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Field Investigation of Relationship between Pavement Surface Texture and Friction

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ABSTRACT

Proper tire-pavement interaction is essential for the safety of motorists. Pavement surface texture is a major contributing factor to tire-pavement friction. This study performed a series of statistical analyses of field-measured friction and texture data to find the texture-friction correlation. Three test sections with different pavement types were selected within the state of Texas. Data were collected at three locations in the right wheel path and three locations in the center of the lane for each test section. To measure the texture data, the researchers used the Circular Track Meter (CTM) and a prototype measurement device developed in-house and consisting of a line laser scanner (LLS). Friction measurements were obtained with the Dynamic Friction Tester (DFT) and Grip-Tester. The mean profile depth (MPD) was calculated by using the measured texture data. The relationship between the MPD values and the friction numbers obtained from the Grip-Tester and DFT was investigated at speeds of 50 and 70 km/h (31.1 and 43.5 mph). The repeatability and reliability of both the developed LLS prototype and the Grip-Tester were also evaluated, as well as the effect of test speed on friction measurement. The results indicated a strong positive correlation between the texture and friction data. Additionally, the developed LLS prototype was able to scan the pavement surface texture more reliably and precisely than the CTM in terms of vertical and horizontal resolution. The Grip-Tester showed promising results compared to the DFT with regards to the friction measurement.

Keywords: Pavement surface texture, friction, Mean profile depth, Grip-Tester, Line laser scanner

INTRODUCTION

The direct force developed in the tire-pavement interface is known as *skid resistance*, a property defined by the properties of the tire, the vehicle speed, and the pavement condition and texture. Pavement texture is determinant of the resistance of the pavement surface to a vehicle sliding and skidding *(1, 2)*. The extent of skid resistance on any given pavement is dependent on the design of the surface texture—specifically its micro- and macro-texture—as the texture can affect the skid resistance, splash-and-spray, rolling resistance, and tire wear *(3)*. Pavement design can adjust surface pavement properties to provide the safety needed *(4)*.

Pavement surface texture is influenced by many factors, such as aggregate type and size, mixture gradation, and texture orientation, among others. Pavement texture is the result of the deviations of the surface layer from an actual planar surface *(5)*. The World Road Association has categorized pavement texture by a range of wavelength (λ) and amplitudes (A). The standard specification organizations, such as the American Society for Testing Materials *(5)*, International Organization for Standardization *(6)*, and German Institute for Standardization (DIN on ISO 13473-1), accepted and incorporated these definitions. The ISO 13473-1 refined the terms incorporating typical amplitudes *(7)* as follows:

- Micro-texture ($\lambda < 0.5$ mm, A = 1 to 500 µm) (where λ is wavelength and A is amplitude)
- Macro-texture ($0.5 \text{ mm} < \lambda < 50$ mm, A = 0.1 to 20 mm)
- Mega-texture ($50 \text{ mm} < \lambda < 500$ mm, A = 0.1 to 50 mm)

Micro-texture refers to the small-scale texture of the aggregate surface, which controls the contact between the tire rubber and the pavement surface. Micro-texture is a function of aggregate particle mineralogy, petrology, and source (natural or manufactured), and is affected by the environmental effects and the action of traffic *(8)*. *Macro-texture* refers to the large-scale texture of the pavement surface due to the aggregate particle size and arrangement. In asphalt pavements, the mixture properties (aggregate shape, size, and gradation), which define the type of mixture, control the macro-texture *(9)*. Mega-texture has wavelengths in the same order of size as the tire/pavement interface. Examples of mega-texture include ruts, potholes, and major joints and cracks. It affects vibration in the tire walls but not the vehicle suspension, and it is therefore strongly associated with noise and rolling resistance *(9)*.

Pavement friction is the result of a complex interplay between two principal frictional force components: adhesion and hysteresis. Although there are other components of pavement friction, such as tire rubber shear, they are insignificant when compared to the adhesion and hysteresis force components *(3, 9)*. Thus, friction can be viewed as the sum of adhesion and hysteresis. *Adhesion* is the friction that results from the small-scale bonding/interlocking of the vehicle tire rubber and the pavement surface. It is a function of the interface shear strength and contact area *(9, 10)*. The *hysteresis* component of the frictional forces results from the energy loss created within the tire as it responds the texture. Because the adhesion force is developed at the tire/pavement interface, it is most responsive to the micro-level asperities (micro-texture) of the aggregate particles. In contrast, the hysteresis force developed within the tire is most responsive to the macro-level asperities (macro-texture) formed in the pavement surface. Thus, in principle, adhesion governs the overall friction on smooth-textured and dry pavements, while hysteresis is the dominant component on wet and rough-textured pavements *(3, 9)*.

In 2015, Torbruegge and Wies in Germany studied the correlation between wet skid resistance and pavement texture. Their findings showed no correlation between the mean texture depth (MTD) as a surface texture characteristic and skid resistance as measured by British pendulum *(11)*. Similar results were obtained by Gunaratne et al. in which no significant correlation was found between friction and MTD. However, Gunaratne et al. observed a strong correlation between friction and the texture frequency characteristics, such as the power spectral density calculated by fast Fourier transform *(12)*.

The precise nature of the relationship between friction and texture remains unknown, although several attempts to reveal it have been made using methods such as Fourier, wavelet, and fractal analysis *(13-15)*. These models' degree of complexity and the difficulty in finding the coefficients relating to the calculations results in complications for road engineers.

GOAL AND OBJECTIVES

Understanding the texture-friction relationship is valuable for transportation agencies and engineers for proper pavement maintenance and better design of pavement, especially when higher skid resistance is needed. A few studies have been conducted in this regard, but the effects of pavement texture on the friction produced at the pavement surface are still not fully understood. This study's primary goal is to find the correlation between field-measured texture and friction data. For this purpose, several objectives were defined:

- Develop an accurate texture measurement device, called a line laser scanner (LLS) prototype, and evaluate its performance by comparing its results to those of the CTM.
- Use the Grip-Tester to collect continuous friction data at traffic speed and compare it to the DFT at two different speeds.
- Calculate the MPD values of texture data and perform statistical analysis to establish correlations between texture and friction.

EXPERIMENTAL METHODS AND THEORETICAL EVALUATIONS

Measurement of Skid Resistance

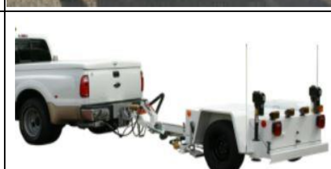
There are three main skid resistance measuring principles: longitudinal friction coefficient (LFC), transverse, and stationary or slow-moving *(16, 17)*. The LFC measurement principle aims to measure friction when a vehicle is traveling forward in a straight line. When the brakes are applied, both the angular velocity of the wheel and the overall velocity of the vehicle decrease. When the braking force on the wheels is too strong, the wheels are "locked" and consequently slide over a surface. LFC measurement devices have slip ratios that simulate the wheel slipping process when a wheel slides over a surface. More specifically, the slip ratio compares the vehicle's velocity to the angular velocity of the wheel. When the slip ratio is 0, the angular velocity of the wheel is the same as the velocity of the vehicle (i.e., no slip between wheel and surface). When the slip ratio is 1, there is no angular velocity in the wheel (i.e., wheel is fully locked and slides over the surface). LFC devices can have either a fixed or a variable slip ratio *(15, 17)*.

The stationary or slow-moving measurement principle is used in compact devices usually found in the laboratory or still testing. One such device uses a pendulum arm; others, such as the DFT, use a rotating head. Both devices use rubber sliders that use the surface friction to slow down the pendulum or the rotating head *(16-18)*.

Table 1 summarizes LFC measurement devices commonly used around the world. LFC devices can measure between 5 and 140 km/h (5.1 and 87 mph) and can come in the form of compact trailers or large-capacity trucks. LFC devices use a watering system, requiring vehicles to carry a water tank for measurement purposes. Transverse friction measurement devices are usually larger, more expensive, and can take measurements for longer distances since greater water capacity increases maximum measurement distance. While inexpensive and easy to use, stationary or slow-moving devices must be operated manually *(18)*.

Table 1 Comparison of the LFC Measuring Devices *(16-18)*

Device Name	Theoretical water film thickness (WFT), Speed, Tire type, Measurement interval (Interval)	Assembly	Device Picture
ADHERA	TWFT: 1 mm Speed: 40–120 km/h Tire type: Smooth PIARC tire 165R15 Interval: 20 m Country/Countries of Use: France	Assembly: Trailer that can be hooked up to vehicle Commercially Available: No	
BV-11	TWFT: 1 mm Speed: 20–160 km/h [C] Tire type: Trelleborg tire T49 Interval: 20 m Country/Countries of Use: England, Sweden, and Finland	Assembly: Trailer that can be hooked up to vehicle Commercially available: Yes	
Grip-Tester	TWFT: 0.5 mm Speed: 5–100 km/h Tire type: Smooth ASTM tire, 254 mm diameter Interval: 10 or 20 m Country/Countries of Use: United States, United Kingdom, and others	Assembly: Trailer that can be hooked up to vehicle. Commercially available: Yes	
ROAR DK	WFT: 0.5 mm Speed: 60–80 km/h Tire type: ASTM 1551 Interval: 5m + Country/Countries of Use: Denmark	Assembly: Trailer that can be hooked up to a vehicle Commercially available: No	
ROAR NL	TWFT: 0.5 mm Speed: 50–70 km/h Tire type: ASTM 1551 Interval: 5–100 m Country/Countries of Use: Netherlands	Assembly: Three-axle tanker truck with two measuring systems mounted at the rear of the chassis. (Tank capacity is about 12,000 liters.) Commercially available: No	
RWS NL	TWFT: 0.5 mm Speed: 50 – 70 km/h Tire type: PIARC smooth 165 R15 Interval: 5 – 100 m Country/Countries of Use: Netherlands	Assembly: Trailer that can be hooked up to a vehicle. Commercially Available: No	

Skiddometer BV-8	TWFT: 0.5 mm Speed: 40–80 km/h TT: AIPCR ribbed, 165 R15, with four longitudinal grooves Interval: 30–50 m Country/Countries of Use: Sweden	Assembly: Trailer that can be hooked up to a vehicle Commercially available: Yes	
SRM	TWFT: 0.5 mm Speed: 40–80 km/h TT: AIPCR ribbed, 165 R15, with four longitudinal grooves Interval: 20 m Country/Countries of Use: Germany	Assembly: The test wheels are mounted on the back of a tanker vehicle at the approximate location of a vehicle tire paths. Commercially available: No	
TRT	WFT: 0.5 mm Speed: 40–140 km/h Tire type: Smooth ASTM Interval: Typically, 20 m Country/Countries of Use: Czech Republic	Assembly: The measuring equipment is under a specially equipped vehicle Commercially available: No	
SRT-3	WFT: 0.5 mm Speed: 30–90 km/h Tire type: Tire with thread (200kPa) Interval: 100 m Country/Countries of Use: Poland	Assembly: Trailer that can be hooked up to a vehicle Note: SRT-3 is more sensitive to micro-texture changes than to macro-texture changes. Commercially Available: No	
IMAG	WFT: 1.0 mm Speed: up to 140 km/h Tire type: PIARC smooth profile tire Interval: N/A Country/Countries of Use: France, Germany, and Poland	Assembly: Trailer that can be hooked up to a vehicle Commercially available: Yes	
ICC	WFT: 1.0 mm Speed: 65 to 80 km/h Country/Countries of Use: United States, and others	Assembly: Trailer that can be hooked up to vehicle Commercially available: Yes	

Among the measurement devices presented in Table 1, the Grip-Tester was selected because it showed the most promise for measuring pavement friction because of its wider range of test speed, better repeatability and reproducibility (depending on the operating speed), greater efficiency in water usage, and commercial availability *(18)*. The Grip-Tester is a friction-measuring trailer that uses a fixed slip wheel to simulate anti-lock braking on a wet road surface. This is achieved by the Grip-Tester having three wheels: two have patterned treads and are connected by a drive axle, while the third is a smooth tread tire. The drive axle, connecting the two drive wheels, has a 27-tooth sprocket; it is connected by a transmission chain to the measuring wheel that has a 32-tooth sprocket *(19)*. The difference in sprocket teeth creates a 15% continuous slippage on the measurement tire. To create wet road conditions, a watering system supplies a constant water thickness specified by the user to the measuring wheel.

The axle connecting the measuring wheel outputs the dynamic friction by using strain gages to measure the horizontal drag force and vertical load force. The information is used to estimate the Grip Number (GN), or coefficient of friction, in real-time. *(19)*. As shown in Equation 1, the GN is the ratio between the fraction of tractive drag force (F_d) and the load force (Q).

$$GN = \frac{F_d}{Q} \tag{1}$$

The Grip-Tester (Figure 1(a)) needs a vehicle capable of towing the trailer as well as a water tank to supply water to the measuring wheel.

Along with the Grip-Tester, the DFT was used to measure the friction of the pavement at different speeds. This machine is specified under ASTM E1911. The DFT (shown in Figures 1(b) and 1(c)) consists of a rotating disk and three rubber pads attached to the bottom of the disk. The disk is pushed by an electric motor to rotate until it reaches the target speed set by an operator. At the same time, water is applied to the pavement surface. The disk drops and the rubber pads come into contact with the wet area. Each rubber pad is loaded vertically at 11.8 N (2.65 lb). The friction force developed between pads and the pavement slows down the disk. The DFT measures the friction coefficient continuously until the disk stops completely *(13, 20)*. The coefficient of friction (μ) is the ratio between the friction force or horizontal torque force (F) and the applied vertical load on the rubber sliders of the DFT *(21)*.

$$\mu = \frac{F}{Q} \tag{2}$$

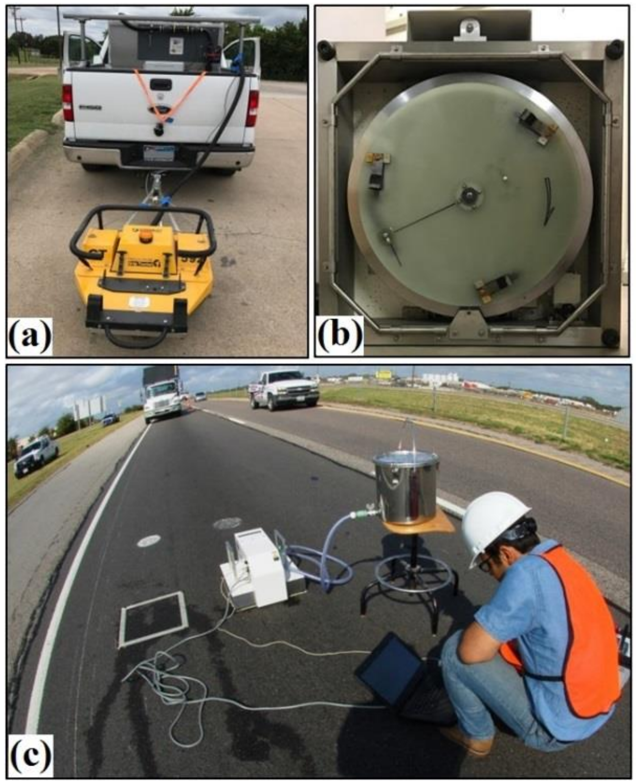


Figure 1 a) The Grip-Tester attached to a vehicle, b) bottom view of the DFT, and c) the DFT connected to a water tank and DCC measuring the friction at the lane center path.

Measurement of Pavement Surface Texture

Circular Track Meter (CTM)

CTM is a common static method used to measure the macro-texture of the pavement surface. According to the ASTM E2157, the CTM (Figures 2(a) and 2(b)) consists of a laser-displacement sensor that rotates over a circle with a diameter of 284.5 mm (11.2 in.) and measures the profile of pavement surface texture. The profile includes 1024 points scanned at an interval of 0.87 mm (0.034 in.). Using the instructions provided by ASTM E 1845, the measured profile then is sectioned into eight equal parts and the highest profile peak in each part is measured *(23, 24)*.

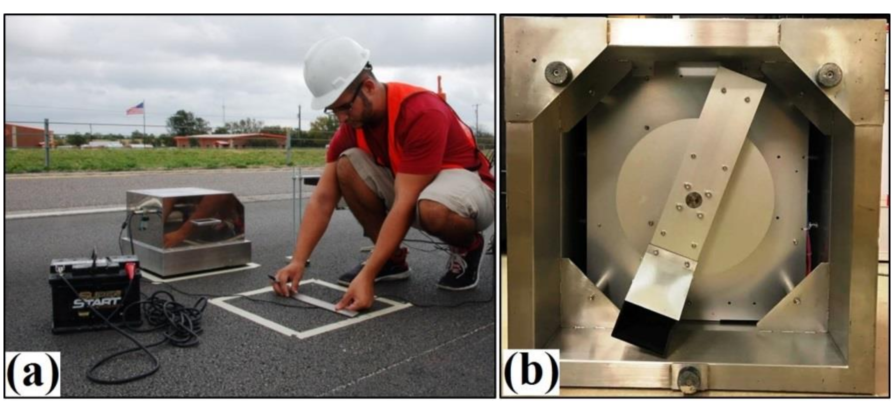


Figure 2 a) The CTM powered by a battery measuring the texture at the right wheel path, and b) bottom view of the CTM.

Developed Line Laser Scanner (LLS) Prototype

LLS was utilized in this research study to scan the pavement texture. This device is two-dimensional non-contact laser sensor that projects blue light in a horizontal line. Small changes in the height due to the texture irregularities can also be captured using this scanner system *(25)*. A prototype (Figure 3(a)) was developed to enable LLS to capture three-dimensional data. For this purpose, the LLS was mounted on a linear motion controller (linear stage) to travel over the surface and scan it at a given interval. Figure 3(c) illustrates the picture of the triangulation system. Due to the angle between the camera and the laser, the system could miss data from vertical edges.

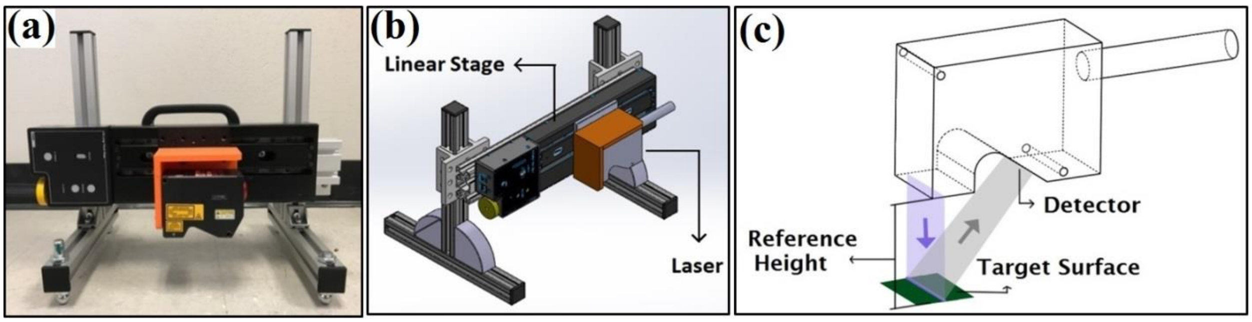


Figure 3 a) A front view of the LLS prototype, b) a 3-D schematic view of the LLS, and c) the triangulation system of laser.

Calculation of Mean Profile Depth (MPD)

In 1992 the Permanent International Association of Road Congresses (PIARC) performed an experiment using 41 friction and texture measuring devices in Spain and Belgium. The results of that experiment showed the MPD parameter as the best pavement macro-texture indicator *(23)*. The MPD is estimated from the surface height profile following ASTM E1845. The first step is to censor the inclination slope of the height profile such that a regression line is calculated and then subtracted from the height profile and so the initial profile will be converted to a zero-mean profile. As a second step (Figure 4), the height profile is divided into two segments with the length of $\frac{L}{2}$ for which the maximum height is detected. By using Equation 3, MPD is calculated as the average of the two determined maximum heights.

$$MPD = \frac{Max\ Height\ of\ 1st\ Segment + Max\ Height\ of\ 2nd\ Segment}{2} \tag{3}$$

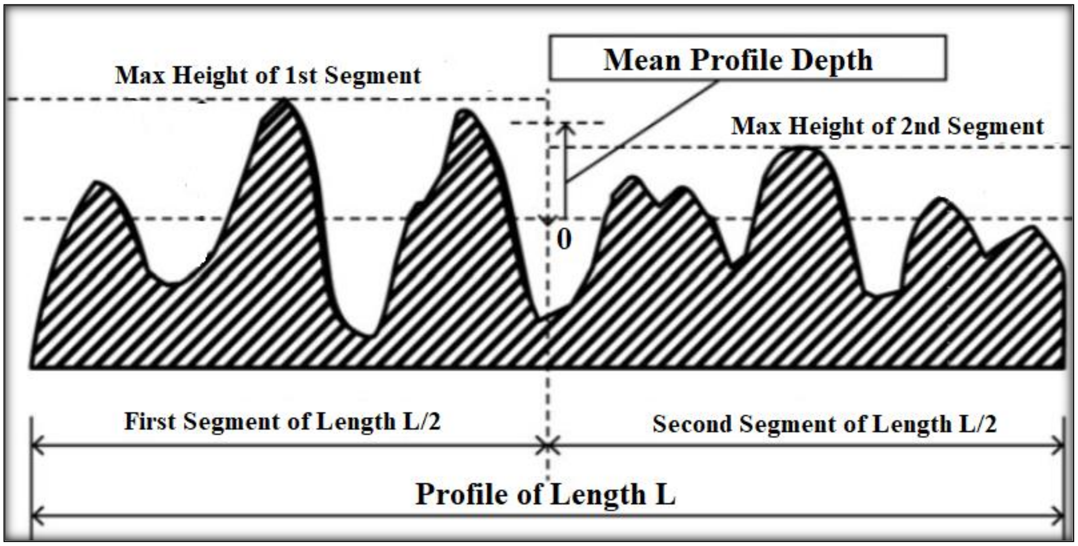


Figure 4 Graphical illustration of MPD calculation *(26)*.

Field-Data Collection

Test sections and pavement type

Three test sections, each more than five years old, were selected. Each section had established measurement data for the DFT, CTM, and LLS. The sections chosen provide a variety of mix designs, ensuring variation of surface texture for the test. The test sections are located in Bastrop, Bryan, and Fort Worth:

- Bastrop:
    - Mix design: Porous Friction Course (PFC)
    - Average annual daily traffic (AADT): 13,972
- Bryan:
    - Mix design: Dense-Graded Type C
    - AADT: 5,843
- Fort Worth:
    - Mix design: Dense-Graded Type D
    - AADT: 57,385

At each location, six samples were taken: three in the right wheel path and three in the center of the lane, with a 12.5 m (41 ft) distance between the locations (Figure 5). Within each location, one CTM and one DFT measurements were obtained. The CTM and DFT testing followed ASTM E2157 and ASTM E1911 procedures, which state the equipment should be placed in the same location.

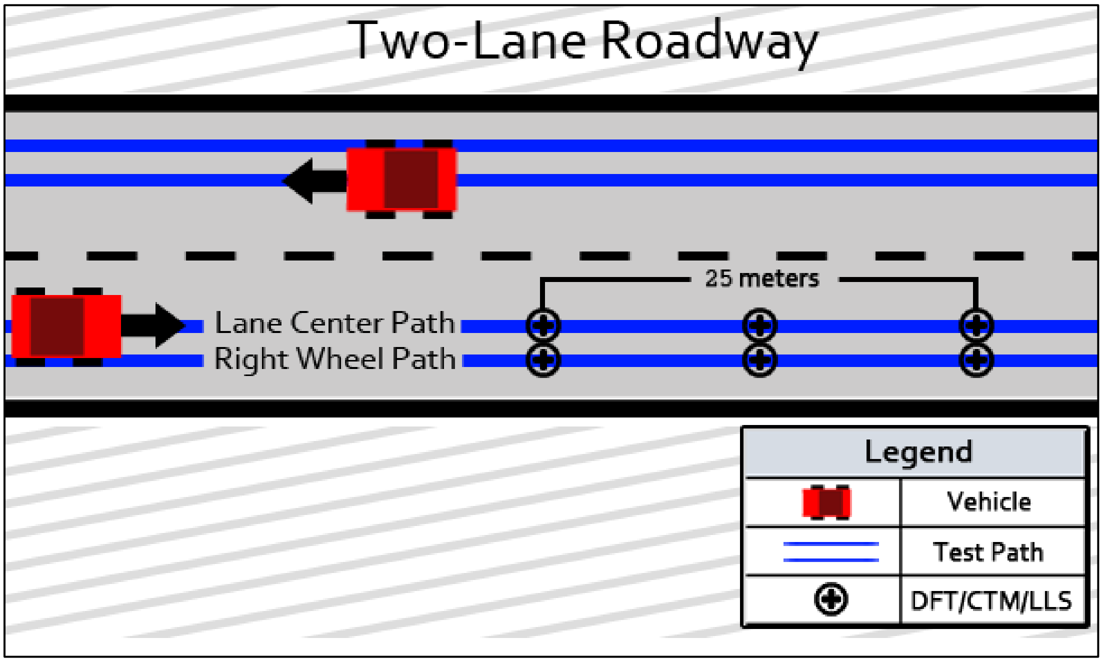


Figure 5 Illustration of test section and test location.

To maintain consistency in the surface measurements, the LLS was placed in the same locations described for the CTM. Note, however, that these devices operate differently due to the mechanism of motion in each: the CTM measures in a circle and the LLS measures linearly. For the CTM, eight segments of 111.5 mm (4.39 in.) arcs are scanned by the laser, which results in a full circle. To ensure an equitable comparison with the CTM's measurements, the LLS was configured to scan a 120 mm (4.72 in.) length at a linear speed of 8 mm/s (0.31 in./s) with a sampling frequency of 1 kHz. The area scanned by the LLS was the same as the segment of the CTM that was parallel to the direction of traffic.

For the Grip-Tester, the test consisted of two target speeds (50 km/h and 70 km/h) to evaluate the dependency of speed on friction. The speed needs to be maintained within 5% of the target speed. The 70 km/h (43.5 mph) target was selected to enable a direct comparison to the DFT equipment, which has a speed range of up to 80 km/h (49.7 mph).

RESULTS AND DISCUSSIONS

Repeatability of Developed LLS Prototype

The LLS results were compared to those from the CTM to investigate the repeatability and reliability of the developed LLS. The MPD, as a surface characteristic, was calculated for all test locations. Then, single values of MPD for the right wheel path and the center were obtained by averaging the three respective samples. This was done for both LLS and CTM as graphed in Figure 6(a)—the -R and -C represent the right wheel path and lane center path, respectively. As this figure illustrates, the MPD values obtained by the LLS, denoted as *MPD-by-LLS*, are very close to the MPD values of CTM, denoted as *MPD-by-CTM*. There were no observable biases between the MPD values with which to draw a general conclusion.

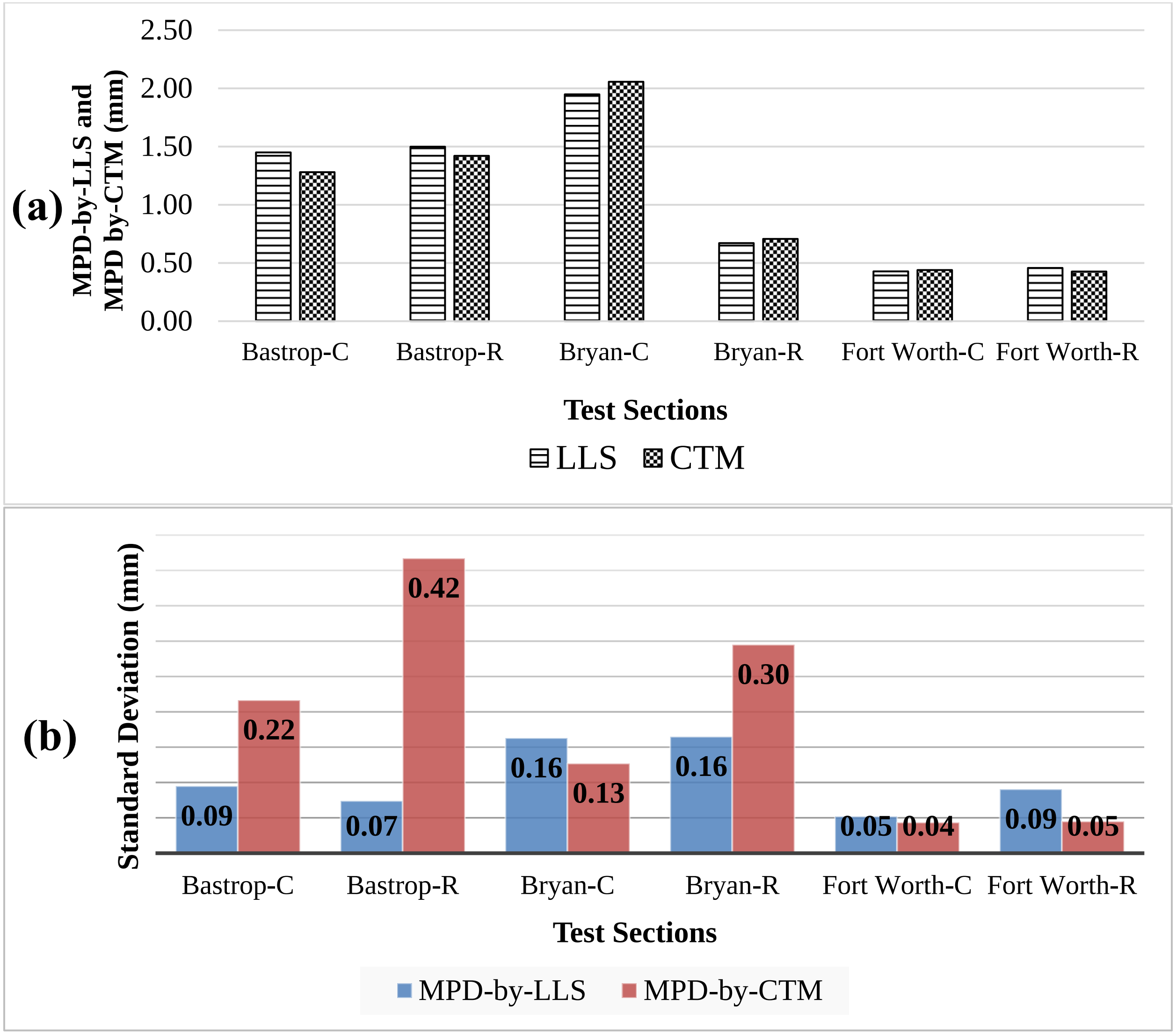


Figure 6 a) Comparison of mean MPD values obtained from developed LLS prototype and CTM, b) Standard deviation of MPD values measured by developed LLS prototype and CTM at six test sections.

Repeatability of the developed LLS prototype was evaluated by calculating the average and standard deviation of three MPD-by-LLS and MPD-by-CTM values obtained at each test section from their respective test paths. Then, the standard deviation of each group of data was compared. For example, the three MPD-by-LLS values for the pavement surface under the right wheel path at the Bryan test section were compared to each other with respect to their standard deviation. Due to the short distance between test locations, similar texture characteristics were expected at those locations. As Figure 6(b) indicates, the standard deviations of MPD-by-LLS data were significantly lower than MPD-by-CTM in three test sections (Bastrop-R, Bastrop-C, and Bryan-R). Comparable MPD values were observed at the rest of the sections. According to these results, one can suggest that the developed LLS prototype is capable of providing an accurate and precise measurement of the pavement surface texture.

Grip-Tester Results

Figures 7(a) and 7(b) show the GN of all test locations plotted against the DFT values at two different speeds of 50 and 70 km/h (31.1 and 43.5 mph). As these figures illustrate, the GN values have a strong relationship with DFT values, with R^2 of 0.93 and 0.91 at the two different speeds. It can be concluded that this relationship is independent of the test speed.

These findings indicate that the Grip-Tester is a reliable alternative for the DFT and does not require traffic control, therefore, it is safer and more efficient. Besides, the Grip-Tester enables engineers to obtain continuous friction data over a long pavement section.

Based on the literature, no given speed has been specified by agencies to perform the test. Hence, understanding the effect of speed on GN, would help researchers and practitioners interpret the friction results in different cases when the test speed is a variable. The results plotted in Figure 7(c) show that the GN decreased when the speed increased. This finding is reasonable but contrasts with the results of a study conducted at the University of Auckland by Wilson et al. in 2013, in which they stated that at speeds less than 75 km/h, the GN may not be affected by test speeds *(27)*.

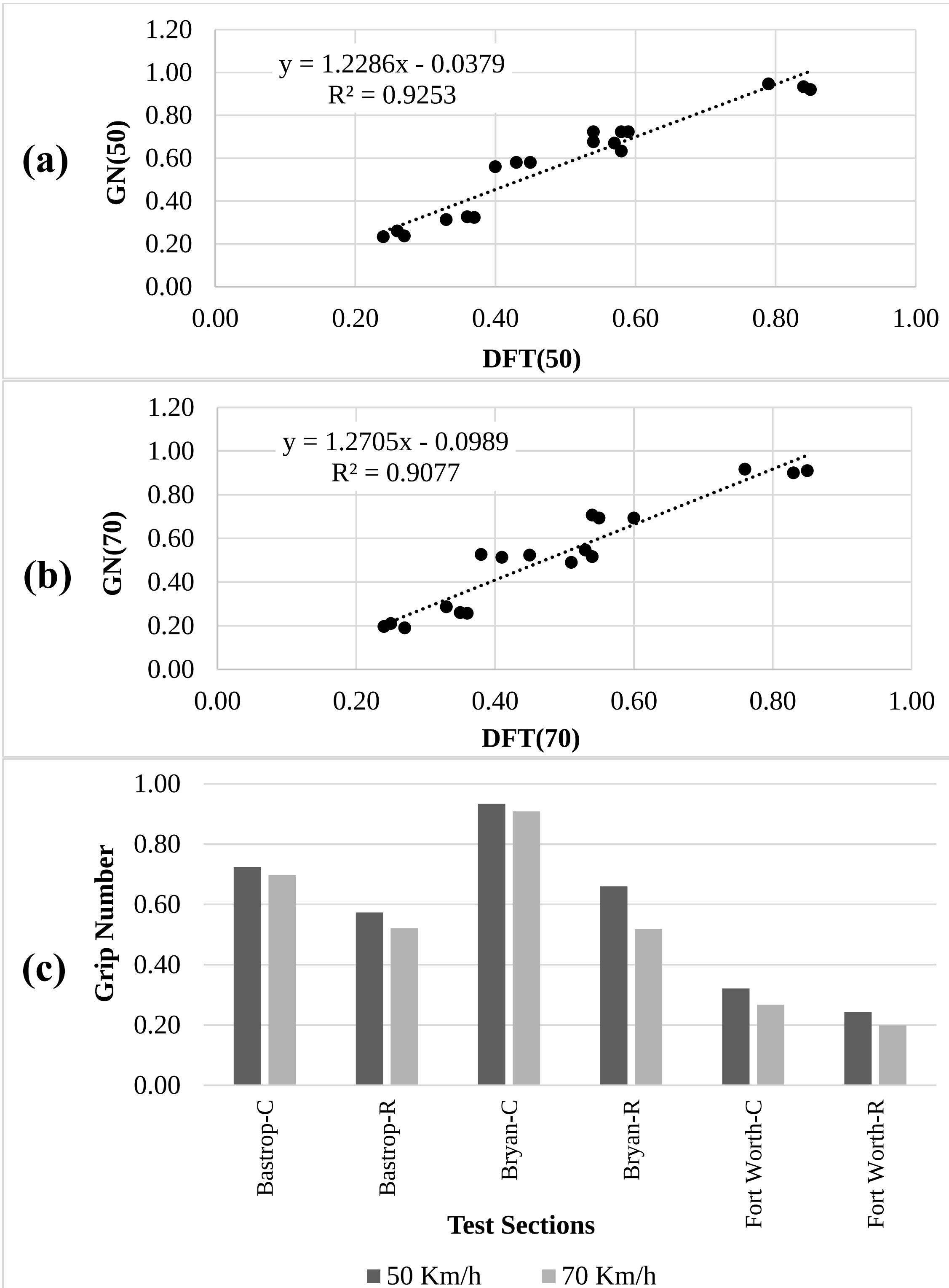


Figure 7 Correlation between GN and DFT values at two speeds of a) 50 km/h and b) 70 km/h, and c) the Grip number at different test sections.

According to Figure 6(a), the MPD value of the section Bryan-R, which is about 0.70 mm

(0.027 in.), is lower than Bastrop-R with MPD of 1.50 mm (0.06 in.). However, interestingly, in Figure 7(c), the GN at Bryan-R is higher than that of Bastrop-R. It should be mentioned that, in these test locations, the water film thickness of 0.5 mm (applied by Grip-Tester) can only cover a portion of surface texture depth. The PFC pavement is an open-graded friction course that allows draingage of water through the aspalt layer. The surface pavement type of the Bastrop test section is PFC; therefore, the lack of small-size aggregates results in higher MPD values. On the other hand, the mix design of the Bryan test section is dense-graded type C, which contains all ranges of aggregate size and thus results in a lower MPD value but a greater tire-pavement contact area. In this case, it can be suggested that the adhesion factor is decisive in friction.

Although a PFC mix design increases the surface MPD (and thus causes more hysteresis), PFC's design also decreases the chance of the aggregates being fully exposed and coming into contact with the tire (thus decreasing the contact area and adhesion). A smooth surface is associated with more contact area and better adhesion, but it significantly decreases the MPD that results in lower hysteresis. Therefore, the balance between adhesion and hysteresis in the pavement surface should be optimized in order to maximize the surface friction and skid resistance. This is achievable by using an appropriate mix design providing both macro-texture and micro-texture *(15)*.

The lowest friction was observed in the Fort Worth test sections where the MPD values were below 0.46 mm (0.018 in.). Considering the water film thickness of 0.5 mm (0.019 in.) applied by the Grip-Tester for wetting purpose, it can be concluded that the surface texture was fully covered by water. In this case, the water trapped in the V- or U-shaped areas of the pavement surface bears the load from the tire and prevents the tire penetrating the spaces between the aggregates—thus reducing the contribution of the aggregate surface to the friction force by decreasing the tire-aggregate contact area *(28)*.

Relationship between the Texture and Friction

The GN and DFT values both represent the friction properties of the pavement surface; however, the MPD values obtained by the LLS and CTM reflect the texture characteristics of the surface. To explore the relationship between the friction and texture, those two groups were plotted against each other in four different forms: GN vs. CTM, GN vs. LLS, DFT vs. CTM, and DFT vs. LLS.

Using statistical analysis, the correlation coefficient (R)was used to evaluate the relationships. The R ranges from -1 to +1, where negative and positive signs represent the negative or positive linear correlation respectively.

The statistical analysis shows that the relationship between the GN values and MPDs is strongly linear with high correlation coefficients (Figure 8). For the Grip-Tester performed at 50 km/h, the R = 0.83 was found for GN-CTM, and R = 0.82 for GN-LLS. In addition, higher correlation coefficients were observed at the speed of 70 km/h. The R values of 0.88 and 0.89 show a strong linear relationship between GN as a friction parameter, and MPDs of CTM and LLS, respectively.

From the results provided in Figure 8, the Grip-Tester data have a better relationship with texture compared to the DFT data in terms of the calculated R^2 values. Thus, it can be suggested that friction and skid resistance could be estimated by means of texture measurement data with high confidence.

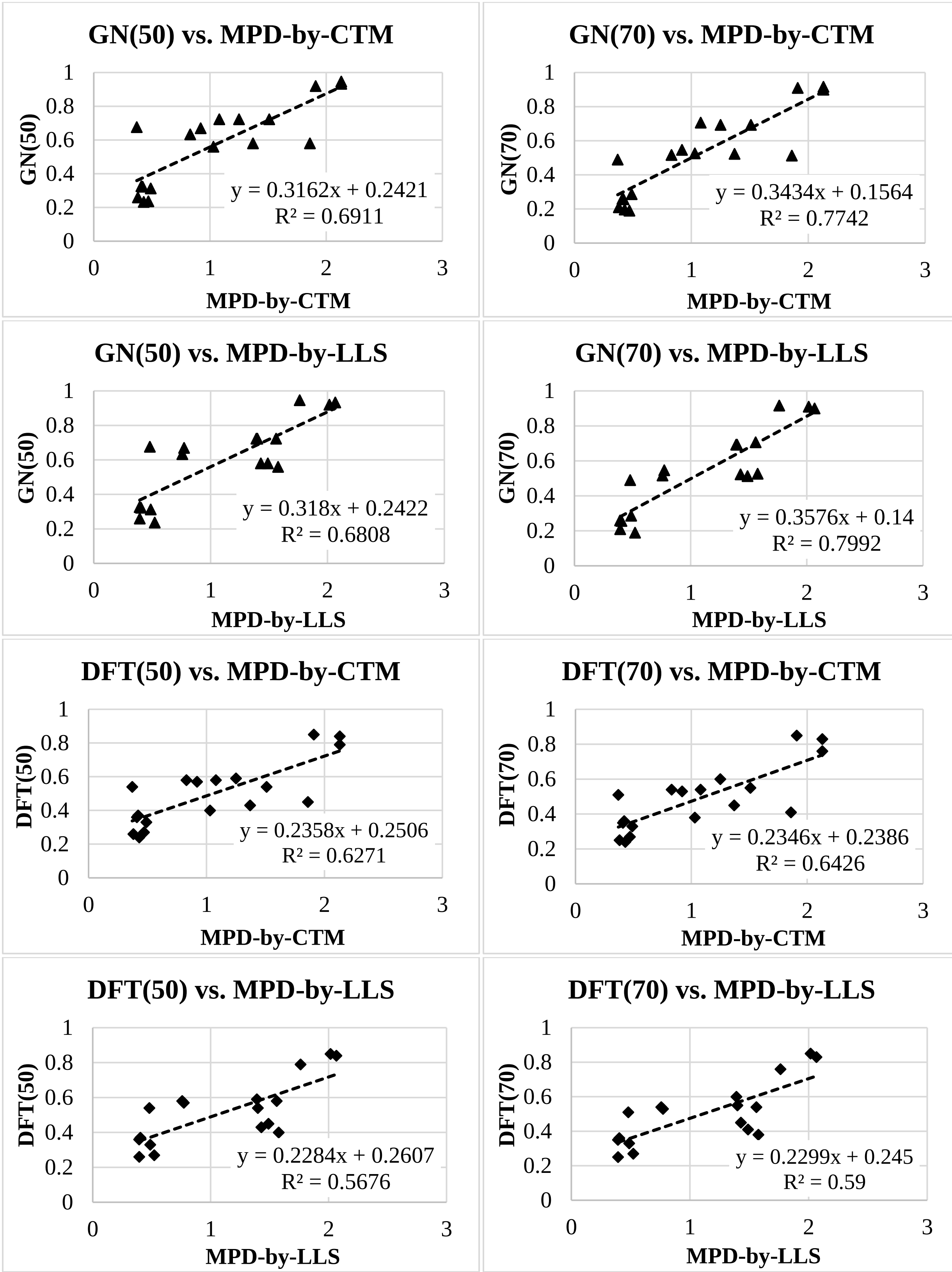


Figure 8 Plotted texture-friction data points including GN, DFT values, and MPD values.

CONCLUSIONS

This study investigated the relationship between the texture and friction of pavement surfaces using field-measured data. During this study, a texture scanner prototype—the LLS—was developed to measure the texture data along with the CTM. The MPD was adopted as a pavement texture indicator. DFT and Grip-Tester were employed for friction measurement. The efficiency and repeatability of the developed LLS were explored through comparison to the CTM results.

The results of the repeatability analysis and standard deviation showed the reliability of the developed LLS prototype for texture measurement. In all the test sections, the MPD calculated from the LLS data was similar to that calculated from the CTM data. Therefore, it is recommended that the developed LLS prototype should be considered as an efficient alternative to the CTM device, especially when three-dimensional texture data are needed.

Regardless of the test speed and pavement type, the friction number obtained by the Grip-Tester showed a strong linear correlation with DFT measurements. Due to the reliable results of the Grip-Tester, its wider range of friction measurement, and the lack of need to control traffic, this device is recommended for use by state DOTs for friction measurement. The quality of the friction data obtained by a Grip-Tester seems to be somewhat sensitive to the test speed, because the GN decreased slightly when the test speed increased from 50 km/h to 70 km/h (31.1 mph to 43.5 mph). This finding implies that keeping the test speed fixed at different test sections is important to achieving comparable results.

This study's statistical analysis findings pointed to a strong positive linear correlation between texture and friction in pavements. The highest linear correlation coefficients (R) were observed between the GNs obtained at 70km/h (43.5 mph) and texture data obtained using either the LLS or the CTM. The authors of this study recommend running the Grip-Tester at higher speeds in cases when the texture-friction relationship analysis is the point of interest. As a further recommendation, accurate friction prediction models could be developed based on the texture measurement data to eliminate the need for direct friction measurement.

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