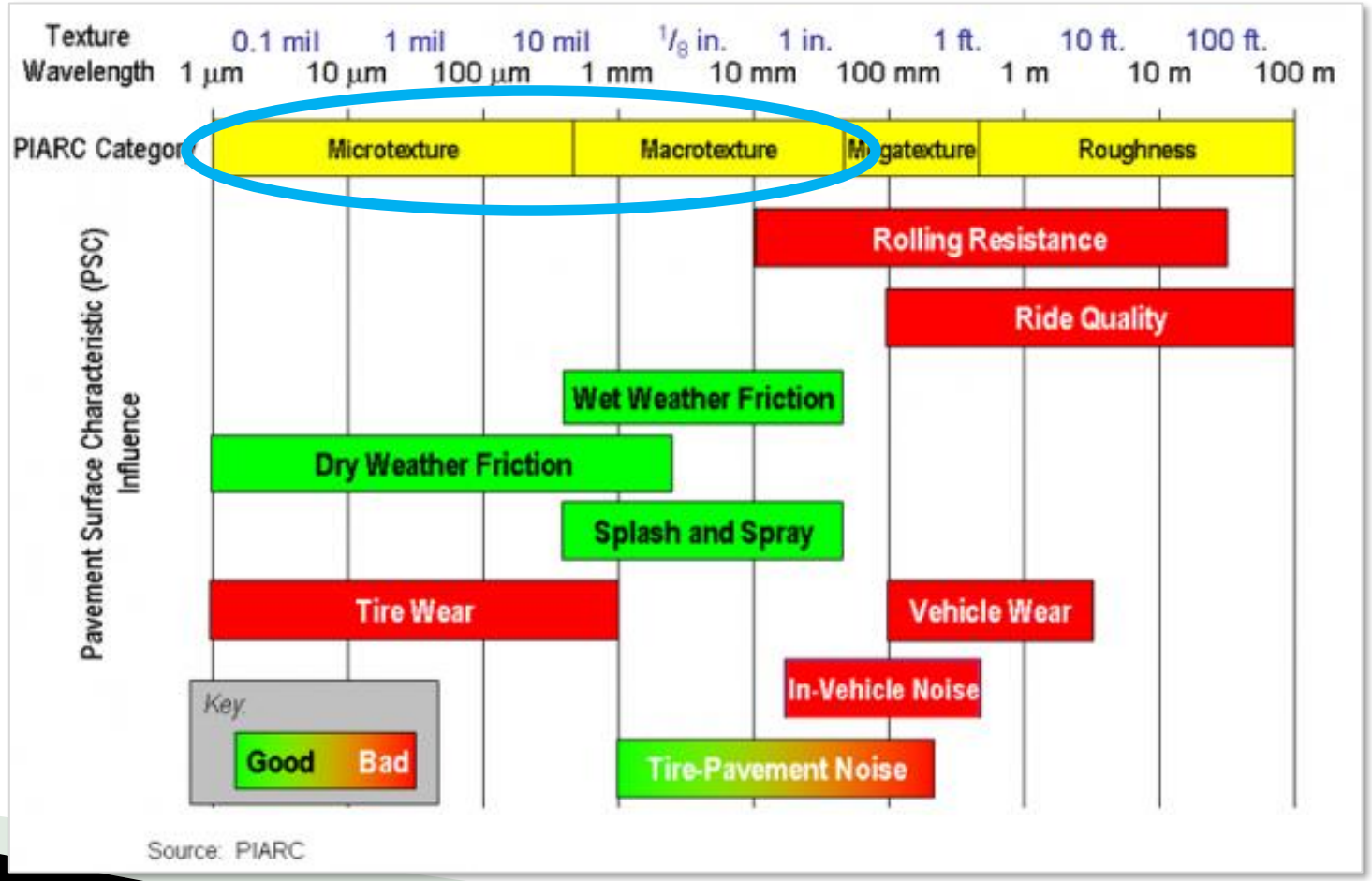


Source: AASHTO Guide for Pavement Friction

Basics of (Tire-Pavement) Friction

- For the pavement surface, it's all about texture!

Both macrotexture and microtexture must be present to provide good friction!



Basics of (Tire-Pavement) Friction

- Macrotexture
  - "Visible" pavement texture from aggregates and/or texture imparted to the pavement.
  - Provides a path for water to escape from beneath the tire.
  - Contributes to the "hysteresis" component of friction.
  - More important as vehicle speed increases, water depth increases, and tire tread depth decreases.
  - Typically measured as Mean Profile Depth (MPD) or Mean Texture Depth (*but these indices are not adequate do not fully characterize*).

Basics of (Tire-Pavement) Friction

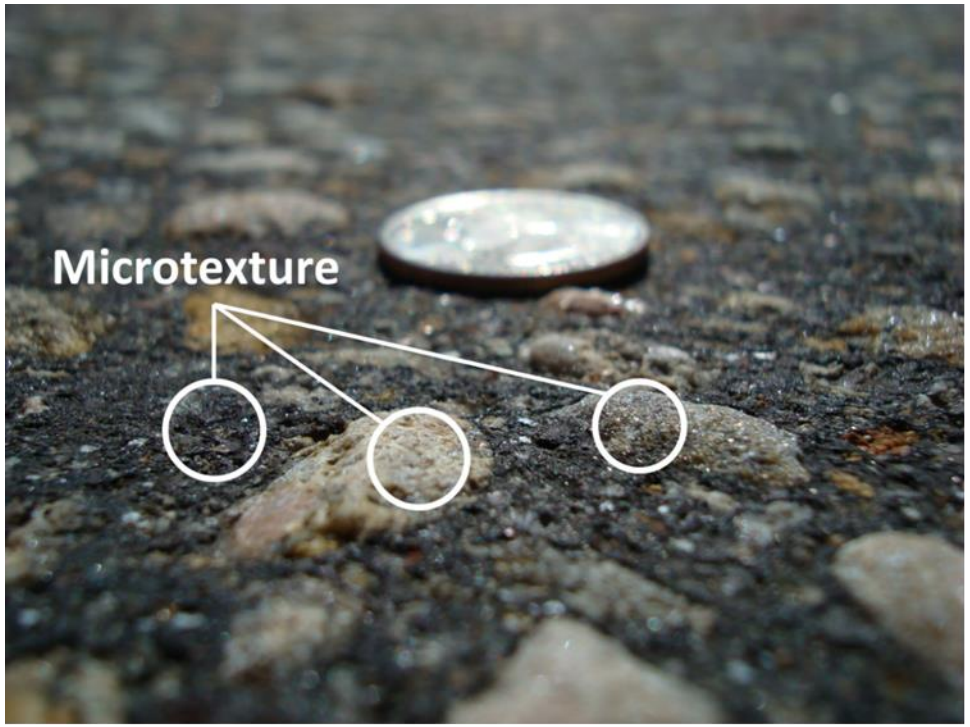
- Macrotexture

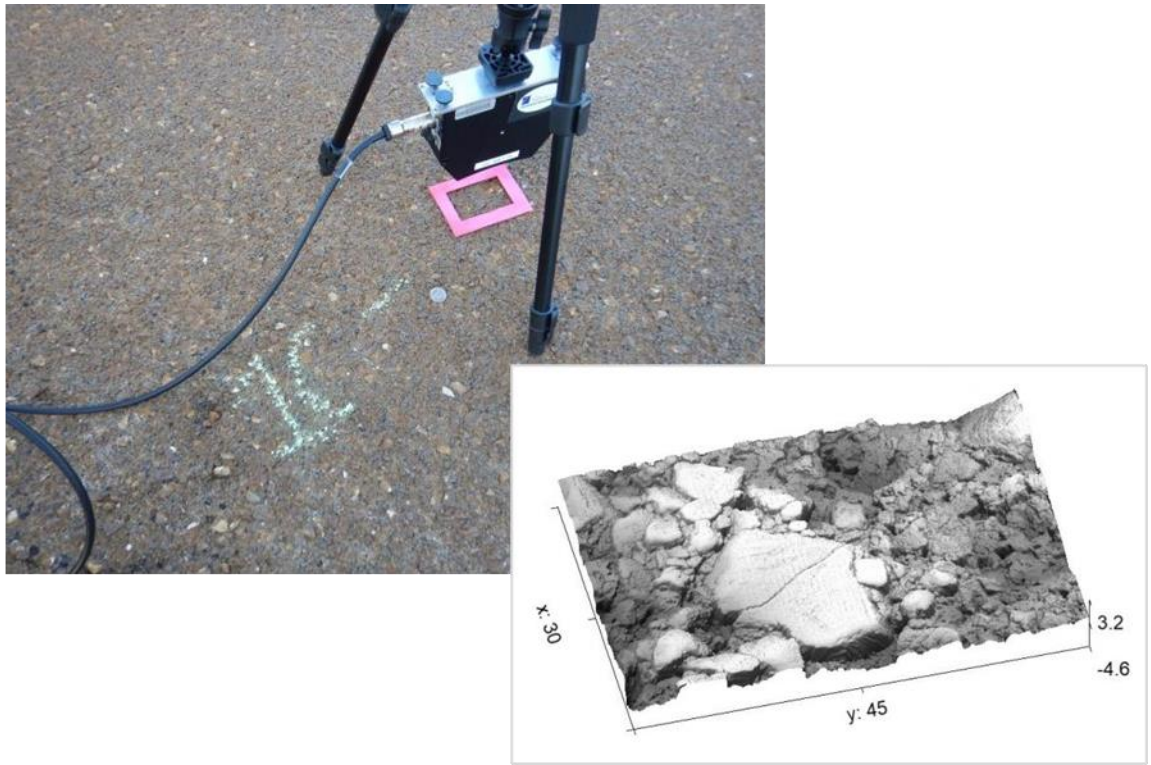
Basics of (Tire-Pavement) Friction

- Microtexture
  - Fine-scale roughness of individual aggregate particles, not readily discernable to the eye.
  - Provides the contact between the tire and pavement surface.
  - Contributes to the “adhesion” component of friction.
  - Provides a degree of “sharpness” necessary for the tire to break through the residual water film that remains a after bulk water has run off.
  - Difficult to measure directly on a larger scale (e.g., network level testing) – normally a surrogate measure (e.g., low-slip friction) is used.

Basics of (Tire-Pavement) Friction

- Microtexture





Basics of (Tire-Pavement) Friction

- Importance of Microtexture

Basics of (Tire-Pavement) Friction

- Importance of Materials, Construction, and Performance
  - Microtexture
    - Polish and Abrasion resistance of aggregates
      - Flexible Pavements – Coarse Aggregates
      - Rigid Pavements – Fine Aggregates (and Coarse Aggregates after wear or grinding)
    - Crushed materials typically provide better textures (micro and macro)

Basics of (Tire-Pavement) Friction

- Importance of Materials, Construction, and Performance
  - Macrotexture
    - Flexible pavements
      - Mix design and aggregate gradation
      - Raveling, Flushing, Bleeding
    - Rigid Pavements
      - Texture imparted to the surface (drag texture, tining, grinding, grooving, etc.)
      - Performance under traffic wear (polish/abrasion resistance of fine and coarse aggregates)

Basics of (Tire-Pavement) Friction

- Importance of Materials/Performance

Basics of (Tire-Pavement) Friction

- Importance of Materials/Performance

Basics of (Tire-Pavement) Friction

- Importance of Materials/Performance

New Surface

Surface After 1 Year

Friction (DFT20) = 0.62 (1 Year) 0.47 (3 years)

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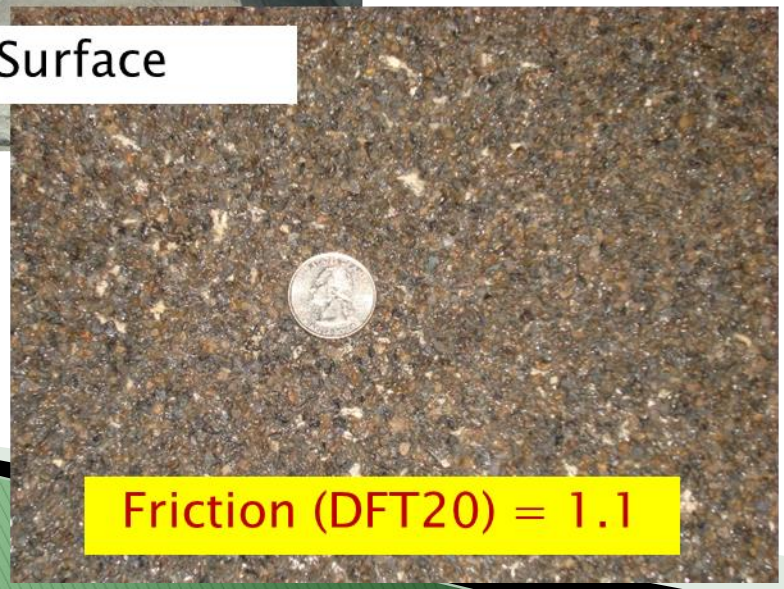
Basics of (Tire-Pavement) Friction

- Importance of Materials/Performance

New Surface



Surface After 3 Years

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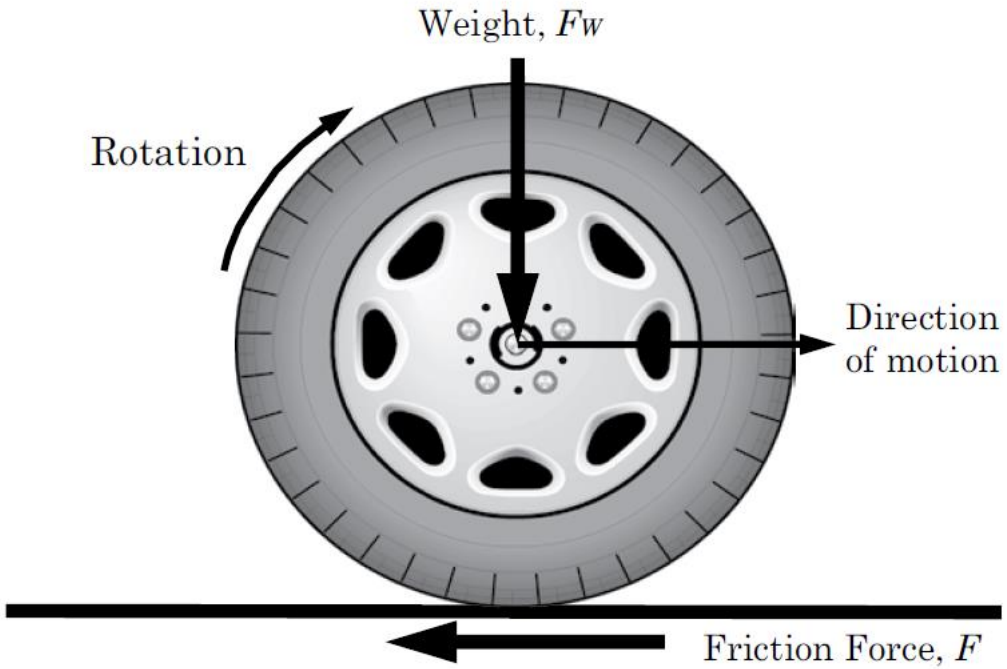
Measuring Pavement Friction

- It's simple, right???

$$\mu = \frac{F}{Fw}$$



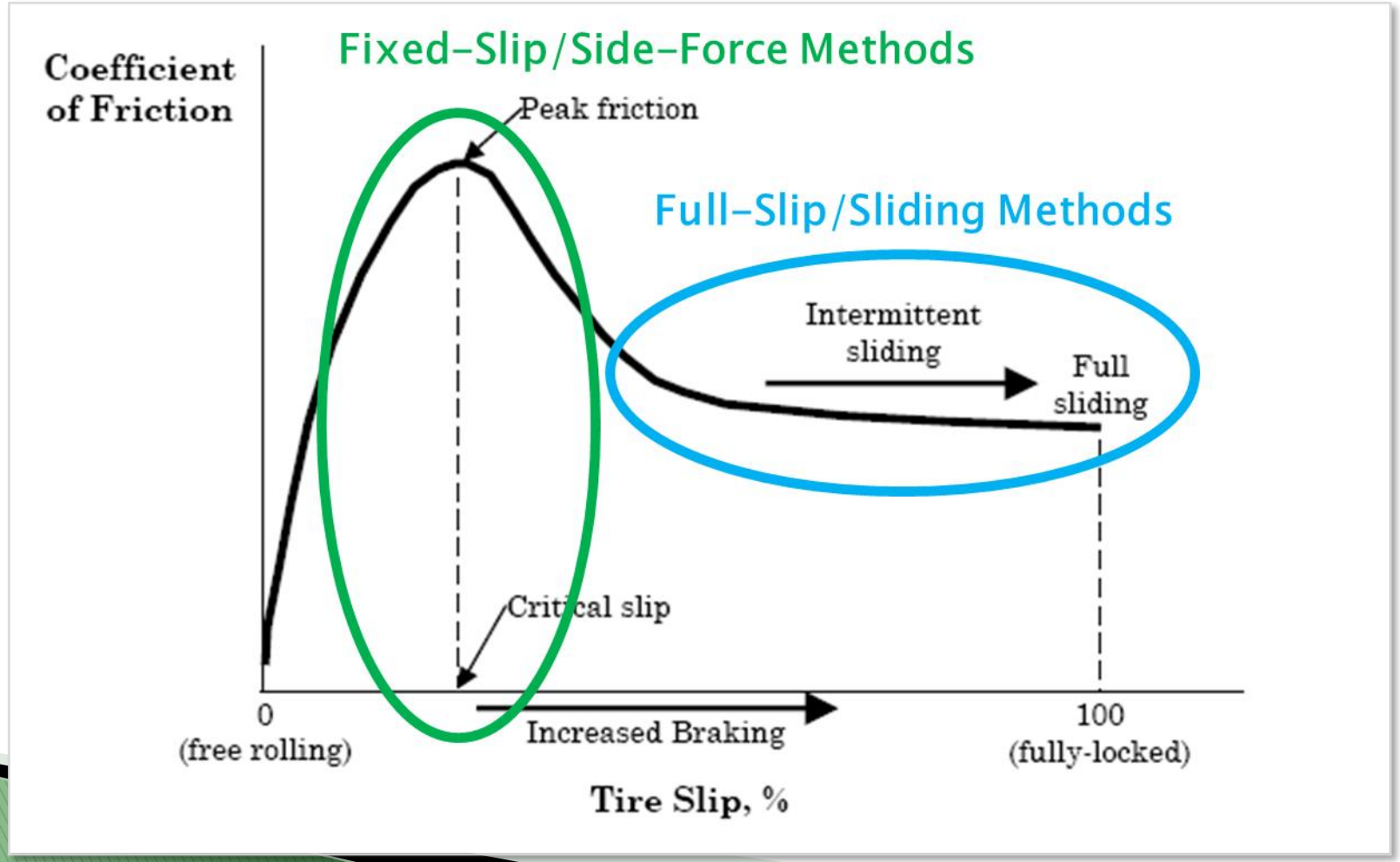
Source: AASHTO Guide for Pavement Friction

Measuring Pavement Friction

- Factors affecting friction measurement
  - Test tire/slider type and rubber compound
  - Test tire type (smooth vs. ribbed tread)
  - Test tire/slider footprint
  - Water film thickness
  - Test speed
  - Contaminants
  - Etc…

Measuring Pavement Friction

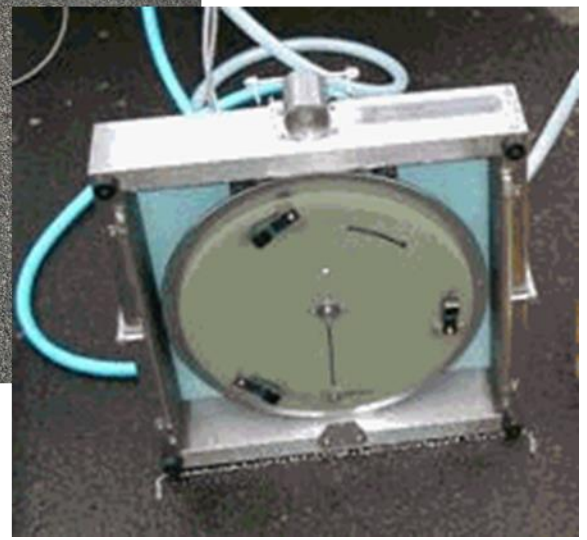
- Various friction measurement methods



Source: NCHRP Synthesis 291

Measuring Pavement Friction

- Full-Slip/Sliding Methods
  - “Worst Case” (fully sliding) measurement
  - Spot measurement

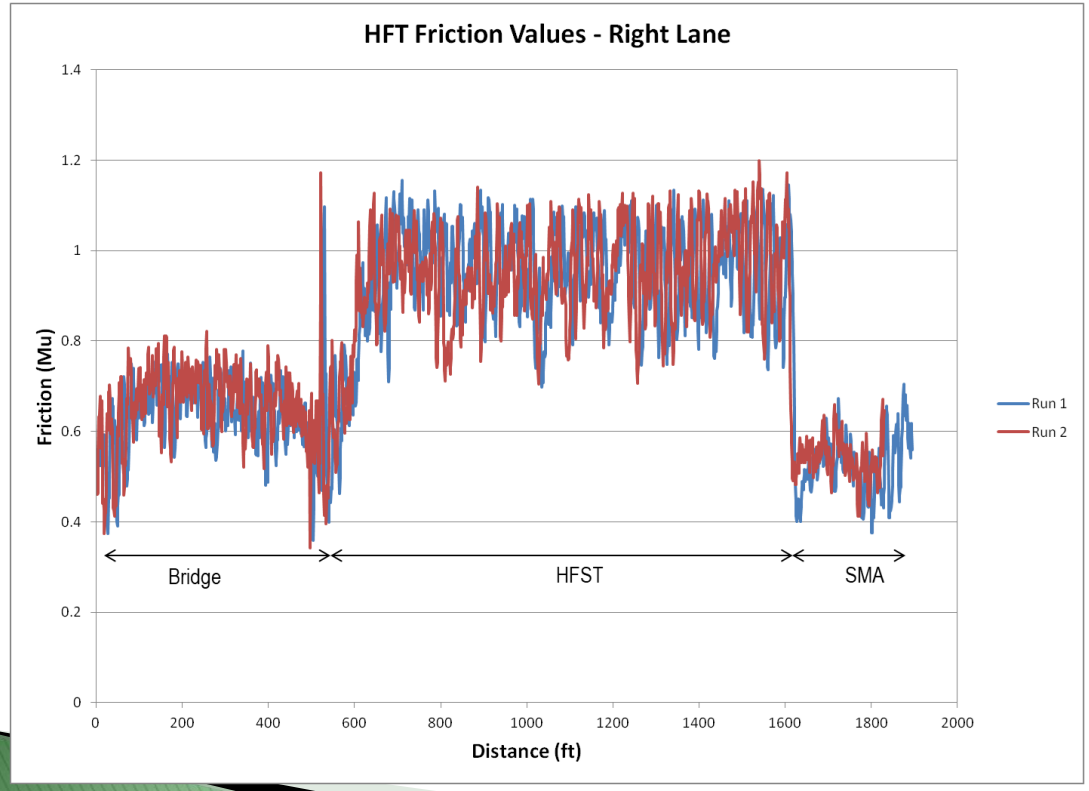


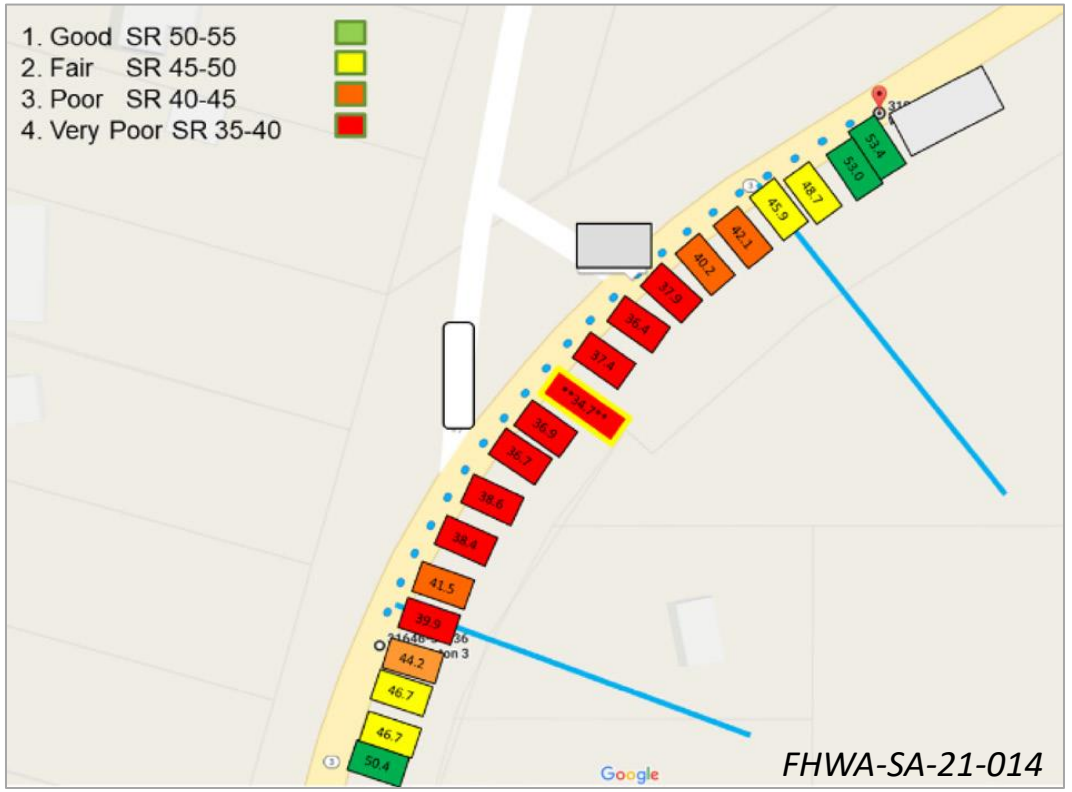
Measuring Pavement Friction

- Fixed-Slip / Side-Force Methods
  - Better measure of available friction (and correlation to anti-lock braking)
  - Longitudinal and Sideway Force Measurement Methods
  - More sensitive to pavement microtexture

Measuring Pavement Friction

- Fixed-Slip Methods
  - Allows for continuous friction measurement through curves, intersections.

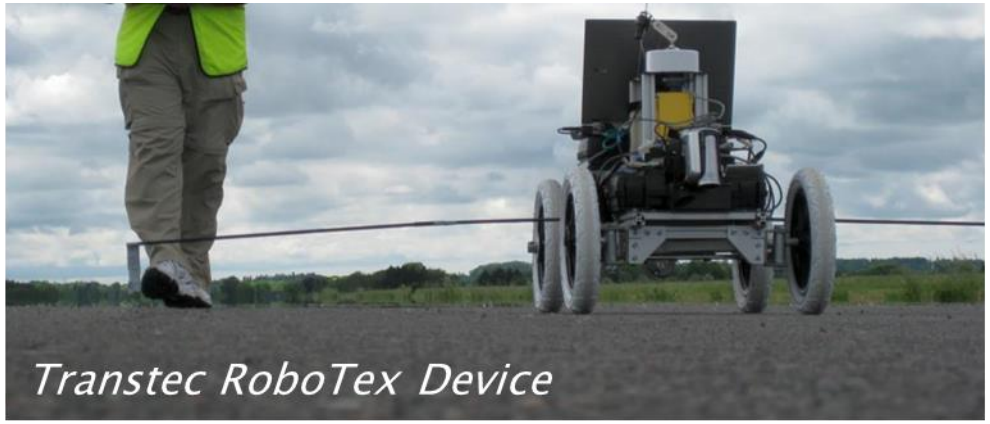


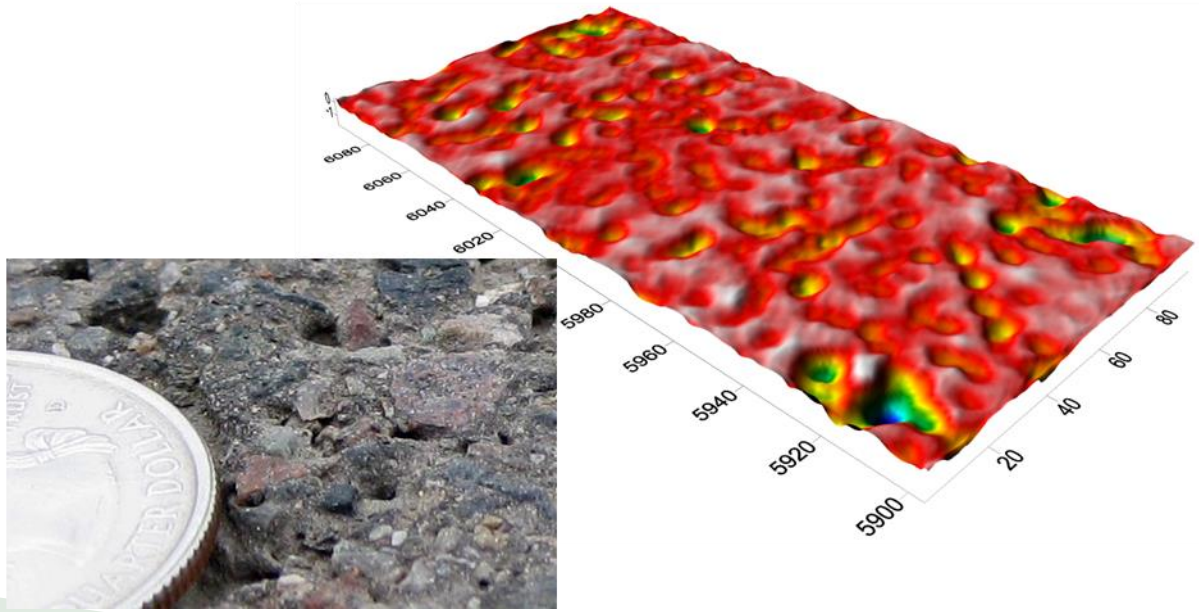


FHWA-SA-21-014

Measuring Pavement Friction

- Establish friction thresholds for the testing method of choice and stick with it!
- Harmonization of friction devices is a continual work in progress.
- Ideally, both texture and friction should be measured.





Measuring Pavement Friction

- Friction cannot be fully characterized by texture measurements alone.
  - Microtexture cannot yet be measured on a larger (e.g., network-level) scale.
  - Any correlations between texture and friction will be surface type specific.

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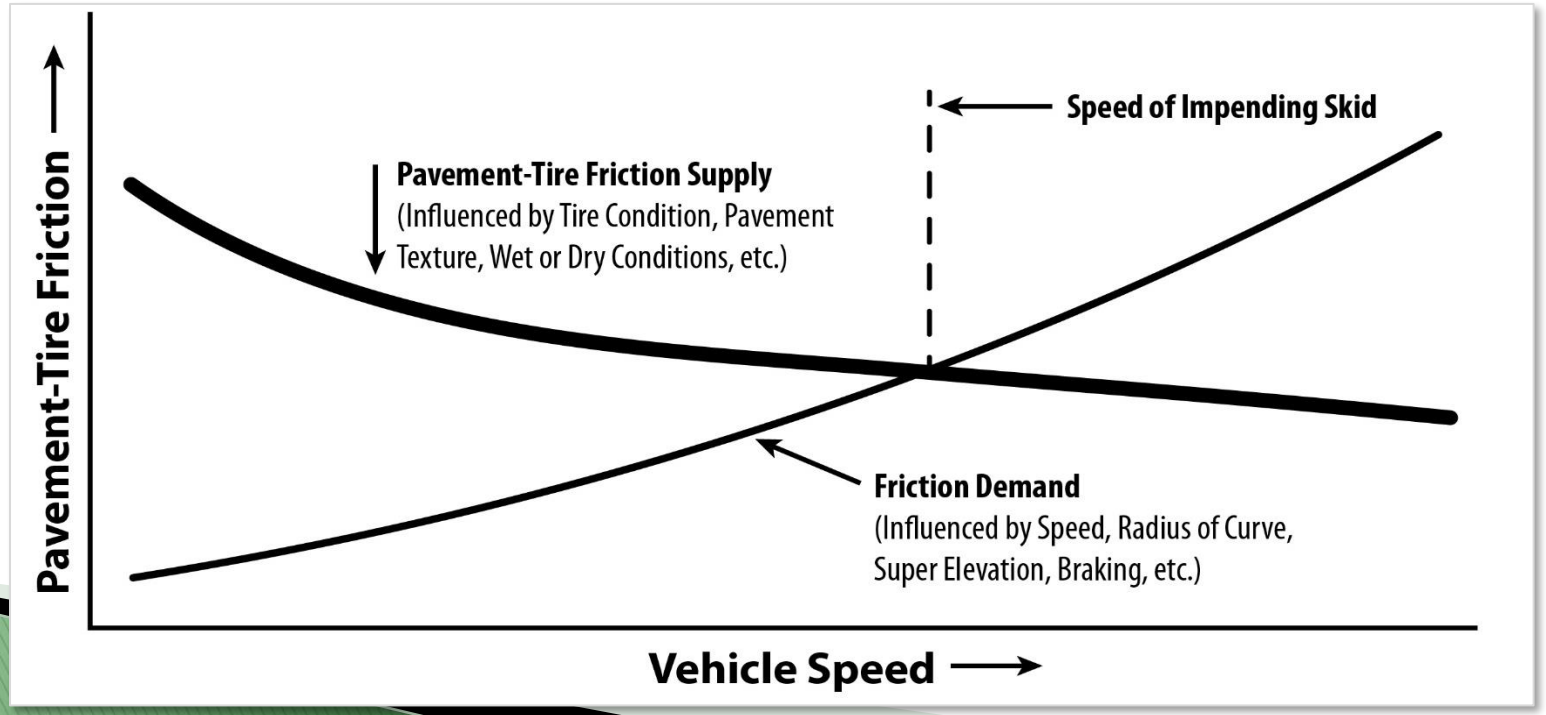
How Much Friction is Enough?

- There is no “One Size” solution for pavement friction.
- Why not make every surface “high friction?”
  - Higher friction is generally more costly.
  - Higher friction leads to increased tire wear and rolling resistance (reduced fuel economy).
- Focus on Friction Demand and Margin of Safety

How Much Friction is Enough?

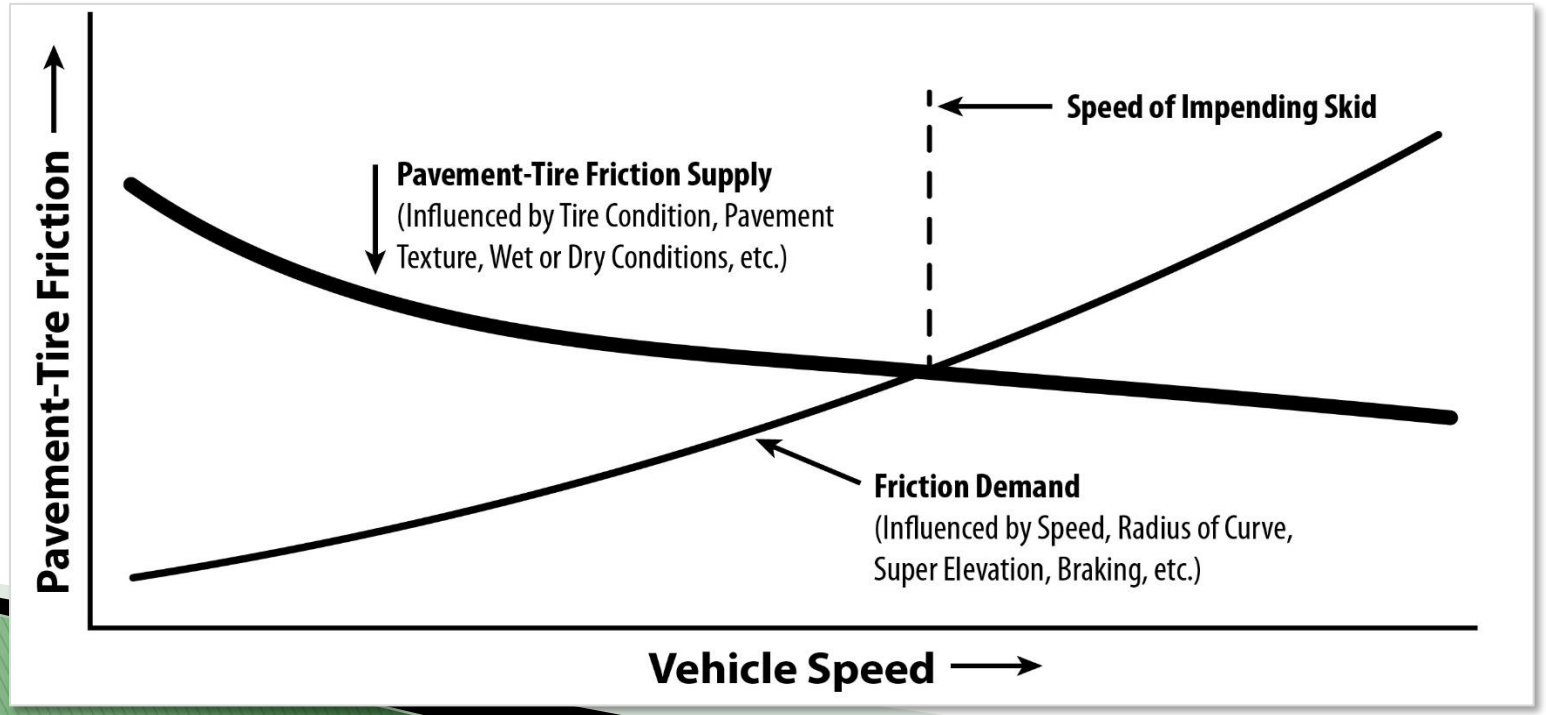
- Friction Demand = friction needed to safely perform braking, steering, and acceleration maneuvers.
  - Curves: traffic, speed, radius, grade, superelevation rate, etc.
  - Other high-risk locations: driven by ability to perform short-term maneuvers (sudden braking, lane changes, etc.)



Source: AASHTO Guide for Pavement Friction

How Much Friction is Enough?

- Margin of Safety = difference between friction supply from the pavement surface and friction demand from vehicles.
  - Increasing friction supply (from the pavement surface/treatment) increases the Margin of Safety



Source: AASHTO Guide for Pavement Friction

How Much Friction is Enough?

- There is no "One Size" solution for pavement friction.

Friction Thresholds by Facility Type

Site category	Site description	IL	PSV required for given IL, traffic level and type of site									
			Traffic (cv/lane/day) at design life									
			1-250	251-500	501-750	751-1000	1001-2000	2001-3000	3001-4000	4001-5000	5001-6000	Over 6000
A	Motorway	0.30	50	50	50	50	50	50	50	53	63	63
		0.35	**50**	**50**	**50**	**50**	**50**	**53**	**53**	**53**	**63**	**63**
B	Non-event carriageway with one-way traffic	0.30	50	50	50	50	50	50	50	53	63	63
		0.35	**50**	**50**	**50**	**50**	**50**	**53**	**53**	**53**	**63**	**63**
		0.40	50	50	50	50	53	58	58	58	63	68+
C	Non-event carriageway with two-way traffic	0.35	50	50	50	50	50	53	53	58	63	63
		0.40	**50**	**53**	**53**	**58**	**58**	**63**	**63**	**63**	**68+**	**68+**
		0.45	53	53	58	58	63	63	63	63	68+	68+
Q	Approaches to and across minor and major junctions, approaches to roundabouts and traffic signals	**0.45**	**60**	**65**	**65**	**68+**	**68+**	**68+**	**68+**	**68+**	**68+**	**HFS**
		0.50	65	65	65	68+	68+	68+	HFS	HFS	HFS	HFS
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
K	Approaches to pedestrian crossings and other high risk situations	**0.50**	**65**	**65**	**65**	**68+**	**68+**	**68+**	**HFS**	**HFS**	**HFS**	**HFS**
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
R	Roundabout	**0.45**	**50**	**55**	**60**	**60**	**65**	**65**	**68+**	**68+**	**68+**	**68+**
		0.50	68+	68+	68+	68+	68+	68+	68+	68+	68+	68+
G1	Gradients 5-10% longer than 50m	**0.45**	**55**	**60**	**60**	**65**	**65**	**68+**	**68+**	**68+**	**68+**	**68+**
		0.50	60	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
G2	Gradient >10% longer than 50m	0.45	55	60	60	65	65	68+	68+	68+	68+	68+
		0.50	**60**	**68+**	**68+**	**HFS**	**HFS**	**HFS**	**HFS**	**HFS**	**HFS**	**HFS**
		0.55	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
S1	Bends radius <500m – carriageway with one-way traffic	**0.45**	**50**	**55**	**60**	**60**	**65**	**65**	**68+**	**68+**	**HFS**	**HFS**
		0.50	68+	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
S2	Bends radius <500m – carriageway with two-way traffic	0.45	50	55	60	60	65	65	68+	68+	HFS	HFS
		0.50	**68+**	**68+**	**68+**	**HFS**	**HFS**	**HFS**	**HFS**	**HFS**	**HFS**	**HFS**
		0.55	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS

Source: Highways England CD 236 , Rev. 4

How Much Friction is Enough?

- There is no "One Size" solution for pavement friction.

Friction Thresholds by Facility Type

Roadway Facility Type	Site Type	Suggested	Graphic Threshold	Approximate UK CSC Eq.	CS 228 ST	CS 228 LR
Freeways	Tangents	40	36 – 38	0.29 - 0.31	0.35	0.30
	Curves	45	42 – 44	0.34 - 0.36	0.45 - 0.50	
	Ramp Access	45	44 – 46	0.36 - 0.37		
Rural Multilane Roadways	Divided Tangents	50	48 – 50	0.39 - 0.41	0.35 - 0.40	0.30
	Undivided Tangents	50	48 – 50	0.39 - 0.41	0.40 - 0.45	0.35
	Curves	55	54 – 56	0.44 - 0.46	0.45 - 0.50	
	Intersections	55	54 - 56	0.44 - 0.46	0.45 - 0.55	0.40
Rural 2-lane, 2-way Roadways	Tangents	50	48 - 50	0.39 - 0.41	0.40 - 0.45	0.35
	Curves	55	54 - 56	0.44 - 0.46	0.50- 0.55	0.45
	Intersections	60	54 - 56	0.44 - 0.46	0.45 - 0.55	0.40
Urban and Suburban Arterials	Divided Tangents	50	48 - 50	0.39 - 0.41		
	Undivided Tangents	50	48 - 50	0.39 - 0.41		
	Curves	50	48 - 50	0.39 - 0.41		
	Intersections	55	54 - 56	0.44 - 0.46		

Note: Friction thresholds are specific to the device used for measurement.

Source: FHWA-SA-23-006

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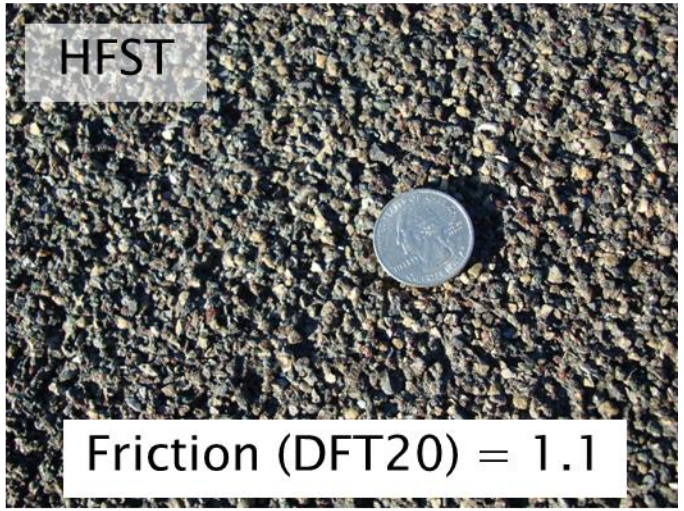
How Much Friction is Enough?

- Friction Demand vs. Friction Supply



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Thank You!

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