Continuous Pavement Friction Measurement for a Safe System

Measuring Pavement Friction for a Safe System

A Safe System Approach accommodates human mistakes by designing and managing road infrastructure to reduce incidence and severity. The six principles that form the basis of a Safe System include: deaths and injuries are unacceptable, humans make mistakes, humans are vulnerable, responsibility is shared, safety is proactive, and redundancy is crucial.

The Safe System Approach principles and elements. Source: FHWA

More than 50 years ago, National Cooperative Highway Research Program (NCHRP) Report 37 stated that "the lowest friction levels are found on high-speed roads, curves, and approaches to intersections; in short, at locations where high friction values are needed most." Essentially, this research recognized that a clear friction "supply and demand" relationship exists, and is a factor in determining the safety performance of a road. Roadway departure and intersection crashes result in 75 percent of traffic fatalities across the United States.[1] Both wet-pavement and dry-pavement crashes can be mitigated by improving pavement friction and texture. Although most drivers adjust their speed to navigate tight curves or approaching intersections, they cannot account for pavement friction and texture because they simply cannot estimate these characteristics. The friction provided by a roadway surface affects braking and steering control, which can contribute to crashes. One action that can help agencies achieve a Safe System is to provide adequate friction at curves and intersections where it is needed most.

Why your agency should use Continuous Pavement Friction Measurement to Save Lives

Imagine if the safety performance of a specific horizontal curve or intersection were reported as an average of crashes observed (or expected) at locations several thousand feet or more away? Yet this is usually how friction is reported for most locations. Furthermore, pavement friction is not currently a parameter used in crash-based safety modeling in the same way as other roadway characteristics such as number and width of travel lanes; presence, width, and type of shoulder; degree of curvature, etc. For these reasons, Continuous Pavement Friction Measurement (CPFM) offers a two-fold opportunity for developing Safe Roads.

1 Fatality Analysis Reporting System, National Highway Traffic Safety Administration, https://www-fars.nhtsa.dot.gov/Main/index.aspx

Methods for Measuring Pavement Friction

Today, it is standard procedure for network level friction in the United States to be measured using a sample-based, discrete (i.e., not continuous) measurement called the Locked-Wheel Skid Trailer (LWST) test, in which a measurement is taken over a 60-foot distance by locking a wheel on a tow-behind trailer. This method is repeatable and provides point information. However, reported values that reflect averages across long distances through changing road conditions do not effectively differentiate the changes in friction along the route corridor. Furthermore, LWST equipment is difficult to utilize in critical high friction demand locations, such as horizontal curves or intersections, which tend to experience greater tire scrubbing and polishing that lead to loss of pavement friction. For this reason, surrogate safety metrics, such as the number or ratio of wet weather crashes relative to total crashes, are used to screen for locations that may respond favorably to friction improvement. As a result, opportunities to improve friction and enhance safety at locations below the wet weather crash threshold may be overlooked.

Fortunately, CPFM is an established and proven approach that has been used for several decades in other countries and could revolutionize the role of pavement friction in framing our understanding and management of the safety performance of our Nation's roads. CPFM equipment is able to measure pavement friction continuously, through tangents, curves and intersections, at speeds as high as 50 mph. This data can then be post-processed at user-defined increments as short as 1-foot. This approach is commonly used by road authorities in many European countries, Australia, and New Zealand, and even by airport authorities in the U.S. to measure friction on runways. Figure 1 presents CPFM data acquired at one U.S. location that was part of a recent FHWA pilot project, where it was found that pavement friction varied throughout the curve, and it was considerably less through the curve and intersection area than on the tangent approaches. It would have been very difficult, if not impossible, to measure pavement friction using LWST equipment at this resolution at these locations.

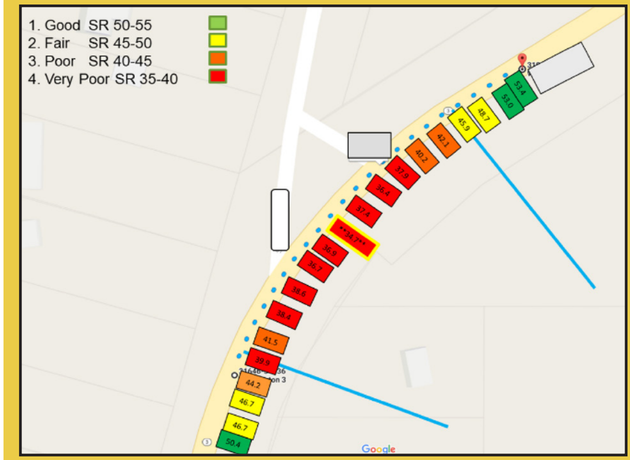

Figure 1: Visualization of CFM data through a curve with an intersection (presented in 30-foot averaged intervals).

Measuring Microtexture and Macrotexture

There are two types of surface texture that affect pavement friction: microtexture (wavelengths of 1µm to 0.5mm) and macrotexture (wavelengths of 0.5mm to 50mm).[2] These characteristics are controlled by an agency's pavement specifications. Microtexture is the very fine texture of the pavement surface that is analogous to the feeling of rubbing sandpaper on skin. On pavements, the jagged edges of aggregate material provides the roughness needed to provide friction to the tires. Macrotexture is the visible texture of the surface that provides voids for water to escape. Both are important for providing an adequate friction supply; however, macrotexture becomes more critical at higher speeds. CPFM systems can collect data that is related to both microtexture and macrotexture. By being able to collect information related to both of these key components of pavement friction, agencies can specify, monitor, and maintain an appropriate level of friction to support safe roads.[3]

2 Guide for Pavement Friction, American Association of State Highway and Transportation Officials

3 FHWA's Technical Advisory TA 5040.36 "Surface Texture for Asphalt and Concrete Pavements" provides additional information on pavement surface texture.

CPFM: An International Best Practice

While aggregate testing and specifications, pavement mix designs, and rubber tire manufacturing have evolved in the years since TA 5040.36 “Surface Texture for Asphalt and Concrete Pavements” was published, the basic friction supply and demand relationship is still relevant. Research conducted in other countries has consistently found a relationship between pavement friction levels and safety, and programs that subsequently established maintenance values for friction that are grounded in safety performance rely upon CPFM for monitoring. Furthermore, using CPFM data can help target more efficient and effective installations of pavement friction treatments, including High Friction Surface Treatments (HFST).

United Kingdom

Since the 1980s, pavement friction of the English Strategic Road Network has been managed through a requirement to provide specific levels of skid resistance and texture depth, using CPFM as the basis for monitoring. A 1991 paper by Rogers and Gargett referenced a National Skidding Resistance Survey report that estimated this approach would result in 6 percent fewer casualties per year on trunk roads, and a benefit-cost ratio of 5.5-to-1. In 2016, the Transport Research Laboratory published PPR 806, which further reviewed the relationship between crash risk and skid resistance. The study found that for curves and steep grades, roadways with higher skid resistance have a lower risk of collisions, even in wet conditions, and recommended that enhanced skid resistance treatments be prioritized for those sites.

New Zealand

Throughout the 1990s, the New Zealand Transport Agency (NZTA) sponsored road surface friction research and development and established their first skid resistance policy and specification in 1997, which required CPFM equipment be used for network skid resistance measurement. Consistent with UK experience, the 1998 Transfund New Zealand Research Report 141 documented a statistically significant relationship between crashes and skid resistance at junctions, curves and steep grades, and indicated that wet road crashes could be reduced 45-61% at these locations with targeted enhanced skid resistance. Finally, a 2011 paper by Whitehead, et al, reviewed 11 years of experience with the NZTA policy and found the benefit-cost ratio ranged between 13:1 and 35:1.

Collaborating for Safe Roads

In addition to technical considerations such as testing specifications and data management, agencies must plan for internal collaboration. Friction data is multi-disciplinary in terms of benefits and impacts, involving Safety, Maintenance, Programming, Pavements, and Materials. For example, Safety provides expertise on crash data and conducts data analysis, while Pavements and Materials identify and specify mixes, materials and treatments that provide sufficient friction where needed, including HFST. A Pavement Friction Management Program that is multi-disciplinary in nature and utilizes CPFM will lead to pavement surfaces that are designed, constructed, and maintained to minimize friction-related crashes in a cost-effective manner.

Case Study: FHWA Demonstration Project

In 2015, FHWA initiated a Pavement Friction Management Program demonstration project in collaboration with four State agencies to collect and analyze pavement friction, crash, traffic, and other geometric data. The research team collected, processed, and analyzed approximately 4,000 miles of data, and recommended a methodology to identify sections of roadway with high friction-related crash risk, suggesting corrective friction treatments in a cost-effective manner to reduce friction-related crashes.

The study demonstrated methods for establishing investigatory levels of friction for different friction demand categories and developed pilot pavement friction management plans (PFMPs) for the four States using proven safety analysis methods. The results of the study confirmed a strong association between crashes and continuously measured frictional pavement properties and that the adoption of CPFM data within a PFMP instead of the traditional sampling approach using LWSTs can have a significant positive impact on crash reductions. The analysis of the networks tested suggests that a PFMP implemented with CPFM data can result in high potential crash reductions, yielding significant potential economic savings with a favorable benefit/cost ratio. Based on the pilot results, FHWA encourages the use of CPFM to provide comprehensive pavement friction data, combined with existing safety data and analysis, to create an overall pavement friction management program anchored in safety.

Case Study: Florida Department of Transportation

In 2019, the Florida Department of Transportation (FDOT) conducted intersection Road Safety Audits (RSAs) using CPFM data from the FHWA Pavement Friction Management Program demonstration project. The CPFM data revealed where pavement friction and macrotexture in intersection areas was significantly less than the adjacent pavement sections, prompting an RSA team recommendation to consider installing HFST, which was completed at one intersection in 2020. In the months following, traffic cameras mounted at the intersection facilitated analysis of stopping behavior at the intersection. It was found that improper stopping, defined as a vehicle crossing the stop line and resulting in an incursion into the crosswalk while the signal was red, was reduced by 25-30%. These results indicate that application of HFST at the intersection reduced stopping distance and incursions into the crosswalk, improving conditions for pedestrians. The CPFM data used by the RSA team was critical to the HFST recommendation that led to positive results.

Conclusion

Data collection methods using a sample-based approach do not adequately characterize the pavement friction in high friction demand locations for in-depth safety analysis. A Pavement Friction Management program utilizing CPFM can be an effective component of an agency's Safe System Approach to save lives and prevent serious injuries.

To foster a safe road environment:

- Include pavement friction as a parameter in road safety performance modeling
- Establish friction performance thresholds based on context
- Proactively and systemically manage friction
- Deploy proven friction improvement treatments foster a safe road environment.

For more information:

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