Identification of Laboratory Techniques to Optimize Superpave HMA Surface Friction Characteristics

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RESEARCH PROJECT TITLE

Identification of Laboratory Technique to Optimize Superpave HMA Surface Friction Characteristics

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Laboratory techniques can be used to predict and compare friction values of asphalt pavements of various types with differing aggregate combinations.

Introduction

When designing a pavement surface, engineers must strive to balance several competing parameters, including load capacity, durability, ride quality, construction and maintenance costs, as well as safety and traffic noise. While most of the above parameters can be achieved by using proper materials and construction techniques, current design methodologies do not routinely address friction and texture control. Adequate pavement friction is of paramount importance in reducing the number of collisions, especially on wet pavements.

Pavement friction is primarily a function of the surface texture, which includes both micro- and macrotexture. Pavement microtexture is a function of the surface texture of the aggregate particles and provides a gritty surface that disrupts the continuity of the water film and produces frictional resistance between the tire and pavement. Macrotexture is determined by the overall properties of the pavement surface and provides surface drainage channels for water expulsion from the contact area between the tire and pavement.

Objectives

Due to limited availability of high friction aggregates in some areas, there is a need to combine them with locally available materials that may have lower polishing resistance. The main objective of this research was to evaluate various blends of aggregates to optimize the combination of micro- and macrotexture to achieve a desired level of friction. The goal was to maintain the currently provided level of friction while reducing the reliance on the microtexture provided by special friction aggregates, if possible, by increasing the mixture macrotexture.

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To achieve this primary objective, a secondary objective was necessary; that is, to identify an accelerated method for polishing or abrading samples and measuring their surface friction characteristics.

Another objective was the development of preliminary procedure for determination of an International Friction Index (IFI)-based flag value that can be used as a baseline indicator for laboratory friction measurements. In addition, field investigation of the relationship between traffic volume and changes in the friction values was also undertaken in this study.

Research Approach

The scope of this study included the investigation of the relationship between mixture composition and the following pavement characteristics: surface texture, friction and polishing resistance. Based on the relationship between texture and friction, an International Friction Index (IFI)-based flag friction value was developed to serve as a reference point for laboratory type testing.

This study involved laboratory testing of various aggregate gradations (fine, s-shaped and coarse) and aggregate sizes (9.5 mm and 19 mm Nominal Maximum Aggregate Size, NMAS) of Superpave mixtures. Aggregates commonly used in HMA in the north central region of the USA (natural sand, dolomite and two types of limestones) were combined with different percentages (from 0 to 70%) of two high friction aggregates (quartzite and steel slag) to produce the mixes used in the study. In addition, one stone matrix asphalt (SMA) and one porous friction course (PFC) mix were also tested.

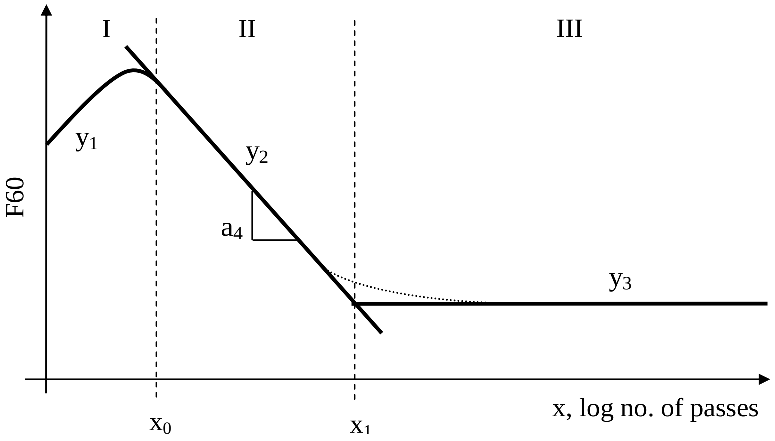
Friction and texture measurements were conducted on 50 laboratory-prepared and polished HMA slabs. These included 46 slabs prepared using Superpave mixtures, two slabs prepared using an SMA mixture and two slabs prepared using a PFC mixture. In order to obtain frictional resistance curves, measurements were performed after compaction of the slabs and periodically during the slab polishing cycle. Laboratory texture and friction tests were conducted using the Circular Track Meter (CTM) and Dynamic Friction Tester (DFT) devices, respectively.

In addition to the laboratory tested slabs, the field friction and texture data were collected from 25 sites on existing highways and test track sections. These data were used to obtain the friction baseline values. Field measurements were conducted using the CTM, DFT and ASTM E 274 towed friction trailer. The field test sites included Superpave designed HMAs, Marshall designed HMAs, PFC, SMA and concrete (tined and smooth) pavements. Using these field data and recommendations found in the literature, the IFI flag value was determined.

Laboratory devices used to assess friction.

Key Findings

- A new laboratory testing methodology was developed and refined during this study that allows for determination of two crucial properties for characterizing and predicting pavement friction: polishing rate and terminal friction value. The Circular Track Machine (CTM) together with a Dynamic Friction Tester (DFT) can be used as a tool to assess the micro- and macrotexture of a mix and then to calculate the frictional properties (F60) of various pavement surfaces. A Circular Track Polishing Machine (CTPM), refined in this study, may be used for the laboratory simulation of the polishing action of highway traffic. In the future, a mixture approval procedure involving determination of the predicted polishing rate and terminal friction values for a given mixture could be used to evaluate the mixture frictional properties.
- The research proved that it is possible to modify frictional properties of the pavement by changing the aggregate type and HMA composition.
- Increasing the friction aggregate (quartzite or steel slag) content substantially improved the polishing resistance of HMA mixes. In general, mixes with steel slag generally exhibited slightly higher polishing resistance (lower polishing rate) than mixes with quartzite.
- In general, the mixes with soft limestone exhibited lower friction values than those with dolomite and hard limestone.
- When the carbonate aggregates used in this study were blended with high friction aggregates (steel slag and quartzite), the overall friction level generally increased. Increasing the friction aggregate content from 10 to 20% had relatively little effect on the friction level, but friction increased dramatically when the friction aggregate content was increased to 40 or 70%. If friction is to be improved only by adding high friction aggregates to the local carbonate aggregates, the friction aggregate content should be 20% or greater, depending on the amount of improvement needed. There may be, however, other ways of increasing the overall surface friction.
- Larger NMAS sizes are desirable from a frictional point of view, and they should be used where other considerations (such as layer thickness and smoothness, among others) allow.
- An International Friction Index (IFI) based model using the parameters measured with the CTM and DFT during polishing in the CPTM was developed to describe the change in frictional properties under traffic/polishing.
- The International Friction Index parameters (F60 and S_p) can be improved by increasing the pavement macrotexture.
- The value of the fineness modulus (FM) of the aggregate blend correlates well with the pavement macrotexture and thus has a great influence on the pavement frictional properties. Pavement frictional properties can be improved either by using highly polish resistant aggregate (such as quartzite or steel slag) blended with the locally available carbonate rocks or by modifying the aggregate blend in such a way that the FM will be increased. Mixes with FM values of 4.6 or higher generally had high macrotexture and friction levels.



Proposed polishing model.

- Based on the literature findings and field measurements using the ASTM E 274 towed friction trailer (equipped with both rib and smooth tires) and using the CTM/DFT devices, the approximate frictional flag value (F60) was determined.
- Comparison of the range of friction values obtained during the laboratory part of this study with results of the field measurements suggested good correlation between the laboratory measurements and actual

highways conditions. Similarly, measurements with different friction measuring devices showed the same trends in the data.

- Further work is needed to improve the compaction technique for laboratory slabs and to correlate the number of wheelpasses in the CPTM to actual traffic levels. The proposed polishing model should be validated by testing more types of materials under actual field conditions; work has already begun on this effort under another research project involving extensive field testing.

Implementation Notes

- The results of this study resulted in the development of a polishing model. Application of this model to the frictional properties allows for the determination of two crucial polishing parameters for a given mixture: a_4 (polishing rate) and F60@x_1 (terminal friction level). Frictional parameters of a mixture can then be assessed and the decision may be made whether the given mixture meets the desired friction criteria.
- An F60 flag value was estimated based on the current Indiana DOT practice, measurements with CTM/DFT devices and a towed friction trailer, as well as conclusions from a PIARC study [Wambold et al. 1996]. While this value should be further verified, it can be used as a starting point for the lab evaluation of the frictional properties of various HMA mixtures.
- A CTPM machine and test protocol developed in this study are very promising tools to evaluate frictional properties of various HMAs, however, additional field verification of that method is needed.
- The lab compaction method should be further improved so it more closely simulates field construction processes.
- If the use of an aggregate blend consisting mostly of polish susceptible aggregates is desired, the high friction coarse aggregate content should be 20% or greater in the overall aggregate blend. This finding should be further verified by performing field friction measurements of pavements with varying percentages of polishing aggregates.
- Both steel slag and quartzite were found to improve the frictional characteristics of HMA mixes in which they are used. The choice of which high friction aggregate to use should be used based on availability and cost.
- In addition to substituting high friction aggregates for a portion of the polish susceptible aggregates, however, this study showed that the frictional characteristics of the surface can also be improved by changing the value of the fineness modulus (FM) of the surface mix. Based on the limited field observation, in general, HMA blends with a FM of about 4.6 or greater should provide a relatively “deep” pavement macrotexture (MPD above about 0.6 mm).
- In general, the s-shaped gradation resulted in higher MPD (“deeper” texture) and thus improved friction at high speeds.
- One other way to increase the macrotexture of the surface is to use aggregates with larger NMAS sizes. Such mixtures are desirable from a frictional point of view and should be used where other considerations (such as tire pavement/noise, layer thickness and smoothness, among others) allow.