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Evaluation of pavement surface friction subject to various pavement preservation treatments

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HIGHLIGHTS

- Investigate effectiveness of pavement preservation on friction.
- Consider four preservation treatments (thin overlay, chip seal, crack seal, and slurry seal).
- Investigate variation of friction subject to material, traffic, and environmental factors.
- Aid state agencies making better pavement maintenance decisions.

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ABSTRACT

This study compared the effectiveness of preservation treatments on pavement surface friction and investigated the long-term variation of friction using the data collected in the Specific Pavement Studies-3 (SPS-3) of the Long Term Pavement Performance (LTPP) program. The SPS-3 focuses on the effect of four preservation treatments (thin overlay, chip seal, crack seal, and slurry seal) on pavement performance under five design factors (traffic, precipitation, temperature, existing pavement condition, and subgrade type). Both the simple ranking method and statistical methods (boxplot and Fisher's Least Significance Difference test) were used to compare the effectiveness of preservation treatments on friction improvement. The statistical analysis results indicate that slurry seal causes significantly greater friction number compared to the control section; and the ranking from high to low based on the average friction number among four preservation treatments is: slurry seal, chip seal, thin overlay and crack seal. Among the five design factors, subgrade type and existing pavement condition show less influence on pavement friction compared to climate and traffic factors. Stepwise regression analysis was conducted to quantify the influence of various factors (material, traffic, temperature, precipitation, and freezing index) on the long-term variation of pavement friction within the monitoring period. It was found that the application rate of slurry seal and chip seal affected the friction variation and temperature showed negative correlation with friction. In addition, pavement roughness was found having certain correlation with friction for the control sections and the sections with crack seal.

1. Introduction

Adequate friction (skid resistance) generated at the tire–pavement interface is a significant contributing factor to reduce the risk of road accidents and improve public safety. Higher pavement friction can decrease vehicle braking distance and prevent vehicle-related crashes. However, pavement friction performance deteriorates with time under repeated traffic loading and due to environmental effect. The evolution of pavement surface friction varies with age, traffic, temperature, distress, wet/snow/ice condition, and contamination, among other factors [1]. Therefore, it is important to continuously monitor pavement friction and understand the long-term friction degradation for highway safety management. This would help developing effective pavement maintenance practices in providing good skid resistance over the total pavement service life.

Pavement preservation (or preventive maintenance) is a cost-effective maintenance activity, which includes treatments that are applied to pavements mainly to prevent distress development and restore pavement serviceability. Preservation activities are focused mainly on improving pavement functional performance and prolonging pavement life. It can seal cracks and other distress in the pavement and prevent moisture from penetrating into the base or subgrade layers. However, pavement preservation does not have a direct improvement of pavement structural capacity as pavement rehabilitation does.

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The Long-Term Pavement Performance (LTPP) program is a 20-year study of in-service pavements in the US and Canada. Its goal is to extend the life of pavements through various designs of pavement structures using different materials and under different factors such as precipitation, traffic, temperature, subgrade soil, or maintenance practices. The Specific Pavement Studies-3 (SPS-3) experiment in the LTPP program was designed in 1990 to evaluate the effectiveness of preservation options and to decide the cost-effective methods for applying preservation treatments for flexible pavements [2]. It provides large amounts of data that can be utilized to analyze the effectiveness of preservation on pavement performance. A number of studies have been conducted using the LTPP SPS-3 data to investigate the effectiveness of preservation treatment on the development of pavement distress (fatigue cracking and rutting) and roughness [2–5]. However, few studies considered the effectiveness of preservation on restoration of pavement surface friction that is an important component of pavement functional performance.

1.1. Background on pavement friction

Pavement friction is a complex phenomenon and affected by many factors, including material, traffic, and environment. For example, pavement surface properties such as aggregate sizes, gradation, asphalt binder content, produce different macro- and micro-texture that attribute to the variation of friction at different speeds after cumulative traffic passing. It has been established that good micro-texture is important for pavement friction at low speeds and good macro-texture is more important at high speeds [6,7].

Many environmental aspects influence pavement friction, such as rainfall, snowfall and temperature. Previous studies concluded that when the friction testing was conducted in wet regions, the water film may cover the pavement surface and act as a lubricant, which can reduce the contact between the tires and surface aggregate. This is one of the reasons why wet-pavement surfaces exhibit lower friction than dry pavement surfaces [8]. Some researchers attributed the seasonal variation of friction to rainfall. The reason is that the rainfall is low and the evaporation rates are higher in the spring and early summer, which may impair the function of rainwater to remove lubricating agents and contaminants on the surface of roadway [9]. On the other hand, McDonald et al. [10] found that the contribution of snowfall removal and winter weather highway operations to the seasonal variation of pavement friction is relatively negligible compared to the effect of temperature [10].

Most previous studies agree that air temperature affects flexible pavement friction because both the tire rubber and the asphalt mixture are viscoelastic materials. The variation of viscoelastic modulus due to temperature change will affect the contact mechanism at the tire-pavement surface. Flintsch et al. [11] found that both friction parameters (friction number at zero speed – SN_0 and percent normalized gradient – PNG) in the Penn State model tended to decrease when the pavement surface temperature increased. Additionally, the temperature effects on the friction number were relevant to the testing speed [11]. Bazlamit and Reza [12] showed that the hysteresis component of friction decreased with the increasing temperature whereas the adhesion component increased with the increasing temperature and had a high influence on the overall friction. They proposed an equation to adjust the friction numbers measured at different temperatures where every 1 °C below 20 °C caused 0.2 unit of increase in friction number compared to the friction number at 20 °C [12]. Similarly, another study concluded that every 1 F below 80 F caused 0.08 unit of increase in friction number compared to the friction number at 80 F [13].

1.2. Pavement preservation treatments in LTPP

There are a number of preservation treatments for flexible pavements, such as cape seal, chip seal, slurry seal, microsurfacing, crack seal, and fog seal [14]. On the LTPP SPS-3 sites, four major preservation treatments were used: thin overlay, slurry seal, crack seal and chip seal.

The slurry seal is a mixture of emulsified asphalt, well-graded fine aggregate, water and mineral filler that has a creamy fluid-like appearance when applied. As a hard wearing surfacing for pavement preservation, slurry seal can be used for sealing aged pavements, filling minor cracks, restoring skid resistance and enhancing aesthetic appearance.

Chip seal is the application of bituminous binder immediately followed by the application of aggregate. The aggregate is then rolled and embed into the binder. Multiple layers may be placed and different types of binder and aggregate can be used to address specific distress or traffic situations.

Crack seal requires thorough crack preparation and often requires the use of specialized high quality materials placed either into or above working cracks to prevent the intrusion of water and incompressible materials. The sealants in crack seal are typically bituminous materials that soften upon heating and harden upon cooling. Its main purpose is to prevent the intrusion of moisture through existing cracks.

Thin overlays are generally used with a relatively high cost compared to other preservation treatments. The purposes are to improve pavement surface condition, protect pavement structure, reduce the pavement deterioration rate, correct surface deficiencies, reduce permeability, and improve the ride quality of the pavement.

2. Objective and scope

This study intends to utilize the available friction monitoring data in LTPP SPS-3 sites to statistically analyze the variation of pavement surface friction subject to different preservation treatments. The objectives of this study are to:

(1) Evaluate the effectiveness of four pavement preservation treatments (chip seal, slurry seal, crack seal and thin overlay) on friction performance improvement.
(2) Identify the influence of climate (temperature and precipitation), traffic, subgrade type, and existing pavement condition on pavement friction performance.
(3) Develop a long-term friction variation model considering the combined effects of material, climate and traffic loading;

3. Data collection in LTPP database

In the LTPP program, there are totally 81 SPS-3 sites distributed in the US and Canada. Among these sites, the friction monitoring data are available in the 53 sites because the collection of friction data in LTPP is voluntary for agencies. At each site four preservation treatments (thin overlay, slurry seal, crack seal and chip seal) are implemented continuously on the pavement sections with the average length of 500 ft in addition to the control section. Therefore, the pavement sections with preservation treatments and the control section have the same climate and traffic conditions. To consider the major design factors influencing pavement performance, the experiment sites in the LTPP are specifically divided into 11 categories. The design factors for dividing categories include climate (precipitation and temperature), pavement structure (subgrade type and existing pavement condition) and traffic loading as defined by LTPP program [2]. The number of sites in each