Joint Transportation Research Program

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Investigation of Durability and Performance of High Friction Surface Treatment

Introduction

High friction surface treatment (HFST) is increasingly being used to reduce vehicle crashes at friction-sensitive locations. Nevertheless, several major issues have remained unsolved.

- The epoxy-resin binder for HFST is commonly produced in accordance with the requirements for applications to Portland-cement concrete (PCC). Concerns may arise about its applications to hot-mix asphalt (HMA) that affects not only the reflective distresses in HFST but also the bonding at the HFST-HMA interface.
- The friction performance of HFST relies on its surface characteristics. An efficient method is needed to timely determine catastrophic drop in HFST's surface friction due to immediate and excessive loss of aggregate.
- The Indiana Department of Transportation (INDOT) conducts the locked wheel skid tester (LWST) friction testing using the standard smooth tire. However, the friction requirement in the current unique special provision (USP) for HFST by INDOT was defined in terms of the standard rib tire.
- Determining the cost-effectiveness or crash modification factor (CMF) of HFST requires field friction and vehicle crash data. Although there are a few CMFs for HFST reported by other states, a state-specific CMF would allow INDOT to address the state's specific features and utilize safety dollars more efficiently.

This study attempted primarily to investigate the durability and performance of HFST in terms of its system integrity and surface friction. The other objectives included (1) determining the physical and mechanical properties of HFST epoxy-bauxite mortar; (2) investigating the mechanical behaviors of interaction between HFST and the underlying pavement (especially chip seal); (3) examining the variation of surface friction characteristics of HFST over time; and (4) developing CMF from INDOT's HFST initiative projects.

This study performed a comprehensive investigation of the above-mentioned issues based on a total of 25 HFST projects completed in 2018, including 21 projects in an HFST initiative program to address horizontal curves crashes and 4 projects in a pavement resurfacing program. The main tasks completed by the research team included (1) extensive laboratory tests for determining the physical and mechanical properties of HFST epoxy-bauxite mortar; (2) field inspections for identifying early HFST distresses and their mechanisms; (3) laboratory cyclic loading tests and finite element method (FEM) analysis for evaluating the interface bonding and pretreatment for the existing pavement; (4) field friction and texture tests for determining the friction metrics; and (5) analysis of crash data for identifying the CMF for HFST.

Findings

Key findings are summarized as follows:

- HFST epoxy-bauxite mortar properties. An epoxy binder content of approximately 15.9% may be appropriate for making specimens for determining the physical and mechanical properties of the HFST epoxy-bauxite mortar. HFST epoxy-bauxite mortar has a bulk specific gravity of 2.31, a Poisson's ratio of 0.29, and a coefficient of thermal expansion (CTE) of 21.3×10^{-6}/°F (37.72×10^{-6}/°C). The CTE of HFST is significantly higher than those of HMA and PCC, which implies that thermal incompatibilities will arise between HFST and the underlying HMA or PCC pavement.
- Most common early distresses in HFST. The most common early HFST's distresses are reflective cracking, aggregate loss, delamination at the interface of chip seal-HMA pavement beneath HFST, and surface wrinkling (slippage). Any discontinuities in the existing pavement surface, including cracks, pothole patches, and repair patches, will reflect through HFST. The above may imply that there are tangible benefits to placing HFST on new pavements. Aggregate loss is likely to occur in an HFST when the existing pavement is pretreated by scarification milling due to insufficient epoxy binder, HFST installation at low temperatures, or both. Delamination at the chip seal-HMA interface tends to occur when the chip seal surface is pretreated by scarification milling. Surface wrinkling tends to occur due to the combined effect of large traffic loads, low temperature installation, and steep superelevation.

- Existing pavement surface preparation and effects. The MPD of HFST is independent of the methods for pretreating the existing pavement. Scarification milling does not necessarily increase the MPD of HFST surface. Scarification milling produces large valleys and peaks in the treated surface, which will result in stress concentration and increase interlaminar stresses. The bonding strength with scarification milling can be 18.6% lower than that with shotblasting in the tire-pavement contact area. The results of finite element method (FEM) analysis show that shotblasting tends to increase the possibilities of higher interlaminar stresses than vacuum sweeping. No conclusive evidence exists to show that vacuum sweeping, shotblasting, or scarification milling can outperform any of the others in terms of the mitigation of reflective cracking.
- Determination of crash modification factor (CMF) for HFST. The CMF of HFST (i.e., 0.701) calculated from before-and-after crash data is close to the CMF (i.e., 0.696) derived from the crash prediction model developed in terms of curve geometrics, pavement friction, and annual average daily traffic (AADT). The zero-inflated negative binomial model developed for vehicle crashes on curves can be used both to estimate the effects of pavement friction, curve radius, or both on safety performance and to identify highly risky curves and facilitate safety engineers to implement countermeasures efficiently.
- HFST friction metrics and field testing. Great variability may arise in the results of friction tests on horizontal curves measured by the use of the LWST method due to the nature of vehicle dynamics and the operation of test vehicle on horizontal curves. Texture testing is capable of providing continuous texture measurements such as the mean profile depth (MPD) that can be used to evaluate friction performance and implement quality control (QC) and quality assurance (QA) plans for HFST.

Implementation

The test results and research findings can be implemented to enhance the durability and safety effectiveness of HFST as follows:

- Installation temperature. Curing epoxy binders at low temperatures will not only increase the cost for traffic control but also the variation in the property of the epoxy binder system, thereby affecting the durability of HFST. It is recommended to install HFST at the higher end of the temperature range recommended by suppliers.
- HFST epoxy-bauxite mortar specimen. The empirical relationship below can be utilized to estimate the binder content for fabricating epoxy-bauxite mortar specimens:

  $$R = R_0 + (1.755 + 0.090\text{MPD})$$

  where R is the approximated content of epoxy binder, percent by mass; R_0 is the supplier's recommended binder application rate, percent by mass; and MPD is the mean profile depth of HFST.
- Existing pavement surface preparation. The cracks in the existing pavement should be filled prior to the installation of HFST. Cracks reflected through the HFST should be sealed timely to slow the deterioration of cracks. Chip seal in good condition will not affect the durability of HFST in terms of interface bonding strength. Scarification milling does not necessarily provide better interface bonding between HFST and chip seal. Vacuum sweeping and shotblasting, respectively, are recommended as an effective method for pretreating chip seal and new HMA pavement.
- Friction performance and testing. To ensure the durability of HFST, friction or texture testing should be performed 3 months after installation. Field testing right after installation may identify potential problems when corrective actions can still be taken. The requirements for HFST QC/QA can be defined in terms of surface friction, texture, or both as follows:

Time	Friction Number (FN)	Mean Profile Depth (MPD) (mm)
New	83	1.9
3 Months	83	1.2

- CMF determination. A CMF of 0.70 is recommended for use in estimating the safety effectiveness of HFST by INDOT.

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