Road Surface Texture Evaluation with 3-D Laser Data

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ABSTRACT

Road surface friction reduces the number of roadway crashes and is a desirable road surface characteristic. In this study, road surface characteristics were assessed using the Laser Crack Measurement System (LCMS) (three dimensional laser profiler) and ASTM Locked Wheel Skid Trailer. Data was collected on pavements with different surface types. Finally the correlation between the skid number and the texture depth was investigated so that the traditional skid trailer can be supplemented by LCMS for routine skid monitoring. Results show that a good correlation exists between skid number and texture depth at the project level. However, at the network level, skid number did not correlate well with the texture depth.

Keywords: Pavement Surface Texture, LCMS, Skid Resistance, Surface Friction

1. INTRODUCTION

Friction on in-service roads is integral to ensuring safe highway network. Road surface friction helps minimize skidding and reduces the number of crashes. According to the Federal Highway Administration (FHWA), 371,104 fatal crashes occurred in the United States between 2000 and 2009. Ninety percent of those crashes were due to reduced pavement friction (*1*). Therefore, pavement friction must be improved to ensure safety. Since this friction is a function of surface texture, assessment of roadway texture characteristics is essential (*2*).

Surface texture is formed by the irregularities on a pavement surface that deviate from an ideal, perfectly flat surface. A three-dimensional (3-D) profiler precisely measures surface texture to describe pavement texture characteristics. Texture depth of the pavement or the Mean texture depth (MTD) is generally calculated to estimate average vertical height of the pavement surface texture. Although the sand patch test method is most commonly used to determine MTD of pavement surfaces (*3*), Laser Crack Measurement System (LCMS) is more precise and safer because it can be operated at posted highway speeds (*4*).

An ASTM locked-wheel skid trailer (LWST) is universally used to determine road surface friction characteristics. LWST measures pavement skid number (SN). The driving speed of a vehicle should be 64 km/h (40 mph) for skid number determination, but maintaining constant speed is difficult, especially on curves and ramps (*5*). However, because pavement surface friction is a function of surface texture, estimation of texture characteristics could provide useful information about the friction condition on the roadway.

KDOT collected network-level pavement surface texture data using LCMS in 2014 as part of their friction management program. Sixteen thousand kilometer (10,000 miles) of road surfaces were surveyed in this program. The collected pavement monitoring data were stored in the KDOT pavement management information system database. The database contained 2.3

million MTD data points for 11,650 roadway sections. In addition, average skid number (SN_{40}) measured by the ASTM E274 skid trailer was also available for 1,100 roadway sections.

2. STUDY OBJECTIVE

This objective of this study was to assess whether skid resistance on different Kansas Department of Transportation (KDOT) highways can be evaluated using LCMS measurements. In addition the correlation between skid number and texture depth was investigated so that the traditional skid trailer can be supplemented by LCMS for routine skid monitoring.

3. TEST METHODS

3.1 Laser Crack Measurement System

The LCMS consists of two high performance 3-D laser profilers that measure complete transverse road profiles with 1-mm resolution at highway speed. The z-axis resolution is 0.1 mm. The 3D laser profilers that use high power laser line projectors, custom filters and a camera as the detector. The light strip is projected onto the pavement and its image is captured by the camera. The shape of the pavement is acquired as the inspection vehicle travels along the road using a signal from an odometer to synchronize the sensor acquisition. All the images coming from the cameras are sent to the frame grabber to be digitized and then processed by the CPU. Saving the raw images would imply storing nearly 30Gb per kilometer at 100 km/h but using lossless data compression algorithms on the 3D data and fast jpeg compression on the intensity data brings the data rate down to a very manageable 20Mb/s or 720Mb/km (Laurent et. al Undated). The high resolution 3-D data acquired by LCMS is then processed using proprietary algorithms that were developed to automatically extract crack data including crack type (transverse, longitudinal, alligator) and severity, rutting (depth, type), potholes and raveling. LCMS can be operated under various types of lighting conditions and on various pavement types (Laurent and Hebert, 2002). A data analyzing software analyzes data and reports mean texture depth (MTD) values of five standard AASHTO bands (center, right, and left wheel paths and outside bands) (*6*).

3.2 Locked Wheel Skid Trailer

LWST, which measures steady-state friction force, contains a locked wheel that is dragged under constant load at a constant speed over a wet pavement. After the test wheel has been sliding on the pavement after a certain distance to stabilize the temperature, the friction force is recorded for a specified time. The results are reported as Skid Number (SN):

$$SN= (F/W) * 100.$$

where, W = weight and F = tractive force.

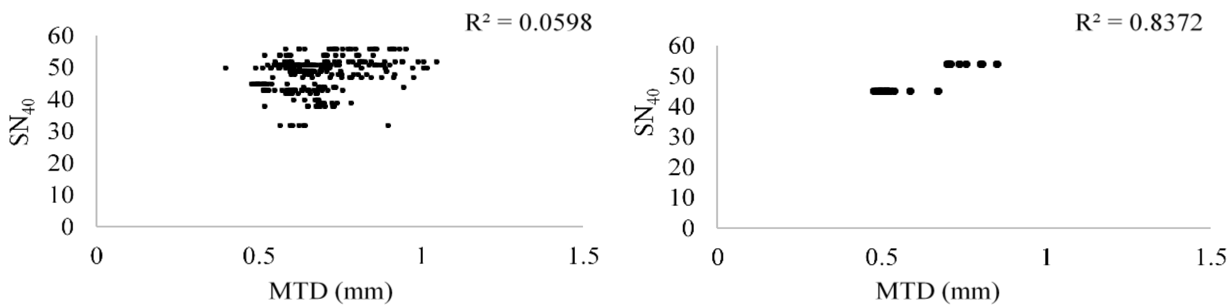
Two types of tire (ribbed and smooth) per ASTM E 274 are used to measure skid numbers on roadway surfaces (Henry, 2000). High skid numbers represent greater skid resistance (7The LWST can be operated near posted highway speed and can take measurements on longer stretch of roadway without causing lane closures.

4. RESULTS AND DISCUSSIONS

In this study, surface texture depth and skid number of five different surface types were examined. KDOT measures skid number (SN) for a project and then stores average SN for every one-mile segments. In order to compare SN with MTD, MTD values on all locations of the corresponding one-mile road segments were averaged and plotted against average SN values to determine possible correlation between SN and MTD.

4.1 Roadways with PCC surface

Fifty two highway sections with Portland cement concrete (PCC) surface type were selected under this category. Surfacing age of these sections ranges from two to fourteen years. Figure 1 shows network-level and project-level relationships between MTD and SN for these surfaces.



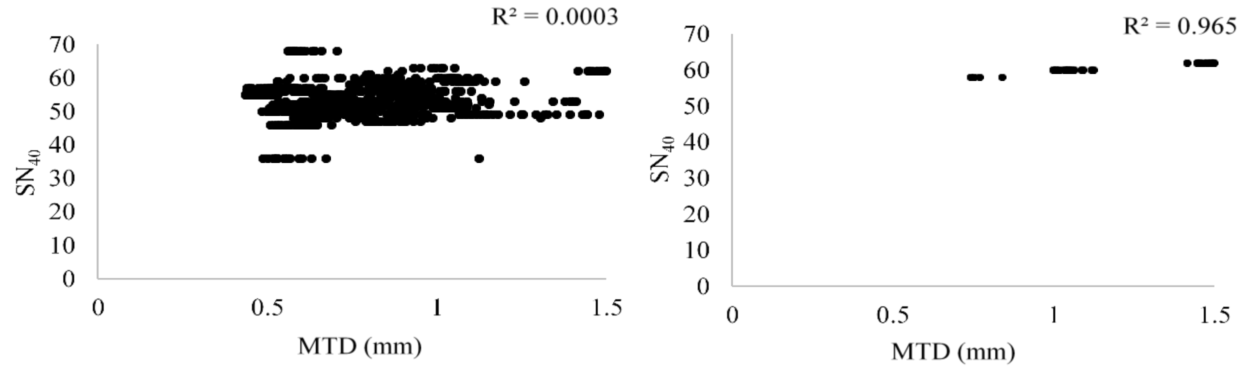
(a) (b)

FIGURE 1 Relationship between MTD and SN_{40} for PCC surface at (a) network level and (b) project level

The correlation between texture depth and skid number appeared to be poor at the network level for the PCC surface. The relationship was evaluated again with data on projects from individual counties. The coefficient of determination, R^2 for MTD vs. SN relationship improved dramatically. This indicates LCMS data can be used in monitoring pavement friction at the project level for the PCC pavements.

4.2 Roadways with SR-12.5A surface

Fifty four sections with SR-12.5A Superpave mix were selected for this study. SR-12.5A is a finely graded overlay mix which is generally placed at 2-inch (50 mm) thickness. Nominal maximum aggregate size of this surface mix is ½ inch (12.5 mm). Surfacing age of the selected sections ranges from two to seven years. Figure 2 shows network-level and project-level relationships between MTD and SN for these surfaces. A good correlation was found between skid number and texture depth at the project level.

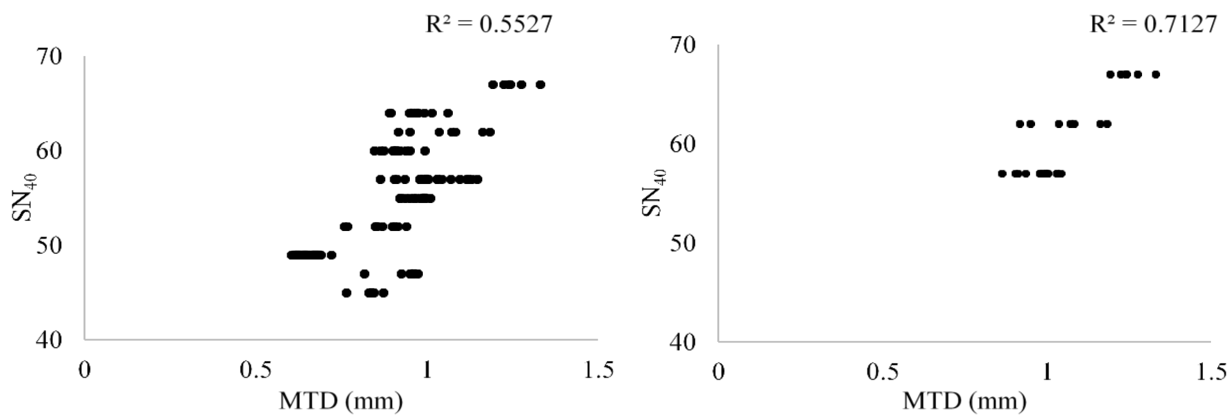


(a) (b)

FIGURE 2 Relationship between MTD and SN_{40} for SR-12.5A surface at (a) network level and (b) at project level

4.3 Roadways with SM-9.5A surface

SM-9.5A is a finely-graded Super-pave surface mix which is generally placed at 1 ½-inch (40 mm) thickness. The nominal maximum aggregate size is 3/8 inch (9.5 mm). Forty roadway sections were selected in this category. Surfacing age of these sections varies from two to ten years. Figure 3 shows network-level and project-level relationships between MTD and SN for these surfaces.



(a) (b)

FIGURE 3 Relationship between MTD and SN_{40} for SM-9.5A surface at (a) network level and (b) at project level

The coefficient of determination, R^2 for MTD vs. SN relationship is higher at the project level when compared to the network level. However, for SM-9.5A, the network-level relationship between MTD and SN appeared to be strong.

4.4 Roadways with chip seal surface

Fifty nine sections with chip seal were selected under this category. This type of surface includes spraying asphalt material (asphalt cement or emulsified asphalt) followed by a thin aggregate cover. Surfacing age of these chip seal sections varies from two to seven years. Figure 4 shows the network-level and project-level relationships between MTD and SN for these surfaces.

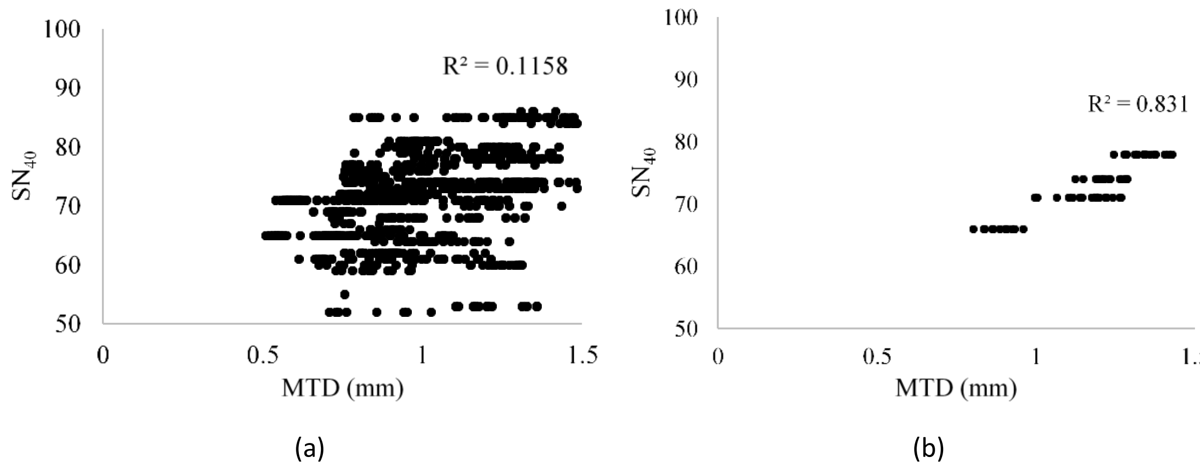


FIGURE 4 Relationship between MTD and SN_{40} for Chip Seal surface at (a) network level and (b) project level

The correlation between texture depth and skid number appeared to be poor at the network level for chip seal surfaces. However, a good correlation was found between skid number and texture depth at the project level.

4.5 Roadways with UBAS surface

Ultra-thin bonded asphalt surface (UBAS) is a thin gap-graded hot mix asphaltic surface which is bonded to the existing surface with a polymer-modified emulsion membrane. Forty five highway sections were selected under this category. Surfacing age of these sections varies from two to nine years. Figure 5 shows the network-level and project-level relationships between MTD and SN for this surface type. A good correlation was found between skid number and texture depth at the project level.

In this study, surface texture depths of five different surface types were examined. In order to assess, how texture depth varies across different surface types, MTD values were plotted against surfacing age. Figure 6 shows the texture depth of different surface types with respect to the surfacing age. In general, PCC surfaces have the lowest MTD and UBAS has the highest.

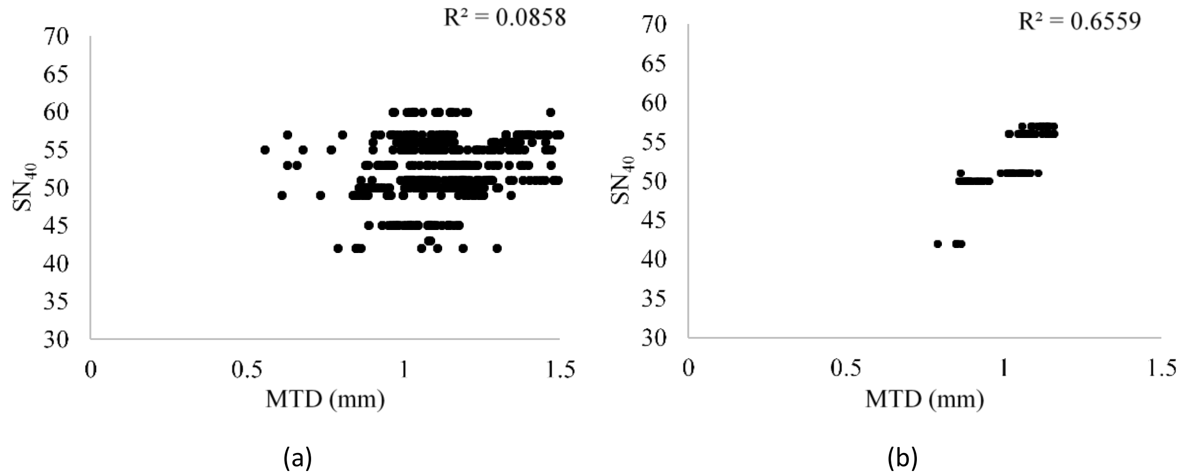


FIGURE 5 Relationship between MTD and SN_{40} for UBAS surface at (a) network level and (b) project level

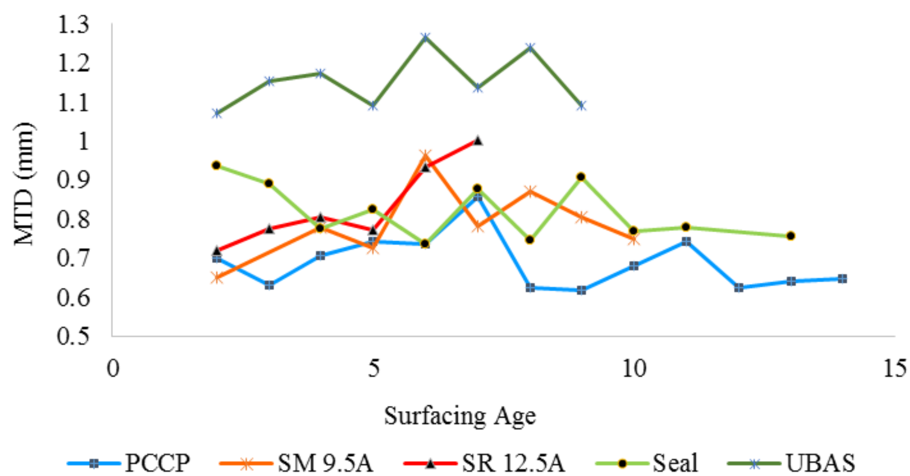


FIGURE 6 MTD measurements on different surfaces with different surfacing age

5. CONCLUSIONS

Pavement texture can provide valuable information about frictional characteristics of pavement surface. However, because each test method provides unique results, comparative testing must be conducted and relationships must be developed among various test outputs. Texture measurements were collected using the LCMS and friction data were collected using the LWST. Five surface types were used for this study. The following conclusions can be drawn:

- Texture depth and skid number vary with pavement surface types
- Surface texture depth did not correlate well with the skid number at the network level for projects with the same surface type. However, the correlation between these parameters at the project level is promising. This indicates that pavement surface friction can be monitored using LCMS data

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