PAVEMENT FRICTION FOR ROAD SAFETY

Primer on Friction Measurement and Management Methods

PUBLICATION NO. FHWA SA-23-007

U.S. Department of Transportation
Federal Highway Administration

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

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FOREWORD

Pavements must have sufficient available friction to allow a driver to properly execute a maneuver, especially those that involve steering, braking or acceleration. In 2021, FHWA added Pavement Friction Management, which involves measuring, monitoring, and maintaining pavement friction, to the list of Proven Safety Countermeasure because it can help prevent roadway departure, intersection, and pedestrian-related crashes. Additionally, the integration of pavement friction management and safety management practices in order to achieve safety performance goals is consistent with the Safe System approach.

This primer is intended as a resource for road safety, maintenance, materials, and pavement engineers and practitioners to provide a basic understanding of pavement surface friction in order to integrate pavement friction into both pavement asset management and road safety management practices. The primer covers pavement friction characteristics such as microtexture, macrotexture, and pavement friction demand. It also discusses different methods of measuring friction and macrotexture, including using continuous pavement friction measurement for collecting friction data at the network-level for safety performance analysis.

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16. Abstract

Pavements must have sufficient available friction to allow a driver to properly execute a maneuver, especially those that involve steering, braking or acceleration. In 2021, FHWA added Pavement Friction Management, which involves measuring, monitoring, and maintaining pavement friction to the list of FHWA Proven Safety Countermeasure because it can help prevent roadway departure, intersection, and pedestrian-related crashes. Additionally, integration of pavement friction management and safety management practices in order to achieve safety performance goals is consistent with the Safe System approach.

This primer is intended as a resource for road safety, maintenance, materials, and pavement engineers and practitioners to provide a basic understanding of pavement surface friction in order to integrate pavement friction into both pavement asset management and road safety management practices. The primer covers pavement friction characteristics such as microtexture, macrotexture, and pavement friction demand. It also discusses different methods of measuring friction and macrotexture, including continuous pavement friction measurement for collecting friction data at the network-level for safety performance analysis.

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SI* (MODERN METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		Area		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	Acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		Volume (volumes greater than 1,000L shall be shown in m^3)		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		Mass		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		Temperature (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		Illumination		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		Force and Pressure or Stress		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

Approximate Conversions from SI Units				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		Length		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		Area		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		Volume		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		Mass		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		Temperature (exact degrees)		
°C	Celsius	1.8c+32	Fahrenheit	°F
		Illumination		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		Force and Pressure or Stress		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003, Section 508-accessible version September 2009.)

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
CFME	continuous friction measuring equipment
CFR	Code of Federal Regulations
CPFM	continuous pavement friction measurement
CSTI	Center for Sustainable Transportation Infrastructure
DGAC	dense-graded asphalt
DOT	Department of Transportation
FHWA	Federal Highway Administration
GPF	Guide for Pavement Friction
HFST	high friction surface treatment
LFC	longitudinal friction coefficient
LWST	locked wheel skid tester
MPD	mean profile depth
MTD	mean texture depth
NCHRP	National Cooperative Highway Research Program
NCSA	National Center for Statistics and Analysis
NHTSA	National Highway Traffic Safety Administration
OGFC	open-graded friction course
PFM	pavement friction management
RSA	road safety audit
RMS	root mean square
SFC	sideway force coefficient
U.S.	United States

1 INTRODUCTION

Pavement friction, often referred to as "skid resistance," is one of many factors influencing road safety performance. According to the National Highway Traffic Safety Administration (NHTSA), in 2021 there were 42,915 people killed in traffic related crashes in the United States (U.S.) (NCSA, 2022). The potential for crashes increases when the available friction does not allow the driver to properly execute a maneuver, especially those that involve steering, braking, or acceleration. Excessive speed, road characteristics, and pavement surface conditions can also factor into higher crash rates where friction demand is higher than what is available. Pavement friction is also explicitly considered in certain aspects of highway geometric design, such as horizontal curvature, superelevation, and stopping sight distance (Hall et al., 2009). Pavement friction characteristics will vary over time and location due to a variety of reasons. Therefore, pavement friction should be managed throughout a pavement lifecycle, up until the very end-of-life.

Pavement friction management (PFM), which involves measuring, monitoring, and maintaining pavement friction, is a Federal Highway administration (FHWA) Proven Safety Countermeasure (FHWA, 2021) because it can help prevent roadway departure, intersection, and pedestrian-related crashes. It is also consistent with the Safe System approach. First, it involves a shared responsibility, in this case among pavement, materials and safety professionals. Second, it is a proactive approach to safety where the friction measurement becomes the basis for treatment or intervention rather than a reactive approach that relies on crash occurrence. Third, it can provide system redundancy that further supplements the vehicle and tire systems designed to prevent crashes. The Safe System approach, along with continuing improvements to pavement materials and technologies, represents an opportunity to further integrate pavement friction into both pavement asset management and road safety management practices.

This primer is intended to provide road safety, maintenance, materials, and pavement engineers and practitioners a basic understanding of the design, construction, maintenance, and management of pavement surface friction in order to meet safety performance goals. The primer covers the following basic topics of pavement friction:

- Pavement Friction Characteristics
- Pavement Friction Testing Methods and Equipment
- Pavement Friction Management to Support Safety

The FHWA pavement policy found in Part 626 of Title 23 of the Code of Federal Regulations (23 CFR 626) states: "Pavement shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost-effective manner" (Pavement Policy, 1996). It follows that pavement friction—skid resistance—is an inherent component of a pavement that accommodates traffic needs in a safe manner.

> "Pavement shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost-effective manner."
>
> (23 CFR 626 Pavement Policy)

2 PAVEMENT FRICTION CHARACTERISTICS

Pavement friction is defined by the interaction between the tire and the pavement; specifically, the force that resists the relative motion between a vehicle tire and a pavement surface (Hall et al., 2009). This interaction allows drivers to safely perform vehicle steering, braking, and acceleration maneuvers. It includes a lateral or side force that occurs as a vehicle changes direction or compensates for pavement cross-slope and/or crosswind effects. The two principal frictional force components are adhesion and hysteresis. Adhesion is the friction that results from the small-scale bonding of the vehicle tire rubber and the pavement surface as they come into contact with each other. Hysteresis is the friction component that results from the tire compressing against the pavement surface. Surface texture influences both components. Pavement surface characteristics that influence pavement friction include microtexture and macrotexture, as shown on Figure 1.

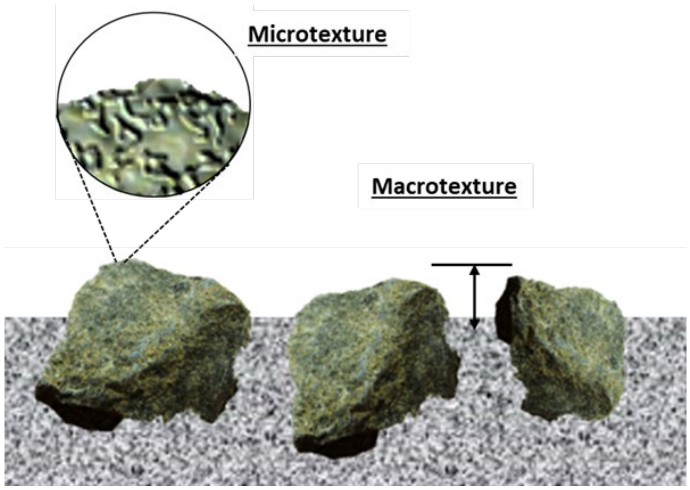

Figure 1. Illustration. Pavement surface texture characteristics that influence friction.
Source: CSTI

2.1 MICROTEXTURE

Microtexture is the fine-scale texture (below 0.5 mm) on the surface of the aggregate in asphalt or the sand in cement concrete that interacts directly with the tire rubber on a molecular scale to provide adhesion. In non-technical terms, this is similar to the texture felt for each individual particle when rubbing one's hand across sandpaper. Microtexture is important for pavement friction on both wet and dry roadways and, at any speed, to allow vehicles to properly maneuver and stop.

The gradual loss of microtexture due to the effects of traffic over time is described as "polishing." Some agencies have different pavement materials requirements for "non-polishing" aggregate to be used in certain cases. Roads with higher friction demand may require more "non-polishing" aggregate in the pavement mixture than roads with lower friction demand, which recognizes the value and importance of microtexture. High friction surface treatment (HFST) is an example of a pavement surface with very high microtexture. Per American Association of State Highway and Transportation Officials (AASHTO) Standard Specification MP-41, HFST uses calcined bauxite, a manufactured aggregate highly resistant to polish. When used by road agencies in spot locations at high friction demand locations, HFST resulted in significant crash reductions in both wet and dry crashes (von Quintus and Mergenmeier, 2015)

2.2 MACROTEXTURE

Macrotexture is the larger scale texture (0.5 to 50 mm) on the pavement formed by the individual aggregate particles in the surface or by grooves cut into the surfaces. Macrotexture is influenced by either the mixture design (aggregate shape, size, and gradation) for asphalt pavements or method of finishing (dragging, tining, grooving; depth, width, spacing and orientation of the grooves/channels) for concrete pavements. The macrotexture provides drainage channels for water to be expelled between the tire and the pavement which allows for better contact of the tire with the pavement, improving frictional resistance and preventing hydroplaning, especially at higher speeds. The level of macrotexture needed to provide frictional resistance depends on the speed limit of the roadway. Hall et al. (2009) found that at speeds above 56 mph on wet pavements, macrotexture is responsible for a large portion of the friction. Measuring and evaluating macrotexture is essential when analyzing the safety performance of a roadway, especially for higher speed facilities.

Most highway agencies do not collect or analyze measurements of macrotexture at the network level. In 2021, the National Cooperative Highways Research Project (NCHRP) Research Report 964 Protocols for Network-Level Macrotexture Measurement, developed standards that were approved by AASHTO (AASHTO MP 48, PP 115, PP116) related to assessing quality in the measurement of macrotexture at highway speeds (Flintsch et al., 2021). This study found that the mean profile depth (MPD) is currently the most widely used macrotexture measurement in the U.S. A project for the North Carolina Department of Transportation (DOT) provided post-construction MPD recommendations for roads based on posted speed limits; specifically, for 50 mph at least 0.80 mm, and for 70 mph (or higher) at least 1.0 mm (de León et al., 2017). In the U.S., normal ranges of macrotexture for a dense graded asphalt concrete (DGAC) have MPDs between 0.40 and 0.80 mm, whereas an open graded friction course (OGFC) will have MPDs between 0.80 to 1.40 mm. The value of higher macrotexture for high-speed roads is demonstrated by Florida DOT's requirement to use open-graded friction courses (OGFC, FC-5) to provide frictional characteristics to the asphalt pavement surface on high-speed multi-lane roads with speed limits greater than 50 mph (Florida DOT, 2022).

To better visualize the role of texture within the contact region of a tire on a wet pavement the "Three Zone Concept", first suggested by Gough and later extended by Moore, is shown in Figure 2 (Moore, 1966). In Zone 1, water is squeezed out by the macrotexture of the pavement surface. In Zone 2, the microtexture provides the drainage for the thin film of moisture. In Zone 3, the tire comes into dry contact with the pavement's surface. It is in this last zone, that the forces of adhesion and hysteresis must combine to overcome the friction demand.

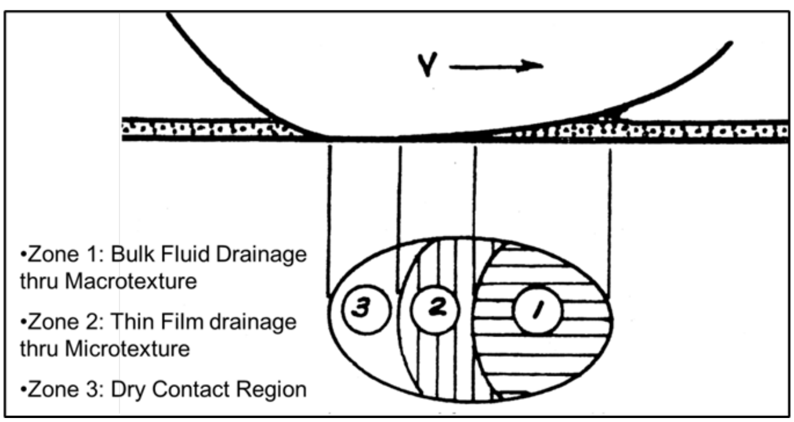

Figure 2. Diagram. "Three Zone Concept" of a wet surface.
Source: Moore, 1966

2.3 FRICTION DEMAND

Pavements must have sufficient available friction to allow a vehicle on a roadway to safely perform steering, braking, and acceleration maneuvers. The level of pavement friction needed will vary across the roadway network and at specific locations due to changing geometrics, site conditions, traffic characteristics, and driver/vehicle characteristics. In 1967, NCHRP Report 37 acknowledged that "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" (Kummer and Meyer, 1967). Figure 3 shows the conceptual relationship between friction demand, speed, and friction supply.

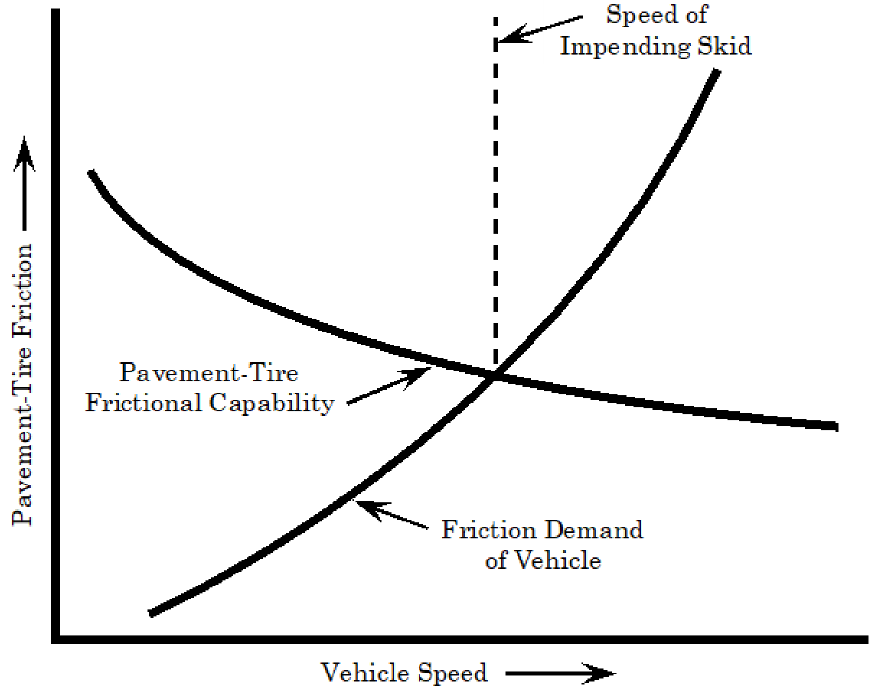

Figure 3. Diagram. Conceptual relationship between friction demand, speed, and friction availability.
Source: Hall et al., 2009

Intersections require motorists to slow, stop, turn, and react due to changing conditions, especially where there may be an increased potential for crossing pedestrians. Ramps and curves involve changes in speed and direction that require greater lateral forces for drivers to maintain control. The amount of friction available at a location (i.e., friction supply) must be equal to or higher than the amount of friction needed (i.e., friction demand) for a vehicle to safely execute these driving maneuvers and avoid a crash.

The AASHTO Guide for Pavement Friction (GPF) states that friction demand categories should be established logically and systematically based on highway alignment, highway features/environment, and highway traffic characteristics (Hall et al., 2009). The GPF further indicates that friction demand categories should be established for individual highway classes, facility types, or access types, and that the number of demand categories should be kept reasonably small so that there are enough PFM sections available for each category to establish investigatory friction levels. An investigatory friction level is defined as the value of friction below which a detailed site investigation should be performed to determine if there is a need for friction enhancement. Several examples of investigatory levels used in other countries can be found in a recent FHWA report (de León, et. al, 2019).

2.4 PAVEMENT FRICTION AND CRASHES

Historically, PFM has been associated more with wet pavement conditions and relied on identifying locations with an overrepresentation of wet pavement crashes for friction enhancement. However, this reflects a reactive and narrow approach since wet pavement crashes generally only represent about 15 percent of all crashes. Since dry pavement crashes can also be affected by friction, a comprehensive PFM approach expands the opportunity to further reduce fatal and serious injury crashes through appropriate pavement friction enhancement strategies. In fact, as HFST implementation increased in the U.S., studies confirmed that all locations treated (ramps and curves) experienced significant reductions in both wet and dry crashes (von Quintus and Mergenmeier, 2015).

3 FRICTION MEASUREMENT EQUIPMENT

Many different devices have been developed over the years to assess the friction of a pavement surface. As mentioned earlier, the pavement surface characteristics that influence pavement friction are microtexture and macrotexture. Currently, there are no direct measurement systems of microtexture that relate to friction, but there are measurement systems that provide an indication of microtexture that relates to friction. These systems rely on the broad principle of sliding rubber over a road surface and measuring the reaction forces in some way. There are direct measurement systems of macrotexture, although there is no one macrotexture measurement that has been determined to be the most appropriate for safety analysis.

3.1 FRICTION MEASUREMENTS

There are four general methods to measure pavement friction and they all involve rubber tires or sliders. These methods are generally more sensitive to the pavement surface microtexture than the macrotexture, thus they are considered to provide more of an indication of the microtexture.

Sliders: An example of a slider device is shown in Figure 4. The slider can be attached either to the foot of a pendulum arm or to a rotating head and slows down on contact with the road surface. The rate of deceleration is used to derive a value representing the skid resistance of the road. A variant of this approach, used by law enforcement agencies, measures the force applied to drag a sled over the road surface (with sliders representing car tires).

Figure 4. Photo. Example of a slider: British Pendulum Tester.
Source: CSTI

Longitudinal Friction Coefficient (LFC) Measurement: This type of measurement uses an instrumented measuring wheel mounted in line with the direction of travel. One type of high speed LFC system uses a fixed gear, or braking system which forces the test wheel to rotate more slowly than the forward speed of the vehicle. Consequently, the tire contact patch slips over the road surface and a frictional force that can be measured is developed. Typically, the ratio of vertical and drag forces is calculated (averaged over a fixed measuring length) to provide a value representing the LFC that is recorded. Within this category, a wide range of slip ratios may be used by individual devices (fixed-slip devices). The slip ratio is usually governed by the control system to a fixed proportion of the forward speed, which, in turn, determines the slip speed. Figure 5 shows an example of a fixed-slip friction tester (TYROSAFE, 2011).

Figure 5. Photo. Example of LFC: Fixed slip device-grip tester.
Source: CSTI

Another type of high speed LFC is the locked-wheel skid tester (LWST; see Figure 6), which measures the longitudinal friction by completely locking the brake of the measuring wheel (AASHTO T242). The LWST can use either a ribbed tire (AASHTO M261) (more sensitive to pavement microtexture) or a smooth tire (AASHTO M 286) (more sensitive to pavement macrotexture).

Figure 6. Photo. Example of LFC: 100% slip-LWST.
Source: CSTI

High-Speed Sideway Force Coefficient (SFC) Measurement: This type of measurement (AASHTO TP 143) uses a freely rotating instrumented measuring wheel set at an angle to the direction of travel of the vehicle (see Figure 7). Due to the wheel being at an angle to the direction of travel, the tire is made to slip over the road surface, and the resulting force along the wheel axle (the "sideways force") is measured. The ratio of vertical and side forces averaged over a defined measuring length provides the value that is recorded to represent skid resistance. The wheel angle determines the slip ratio, and the vehicle speed determines the slip speed.

Figure 7. Photo. Example of SFC: Sideway-force Coefficient Routine Investigation Machine (SCRIM). Source: CSTI

Decelerometer-Based Measuring Systems: These systems are mounted in a vehicle and used to measure the deceleration of the vehicle under emergency braking. Although, widely used by law enforcement agencies to assess road surface friction for collision investigations, and more recently in experimental naturalistic driving studies, these devices are not suitable for road network friction measurements or quality control purposes due to the testing variability resulting from the various vehicle, tire, and braking configurations. Decelerometers are only mentioned for the completeness of this primer and will not be addressed in any further detail.

3.2 MACROTEXTURE MEASUREMENTS

Macrotexture can be measured using both static and high-speed methods. The high-speed devices are more appropriate for network level data collection.

Static Devices – Volumetric Methods: The first, and oldest technique is the volumetric “patch” test which uses a known volume of sand, glass beads, or grease, that is placed on the road surface and spread evenly into a circular patch, filling the voids on the pavement surface. Operators compute the area of the circle and calculate the average depth below the peaks of the surface as a value known as mean texture depth (MTD).

Static Devices – Laser Methods: This technique uses laser technology to measure along narrow lines traversed by the laser (rather than across the area of a patch of sand or glass beads) to determine a surface profile used to compute the MPD as defined in the ASTM E1845 standard, which attempts to estimate the average depth below the peaks in a 100-mm segment of the surface profile. Laser technology is the most prevalent method to measure texture for both static and at high-speed testing and is being used by researchers and practitioners to also compute other parameters, such as the root mean square (RMS) of texture depth. Figure 8 and Figure 9 show two examples of static laser devices: the Circular Track Meter and the Surface Texture Analyzer.

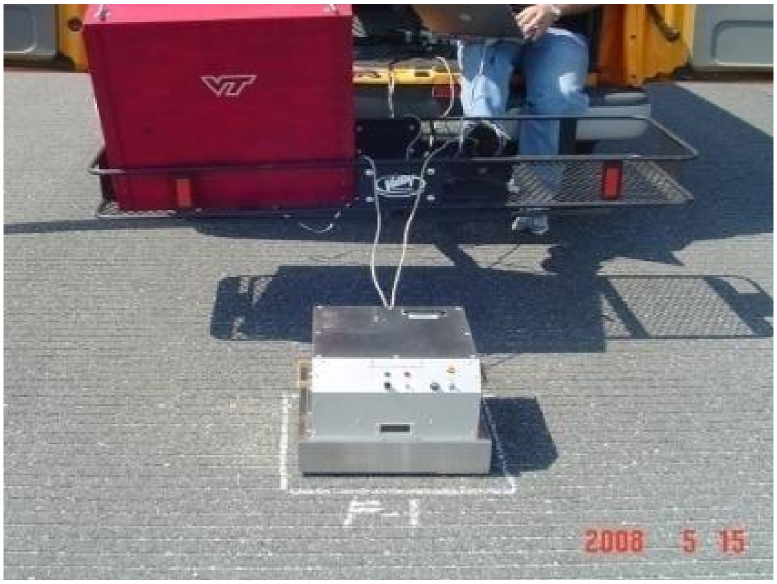

Figure 8. Photo. Static single spot laser: Circular Track Meter.
Source: CSTI

Figure 9. Photo. Static line laser: Texture Analyzer.
Source: CSTI

High-Speed Devices: Single-spot laser or line-laser technology is used in high-speed devices to obtain macrotexture measurements data for network evaluations. Vehicles, primarily used to collect texture data for network evaluations, use computers to record the data and process the reports for both MPD, RMS, and other parameters that are currently being evaluated by researchers to understand their use in PFM. Figure 10 and Figure 11 show the difference between a single-spot laser and a line-laser.

Figure 10. Photo. High-speed single spot laser.
Source: CSTI

Figure 11. Photo. High-speed line laser.
Source: CSTI

4 PAVEMENT FRICTION MEASUREMENT TO SUPPORT SAFETY MANAGEMENT

Currently state DOTs collect network level pavement surface condition data as part of their asset management program. A proactive and systemic PFM program that incorporates network level pavement friction data enhances asset management programs while providing many advantages to help improve the safety performance of the transportation system. Pavement friction varies on roadways across the network and even along a specific corridor, especially at curves, ramps, and intersections. High-speed testing equipment is the only practical alternative for collecting friction data at the network-level. There are two categories of high-speed test methods, non-continuous and continuous pavement friction measurement (CPFM).

4.1 NON-CONTINOUS PAVEMENT FRICTION MEASUREMENT

In the U.S., the standard method of measuring pavement friction used by State highway agencies is the LWST, which is a non-continuous method (Henry, 2000) (AASHTO T 242/ASTM E 274). LWST measures friction by completely locking up the test wheel(s) while simultaneously wetting the surface with a defined water film thickness in front of the test wheel and recording the average sliding force for a period of 3 seconds and reporting a 1-second average after reaching the fully locked slip. Thus, with a 40-mph test speed, a 1-second test time is equivalent to testing the pavement surface for approximately 59 feet. In general, for agencies that collect network-level friction data using the LWST, it is customary to perform one or two tests per mile, which results in only 1 to 2 percent of the pavement surface being tested. As this device is a trailer system, it can be challenging to collect friction data on ramps, curves, or intersections where friction demand and the potential for polishing is higher.

4.2 CONTINOUS PAVEMENT FRICTION MEASUREMENT (CPFM)

Continuous friction measurement equipment (CFME) tests 100 percent of the pavement surface including tangents, curves, and intersections. There are three general types of CFME: (1) fixed-slip (ASTM E 2340), (2) SFC (AASHTO TP-143), and (3) variable-slip (ASTM E 1859) (Henry, 2000). These high-speed methods generally operate between 30 and 50 mph, while simultaneously wetting the pavement surface with a user-defined, uniform water film thickness on the pavement surface in front of the test wheel(s). In 2015, FHWA introduced to the U.S. a SFC measurement device that uses a free-rolling test wheel with a fixed 20-degree slip-angle to measure side-force “transverse” friction. This device records a measure of friction known as the sideway-force friction number (SFN; AASHTO TP-143). SFN can be reported at an interval as short as 4 inches (0.1 m) or averaged to up to 33 ft (20 m), normally used for network-level work. The FHWA device includes additional sensors to measure surface macrotexture and roadway surface geometry (roughness, curvature, cross-slope, and longitudinal grade), and GPS coordinates (de León, et. al, 2019). This helps the practitioner to more readily identify potential factors related to the frequency and severity of crashes.

4.3 SAFETY MANAGEMENT

Network level pavement friction measurement using CFME provides reliable data to properly investigate and proactively assess the friction and the potential for crashes across the entirety of the roadway system. This is of particular importance to addressing locations that historically may be overlooked. Measuring pavement friction in locations with high friction demand (e.g., curves, ramps, approaches to intersections) can be safely and accurately performed using CFME.

CPFM data, combined with crash and road characteristic data, provide significant insight regarding whether increases in friction may reduce crashes. Using network level CPFM data, transportation agencies can identify and prioritize locations to further investigate. CFPM data, combined with various other safety data, enhances project level investigation and road safety audits (RSA). The practitioner can more reliably determine factors, including friction and macrotexture, which are contributing to the frequency and severity of crashes, select the appropriate treatments, determine the limits of improvement, and estimate the potential reduction in crashes. Although installation of HFST has been used to address crashes on curves or at intersections, based on CPFM data, an agency can better define the area with a higher friction demand. This can result in extending the limits of a HFST installation to accommodate that friction demand and reduce crashes. Consideration of multiple locations could result in similar findings and lead to a systemic application or even changes in practice or policy.

Including CPFM data as an element of safety data and integrating it into the safety analysis procedures allows transportation agencies to create an overall PFM program anchored in safety that fully embraces a Safe System approach and results in the reduction of fatal and serious injury crashes.

5 ADDITIONAL INFORMATION

For more information about incorporating pavement friction management and continuous pavement friction measurement into road safety efforts, the following FHWA resources may be of interest:

- Characterizing Road Safety Performance using Pavement Friction (FHWA-SA-23-006). Documents the development of crash modification factors/functions and performance thresholds for friction based on roadway type and category.
- Continuous Pavement Friction Measurement for a Safe System (FHWA-SA-22-052). Short booklet highlighting how using CPFM for safety program purposes aligns with the Safe System approach.
- Improving Pavement Friction for Safety at a Florida Signalized Intersection – Final Report (FHWA-SA-22-10) and Project Case Study (FHWA-SA-22-09). Documents the installation of high friction surface treatment (HFST) at a signalized intersection in Tampa, Florida, in an effort to reduce crashes and improve pedestrian safety. The location was identified through a RSA and utilized CPFM data.
- Proven Safety Countermeasures Pavement Friction Management (FHWA-SA-21-052). Serves as a one-page summary handout for communicating about the value of comprehensive PFM.
- Enhancing Safety through Continuous Pavement Friction Measurement (FHWA-SA-21-014). Serves as a one-page (front/back) summary handout for communicating about the value of CPFM.
- Pavement Friction Management Program Utilizing Continuous Friction Measurement Equipment and State-of-the-practice Safety Analysis Demonstration Project - Final Report (FHWA-RC-20-0009) Documents pilot demonstration experience of CPFM across several states and includes case studies on macrotexture and high-speed roads, macrotexture and friction at intersections, PCCP friction and macrotexture, and raveling of chip-sealed roads.
- FHWA web page on Pavement Friction, including additional information on HFST and other friction enhancement treatments, friction testing, case studies and noteworthy practices.

6 REFERENCES

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