Advancement in Pavement safety assessments

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ABSTRACT: Transportation Safety continues to evolve as a significant area of interest and concern. As a result, evaluation of safety from pavement surface characteristics is also attracting more interest recently. Historically, pavement safety assessments have focused on friction assessments. Curiously, common technology for conducting such assessments has not changed much in the past half century. With significant changes in automotive braking systems, exploration of alternative methodologies for pavement surface assessment are gaining interest. Not surprisingly, current methodologies continue to involve test tyres assessing frictional resistance. Interest has always existed in exploring the relationship between texture and friction, in part, because texture can be assessed with non-contact technologies. Unfortunately, neither friction nor texture were previously collected with sufficient density and precision to establish any meaningful relationships. With the availability of these more comprehensive assessments, more detailed investigations are now more feasible.

1. INTRODUCTION

Low friction surfaces are rarely the sole cause of crashes, which typically involve multiple contributing factors. While friction can play a role, understanding pavement safety requires considering parameters such as traffic load, surface wear, and water dispersion. Areas with inherently low or irregular friction may result from design, materials, or wear over time, varying significantly across locations. As technology advances, authorities face challenges in effectively implementing data to identify segments needing treatment. Continuous data collection as opposed to sample data collected for network-wide assessments are essential for identifying high-risk hazardous areas, determining intervention levels, and taking proactive action. With continuous data collection road authorities can achieve, simultaneous profile data, skid data and geometry with georeferenced images to further understand the mechanism leading to the issues of safety on the roads in the least amount of time.

2. TECHNICAL APPROACH

The testing methodology for a locked-wheel skid tester (LWST) device requires the test wheel to be progressively braked over a time up to the fully locked state, before releasing again ready for the next test. The full lock/release requirement means that measurements can only be recorded periodically over short intervals of time typically resulting in less the 2% of the pavement surface being tested intermittently, and often without repeatability. With the difficulty of aligning of spot tests within short curves and intersections, it is common that these areas of high friction demand are not tested.

In comparison, a sideway force coefficient device (SFC) measures 100% of the surface, continuously, with reporting intervals as granular as 0.1m. Continuous sampling is particularly important on those discrete localised sections within a network that have high demand for friction, such as curves and intersections. These areas typically have the highest levels of aggregate polishing and surface wear due to action of traffic manoeuvres in these high-risk locations and ironically are where high friction is needed the most.

To provide a complete picture of road safety, with all the data needed for comprehensive friction and safety evaluations, continuous friction needs to be collected simultaneously with macrotexture from surface texture (Mean Profile Depth, MPD) data, as well as rutting and geometry data for potential water ponding, rainfall surface flow determination, and digital imagery for visual road safety risk assessments. Whilst there are multiple technical standards out in industry for collecting various safety attributes collecting any data separately is not conducive to fully understanding the hazards on these road segments.

2.1 *Continuous Friction Sideway Force Coefficient Concept*

A SFC device measures the traction availability of the road surface. These measurements can be made of a road network in both wheel paths (Figure 1) continuously, capable of collecting far more data than traditional locked wheel or other small trailer based continuous friction measuring equipment (CFME). Sideway Force Coefficient (SFC) measurement devices use an instrumented measuring wheel angled to the line of the chassis in the wheel path. The test tyre is freely rotating with no restriction, however as it is set at an angle the tyre is compelled to slip over the pavement surface as the vehicle moves forward. The sideway slip resistive force can then be measured through the wheel axle via a load cell. The measurements are continuous while the vehicle is moving, as side slip friction resistive forces are always being generated by the forward motion. The angle of the wheel is chosen to be enough to generate this sideways force while unaffected by typical road curvature. To determine SFC the variables measured are the vertical downwards force on the test wheel - nominally 2.0kN - and the sideways (horizontal) force on the test wheel (Figure 1).

The friction parameters derived from the measurements are:

1.) Sideway-force coefficient (SFC) which is the ratio of the sideways force to the vertical force, and
2.) Sideway-force ratio (SR) which is the SFC x 100 (effectively a %)

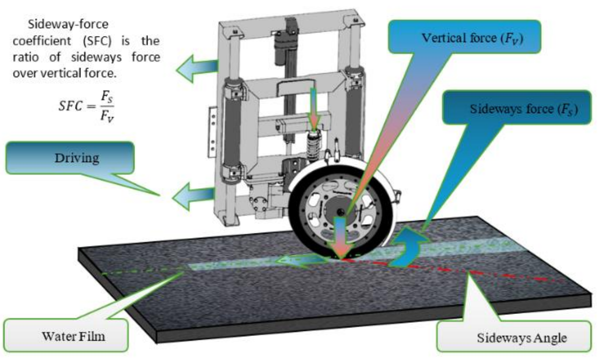

Figure 1: Sideways Force Coefficient concept (PD Sanders and C Browne,2020)

2.2 *Surface texture (macrotexture)*

Macrotexture of the pavement surface is collected using three non-contact 32 kHz lasers. The speed of the laser is sufficient that height measurements are made every 1 mm or less at speed of 100km/h. The three texture lasers are situated in each wheel path at 950 mm as well as along the centre of the vehicle. for comparison purposes.

2.3 *Rut Measurement*

Laser Rut Measurement System (LRMS) are used to digitise transverse sections of the pavement. Transverse profile of the pavement is documented from 1280 points over a nominal 4-meter width. Custom optics and high-power pulsed laser line projectors allow the system to operate in full daylight or in night-time conditions.

With a 150 Hz sampling rate, this equates to one transverse profile being recorded every mm of longitudinal travel per km/h of travel speed (i.e., every 100mm at 100km/h). It does this with a nominal transversal resolution of ±2 mm with a nominal depth accuracy ±1 mm.

2.4 *Spatial referencing*

2.4.1 Distance measurement

Calibrated distance measuring devices provide linear referencing. Conducting appropriate calibrations prior to the commencement of each survey provides greater confidence in the positioning of the data and findings. Having calibration routines within the acquisition software facilitate the calibration process.

2.4.2 Spatial Positioning System

Global Navigation Satellite Systems (GNSS) and Inertial Navigation Systems (INS) provide sub-metre spatial accuracy and precise road geometry data. This includes grade, crossfall (±15%), and horizontal/vertical curvature, sampled every 2 meters and reportable at intervals of 10 meters or more.

2.5 *Imaging*

Digital imaging cameras capture high-quality, distortion-free images of pavement and road assets, with all cameras calibrated for precise linear and geospatial referencing. These systems ensure calibration accuracy through continuous alignment checks and are housed in the cab to prevent fogging. Images are tied to road location data (chainage) and GPS coordinates, allowing for accurate defect identification and asset mapping. Additionally, the captured images enable inventory data collection with unique GPS tagging, providing valuable information for future asset assessment or condition analysis, even if not immediately required.

2.6 *Synchronization of Data*

To ensure precise synchronisation of all collected data, all data streams and reference measurements are recorded from the same original source of odometer Distance Measurement Instrument (DMI) and GPS receiver (spatial coordinates) and are aligned through a high precision software module to synchronise output data at desired road location referencing intervals. Acquisition navigation functionality can deliver faster project completion times, accurate location referencing and reduced error through GIS based referencing, real-time survey route planning.

3. CASES

From previous experiences of projects undertaken in the United States and South Africa, several common scenarios are observed when gathering a more thorough set of safety parameters, continuously. The following representative cases depict how these scenarios practically impact strategic maintenance planning.

For the purposes of this discussion, examples are categorized into cases with conditions as follows:

1.) Low friction and/or low texture, but all other metrics are within acceptable tolerances.
2.) Low friction and/or low texture, with conditions that impact surface moisture (. i.e. transverse profile concerns, geometric transitions, abnormal precipitation).
3.) Acceptable friction and/or texture but similar conditions that impact surface moisture.

3.1 Case 1

When conducting comprehensive safety assessments, it is possible to identify locations where the friction and/or texture is truly the only cause of concern.

1.) Without comprehensive safety assessments, it is possible these cases may go undetected.
2.) Without geometric concerns or the presence of moisture (from transverse profile issues or drainage concerns), such cases may not present the greatest of safety hazards.
3.) With only friction testing, these cases may be planned for treatments that may not be entirely necessary.

3.2 Case 2

In instances where low friction and/or texture are present along with conditions that impact surface moisture.

1.) Geometric concerns or the presence of moisture (from transverse profile issues or drainage concerns), typically necessitate more extensive remediation.
2.) With only friction testing, these other concerns may go undetected.
3.) Surface treatments may not necessarily address these cases, depending on the severity of the other concerns.
4.) Comprehensive safety assessments help to establish if more than just surface treatments are needed to truly reduce the safety risk.

3.3 Case 3

As most recognize, there are instances when acceptable friction and texture may be present, but other conditions may exist that impact safety.

1.) Transverse profile (rutting) and/or other geometric issues that create issues with the presence of surface moisture can create significant safety hazards, regardless of other conditions.
2.) Similarly, adverse geometrics (in horizontal or vertical curvature) can also present significant causes for concern.
3.) Comprehensive safety assessments help to identify/confirm these occurrences and provide for appropriate remediation. Refer to figure 3 below utilising platforms such as Hawkeye Insight illustrates areas of concern viewing all profile and friction data collectively in the form of graphs, helping a client understand their network to make informed decisions.

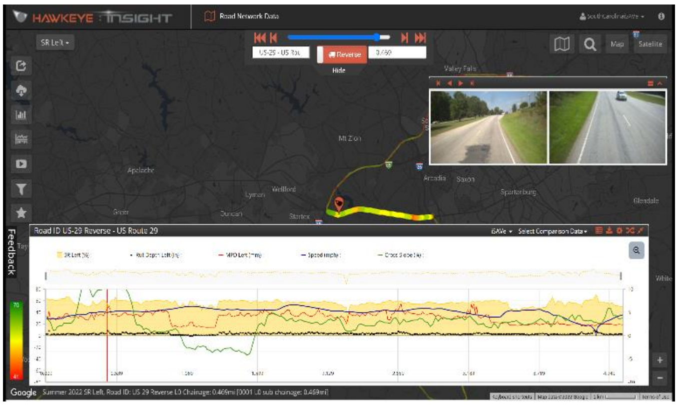

Figure 3: *Friction assessment acceptable, but other metrics show cause for concern (Case 3). (ARRB Systems, 2024)*

Continuous data allows for more detailed project-level assessments, enabling accurate identification and treatment of critical sections rather than relying on average conditions. This approach improves decision-making by leveraging network-level data to inform project-specific needs. However, inconsistencies in relationships between parameters like friction and macrotexture, as observed with line laser data, highlight the need for further research. These additional assessments are essential to enhance understanding of safety parameters and improve road safety outcomes.

4. CONCLUSION

Historically, assessing pavement conditions has been challenged by limitations in traditional methods. Common issues with traditional safety assessment approaches include insufficient sampling, an inability to assess multiple factors at once, difficulty in proactively identifying areas in need, and high costs. resulting in a gap between network assessments and the design of specific treatment applications. As a result, there is increasing interest in new methods that collect data on friction, texture, and other functional parameters continuously, leading to more comprehensive safety assessments and project-level applications. Though the full impact of these methods is still uncertain, many are optimistic about their potential.

Most agencies are embracing network-level assessments and focusing on how to integrate this data into existing management systems. Project-level treatment applications are still being developed, with data being used to identify specific road sections that require special attention, such as targeted surface repairs, geometric changes, or other safety measures. These comprehensive assessments can enhance the optimization and application of pavement funds. However, challenges remain, such as the inconsistency of relationships between friction and macrotexture, which suggests the need for further research. Continuing assessments are essential to deepen understanding of these parameters and improve the ability to create safer roads.

5. REFERENCES

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