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Evaluation of pavement skid resistance using high speed texture measurement

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ABSTRACT

Skid resistance is an important parameter for highway designs, construction, management, maintenance and safety. The purpose of this manuscript is to propose the correlation between skid resistance, which is measured as skid resistance trailer, and mean profile depth (MPD) or the macro surface texture, which is measured by vehicle mounted laser, so that highway agencies can predict the skid resistance of pavement without the use of expensive and time consuming skid resistance trailer, which also causes disruption of traffic in use. In this research skid numbers and MPD from 5 new asphalt pavements and 4 old asphalt pavements were collected using a locked wheel skid trailer and a vehicle mounted laser. Using the data collected, a correlation between the skid number (SN40R) collected by locked wheel skid tester and the texture data or MPD collected by a vehicle mounted laser operating at highway speeds was developed. The proposed correlation for new pavements was positive for MPD values less than 0.75 mm to reach a peak SN40R value, then there was a negative correlation as the MPD increases until the MPD value was equal to 1.1 mm and beyond the MPD value of 1.1 mm to the maximum value of 1.4 mm, SN40R value remained almost constant. There were significant data scatter for the MPD value of 0.8 mm. To explain these results, water film thickness during the friction test was calculated and the critical MPD was defined. The effect of sealed water pool on the SN40R was discussed. The test result showed a similar trend for older asphalt pavements, but with lower SN40R values due to the polishing of pavement micro-texture by traffic. Hence, a reduction factor was proposed for older pavements based on cumulative traffic volume for the above correlation to predict the skid resistance of older pavements.

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1. Introduction

Literature search shows that when pavements are wet, accidents occur at a rate of 3.9–4.5 times that on dry pavements (NTSB, 1980). The skid resistance alone cannot predict the accident rates since many other factors contribute to accidents, including pavement condition state, prevailing speed, and traffic volume (Henry, 2000; Kuttesch, 2004). However, there is statistically significant correlation between skid resistance and wet accident rate, and the wet accident rate increases with decreasing skid numbers (Kuttesch, 2004). Cairney (1997) and Giles et al. (1965) found that the risk of a skid related crash was small when friction values was above 60 but increased rapidly with skid resistance values below 50. Meanwhile, McCullough and Hankins (1966) recommended a minimum desirable friction coefficient of 0.4 measured at 50 km/h (30 mph) from a study of 571 sites in Texas. Their study examined the relationship between skid resistance and crashes, and found that a large proportion of crashes occurred with low skid resistance and relatively few occurred with high skid resistance. Several transportation agencies have developed specified road friction threshold values that define the lowest acceptable road friction condition after which surface restoration will take place. For example, Maine, Washington, and Wisconsin use 35, 30, and 38, respectively, as their cutoff values (Henry, 2000). Tighe et al. (2000) identified the pavement engineering relationships associated with road safety, and incorporated it to pavement management. Recently, tire pavement skid resistance, especially the wet skid resistance, has been recognized as an important parameter used in network surveys for pavement management, evaluation of surface restoration, specifications for new construction, accident investigations, and winter maintenance on highways etc. However, what is still not known is the exact mechanism, which causes the decrease in pavement friction when a film of water covers the road surface and the effect of pavement surface texture on it. As a result, efforts in better understanding of effect of pavement texture, and its incorporation in the pavement safety equation appears to be a promising direction (Noyce et al., 2007).

Wet skid resistance can be measured directly through full-scale friction measuring devices such as locked wheel trailer conducted in accordance with ASTM (2003a). In this method, a rib or smooth tire is towed at 40 mph. The wheel is locked and allowed to slide for a certain distance, usually the left wheel path in the tested travel lane. The operator applies the brakes and measures the torque for 1 s after the tire is fully locked to compute the correspondent friction value. The measurement is reported as skid number or SN40R and defined as the traction force divided by the dynamic load on the tire. Customarily it is multiplied by a constant (100) (ASTM, 2003a), as indicated below.

$$\mathrm{SN} = 100\left(\frac{F}{W}\right) \tag{1}$$

where F is the traction force applied to the tire at the tire pavement contact, W is the dynamic vertical load on the tire, and SN is the skid number. The characters 'S' and 'R' in 'SN40S' and 'SN40R' represent the smooth tire and the rib tire, respectively. According to the research completed by the Florida Department of Transportation, the rib tire provides skid measurements that are better indicators of safety than measurements by smooth tires (Henry, 2000). Hence in this research rib tires (ASTM) are used and as a result, SN40R values are reported.

Skid resistance between tire and pavement interface has 2 major components, namely, adhesion and hysteresis (Cairney, 1997). Adhesion results from the shearing of molecular bonds formed when the tire rubber is pressed into close contact with pavement surface. These interactions are often dominated by weak Van der Waals forces. Hysteresis results from energy dissipation when the tire rubber is deformed and passed across the asperities of a rough pavement surface. On very rough surfaces, the substrate asperities exert pulsating forces onto the rubber surface which, because of its high internal friction at the appropriate frequencies, results in a large dissipation of energy. The adhesive contribution to rubber friction is much smaller for smooth surfaces, mainly because of the small contact area.

The 2 components of skid resistance are related to the 2 key properties of asphaltic pavement surfaces, that is micro-texture and macro-texture. Micro-texture is a surface texture irregularity which is measured at the micro scale of harshness and is known to be a function of aggregate particle mineralogy for given conditions of weather effect, traffic action and pavement age, while macro-texture refers to the large-scale texture of the pavement as a whole due to the aggregate particle arrangement, which controls the escape of water under the tire and hence the loss of skid resistance at high speeds (RTAC, 1977).

Micro-texture values are commonly estimated using low speed friction measurement devices such as the British Portable Tester (BPT), the Dynamic Friction Tester (DF Tester), and the locked wheel skid trailer operating at low speeds (Wambold and Henry, 1995). These measurements always disturb or disrupt the traffic flow. Macro-texture measurements can be divided into 2 main classes, static measurements and dynamic measurements. Common static macro-texture measurement methods include the sand patch method, the outflow meter, and the Circular Texture Meter (CTM). The dynamic measurements are conducted by vehicle-mounted laser devices, which can collect data at highway speeds. As a result, vehicle mounted laser texture measurement is a promising method for collecting macro-texture data of pavement. Flintsch et al. (2003) and McGhee and Flintsch (2003) correlated CTM measurement and Sand Patch Test, and found a strong correlation.

As mentioned before, skid resistance can be measured directly by locked wheel trailer. However, this method is very expensive and disturbs the traffic flows during the test. So it is not a practical and economical method to continually monitor road surface. The surface macro-texture is a predominant contributor to wet-pavement safety (Anderson et al., 1998; Mahone, 1975) and a coarse macro-texture is very desirable for safe wet-weather travel as the speed increases (Galambos et al., 1997) while the micro-texture and adhesion contributions to skid resistance are just the prevailing