1 Introduction to Pavement Friction

The Physics Behind Friction

The Little Book of Tire Pavement Friction

Version 1.0
Submitted for Review and Comment

Pavement Surface Properties Consortium

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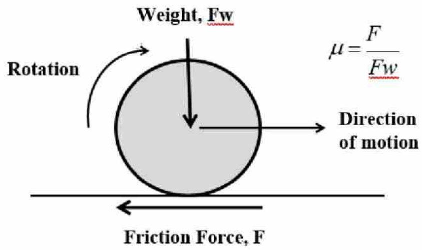


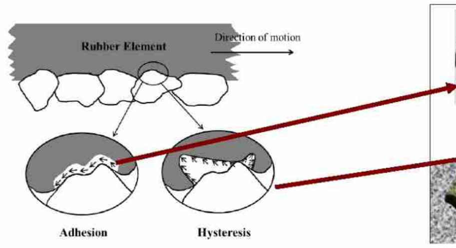


Figure 1.

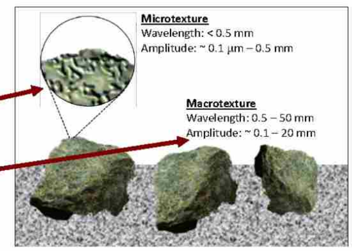


Figure 2.

Friction During Braking

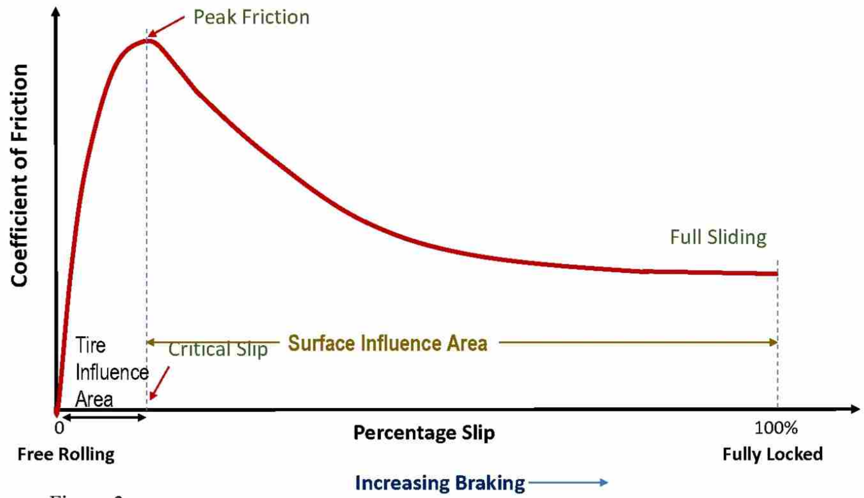


Figure 3.

Wet Friction and Impact of Macrotexture

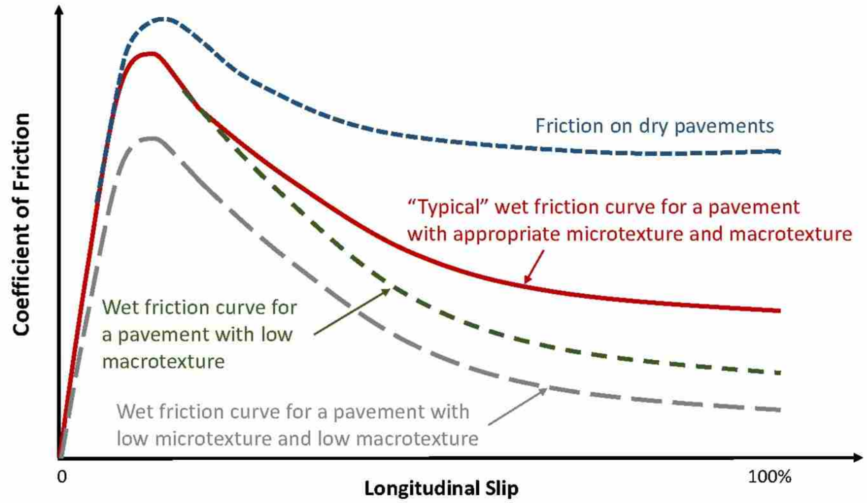
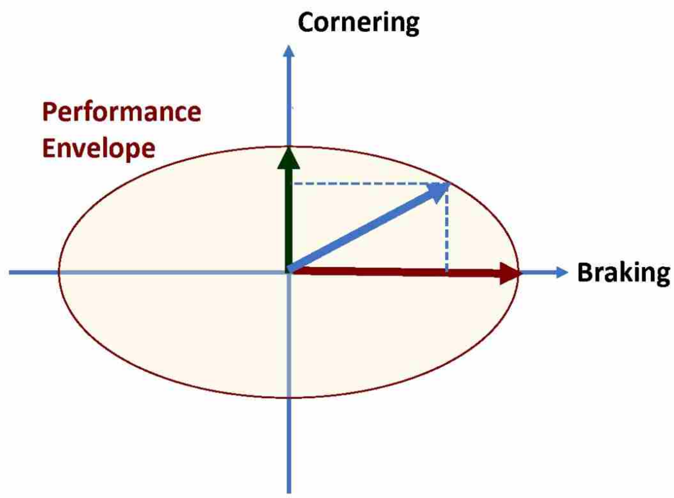


Figure 4.

Simultaneous Braking and Cornering



Measuring Friction - Equipment

- Sliders
  - British Pendulum Test (ASTM E303-93)
- *Longitudinal friction coefficient* measurement equipment
  - Fixed-slip friction testers (e.g., GripTester)
  - Locked-wheel friction testers (ASTM E274-15)
- *Sideway force coefficient*

Figure 5.

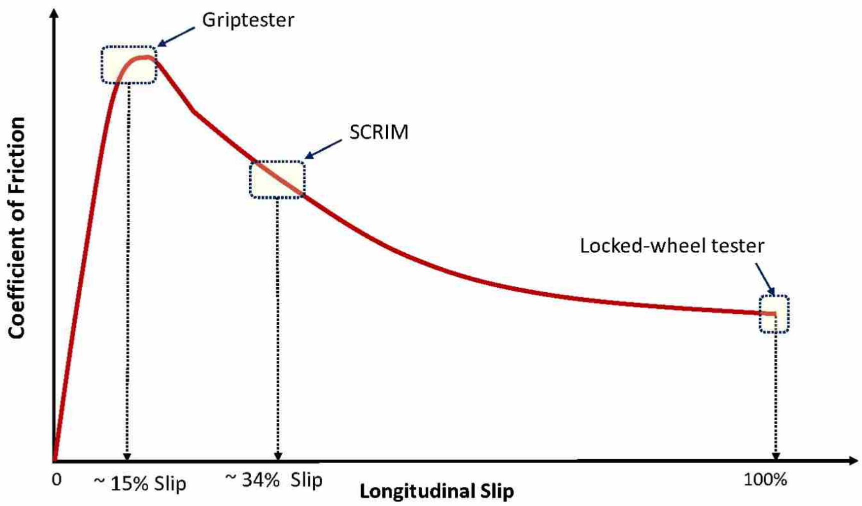


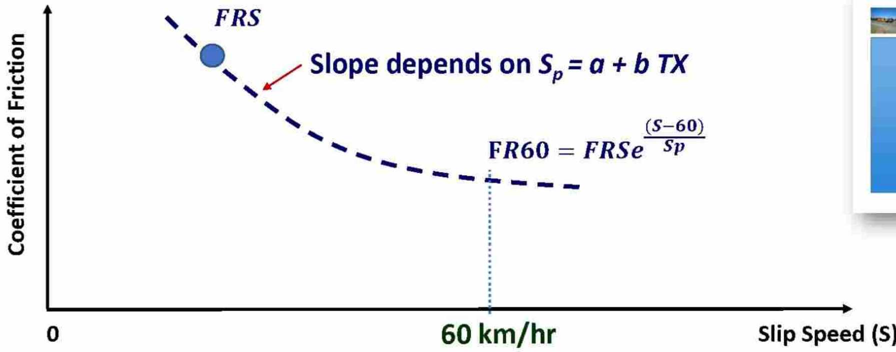
Figure 6. Illustration of the Slip Operational Ranges for Different Friction Measuring Equipment (not to scale)

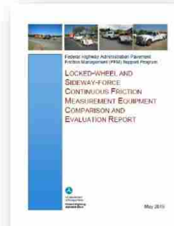
Operational Factors That Affect Friction Measurements

- Water film thickness
- Type and condition of the tire
- Vehicle and sliding speeds
- Temperature
- Contaminants

Interconversion of Friction Measurements

- Many Studies over the years
- Example: International Friction Index





2 Pavement Friction Management

Relationship between Crashes and Friction

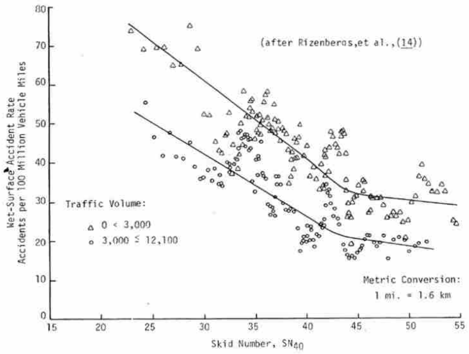


Figure 7. Example Illustration of the Relationship between Wet-Weather Crash Rates and Pavement Friction for Kentucky Highways (after Rizenbergs et al. 1973)

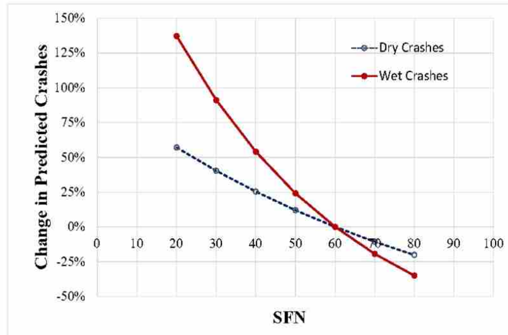


Figure 9. Illustrative example of estimated changes of Average Wet- and Dry-crash Rates vs. Friction (SFN) (after McCarthy et al., 2021)

Examples of Friction Investigatory Levels

Table 1. UK Friction Demand Categories and SCRIM Investigatory Levels (DMRB 2021)

Site category and definition		Investigatory level (IL) of CSC (skid data speed corrected to 50 km/h and seasonally corrected)							
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
A	Motorway	LR	ST						
B	Non-event carriageway with one-way traffic	LR	ST	ST					
C	Non-event carriageway with two-way traffic		LR	ST	ST				
Q	Approaches to and across minor and major junctions, Approaches to roundabouts and traffic signals				ST	ST	ST		
K	Approaches to pedestrian crossings and other high risk signal					ST	ST		
R	Roundabouts				ST	ST			
G1	Gradient 5-10% longer than 50 m (see note 6)				ST	ST			
G2	Gradient >10% longer than 50 m (see note 6)				LR	ST	ST		
S1	Bend radius < 500 m – carriageway with one-way traffic				ST	ST			
S2	Bend radius < 500 m – carriageway with two-way traffic				LR	ST	ST		

'ST' indicates the range of ILs that should generally be used for roads carrying significant levels of traffic.

'LR' in cells indicates a lower IL that may be appropriate in lower risk situations, such as low traffic levels or where the risks present ar mitigated by other means, providing this has been confirmed by the crash history.

NOTE 1 Sites with the same site category can have different levels of risk of skidding crashes. There is therefore the flexibility to set c ILs for different sites within the same category.

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Table 2. Adaptations of the UK Investigatory Levels for a Mark 2 GripTester using a conversion factor of 0.85 (after UKPMS 2005).

Site category and definition			Investigatory level (IL) at 50 km/h							
		SFC	0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
		GN	0.35	0.41	0.47	0.53	0.59	0.65	0.71	0.76
A	Motorway									
B	Non-event carriageway with one-way traffic									
C	Non-event carriageway with two-way traffic									
Q	Approaches to and across minor and major junctions, Approaches to roundabouts and traffic signals									
K	Approaches to pedestrian crossings and other high risk signal									
R	Roundabouts									
G1	Gradient 5-10% longer than 50 m (see note 6)									
G2	Gradient >10% longer than 50 m (see note 6)									
S1	Bend radius < 500 m – carriageway with one-way traffic									
S2	Bend radius < 500 m – carriageway with two-way traffic									

Notes: Reference should be made to Chapter 4 of HD 28/04 and in particular, the notes to Table 4.1 (of HD 28/04) for guidance on interpretation.

Dark Grey indicates the range of ILs that should generally be used for roads carrying significant levels of traffic.

Light Grey in cells indicates a lower IL that may be appropriate in lower risk situations, such as low traffic levels or where the risks present are mitigated by other means, providing this has been confirmed by the crash history.

Example of Macrotexture Investigatory Levels

Table 5. New Zealand Minimum Macrotexture Requirements (NZTA 2013)

Legal Speed Limit	Minimum Macrotexture MPD (mm)					
	Chipseals		Asphaltic Concrete ESC ≥ 0.4		Asphaltic Concrete ESC < 0.4	
	ILM	TLM	ILM	TLM	ILM	TLM
50 km/hr and less	1.0	0.7	0.4	0.3	0.5	0.5
Less than or equal to 70 km/hr but >50 km/hr	1.0	0.7	0.4	0.3	0.7	0.5
Greater than 70 km/hr	1.0	0.7	0.9	0.7	0.9	0.7

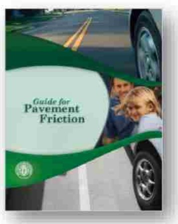
Notes to Table 3

- On curves where the advisory speed limit is 45 km/h or less, consideration may be given to the use of ILM and TLM (as per table 3) for asphaltic concrete where the permanent speed limit is 50km/h and less
- The TLM for chipseals is set at 0.7 mm MPD. In urban areas, where the surveyed macrotexture is equal to or higher than required for asphaltic concrete (i.e., 0.5 mm MPD), maintenance to improve the macrotexture may be delayed provided that:
  - The ESC is above TL.
  - ESC levels are stable, i.e., they have not reduced by more than 0.05 ESC since the previous annual survey.
  - Inspections are programmed and resources are available to ensure prompt treatment is undertaken, should macrotexture levels continue to drop.

Pavement Friction Management in the United States

Early approaches

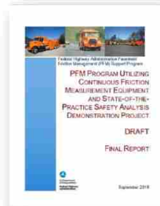
- Focused on reducing wet-weather skidding crashes
- Locked-wheel skid testers
- Use only one threshold

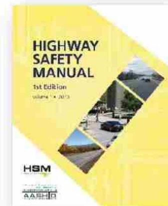


AASHTO Guide for Pavement Friction

- Friction demands
- investigatory and intervention levels

- FHWA *TA 5040.1738 — proposed a Friction Management Approach*





- ***Revised AASHTO Guide for Pavement Friction***

3 Stone-Matrix Asphalt

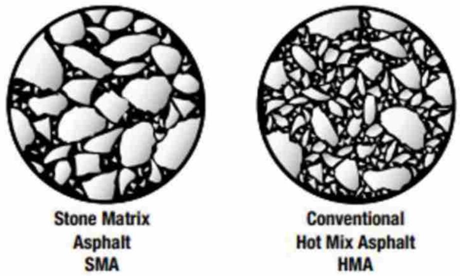
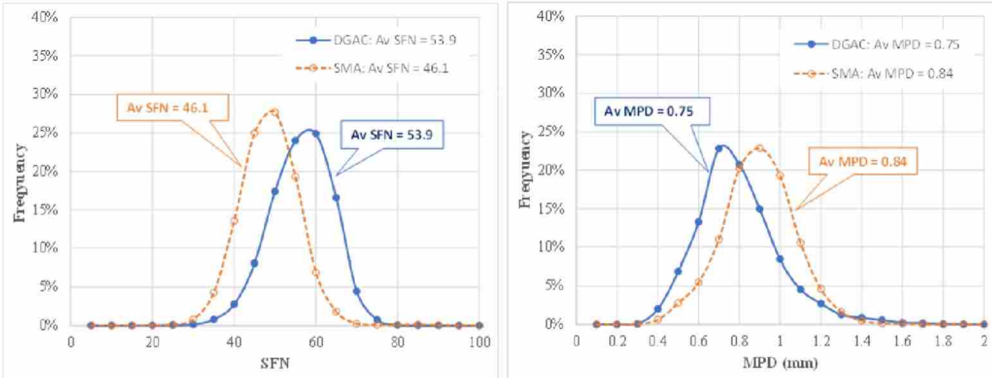


Figure 11. Comparison of the aggregate structure on conventional and SMA mixtures (NAPA 2002).

- **“Premium” wearing course**
  - Gap-graded aggregate structure
  - Modified asphalt binder at elevated asphalt contents
- Better durability
- Higher cost
- **Good durability to cost ratio**

Functional Properties of SMA vs DG HMA



(a) Sideways Friction (b) Macrotexture

Figure 14. Comparison of SMA and dense-graded HMA friction and macrotexture properties for selected roads in Virginia