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The development of a predictive tool to reduce experimentation time for the polishing and frictional evaluation of asphalt pavement surfaces

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HIGHLIGHTS

- A tool to predict asphalt pavement surface deterioration is developed.
- The tool successfully predicts the steady state of pavement surface deterioration.
- The onset of steady state of pavement surface deterioration is predicted.
- A reduction of 40% to 50% of experimentation time is achieved.

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ABSTRACT

The laboratory simulation of asphalt pavement surface deterioration is usually a lengthy process. In this study, a predictive tool (or equation) was developed to calculate the steady state torque-based coefficient of friction (Tfr) and the onset of steady state. To this end, nonlinear regression was utilized and a Graphical User Interface (GUI) was built in MATLAB®. The purpose of the tool is to reduce experimentation time. Eight sets of data were used. Data was obtained from laboratory testing conducted on eight Job Mix Formulas (JMFs) of highway materials obtained from the State of Ohio. The data was collected using a power unit (or motor) attached to a newly developed asphalt polishing machine to detect surface deterioration. The experiment measures torque values that are directly related to friction values; the so called torque-based coefficients of friction. The main characteristic of the equation allows for calculating the steady state Tfr and the onset of steady state. This enables the experimenter to determine when steady state is reached at a desired tolerance during the test, thus reducing the time required for testing. It was concluded that testing time can be reduced significantly (a range of 40% to 50% savings), which may be received positively by Departments of Transportation and other highway material testing laboratories around the world.

1. Introduction

Flexible pavements subjected to traffic loading and environmental factors progressively lose surface frictional properties due to tire-pavement interaction. The reduction in skid resistance can be very dangerous to the driving public. During the service life of a pavement, highway agencies are likely to monitor and maintain an adequate surface roughness (texture) to facilitate traction between automobile tires and pavement surface. It is a well-recognized fact that traffic crashes increase as skid resistance values decrease, especially during the wet periods. Moreover, it is statistically proven that a significant portion of fatal crashes on roadways are skid-related. Usually a friction-deficient pavement surface is repaired by applying a new surface layer. This method is considered a passive approach toward the problem; a more proactive approach is certainly warranted.

In general, aggregates with adequate friction characteristics are identified based on historical field performance and aggregate attributes such as mineralogy or frictional properties thru British pendulum numbers. An accelerated laboratory procedure was previously developed to evaluate asphalt mixtures' surface friction rather than aggregates only [1,2]. The full procedure can be completed in less than one day. During which, Superpave gyratory compacted specimens are prepared. After specimen preparation, it is placed on the accelerated polishing machine. The initial friction properties of the specimen's surface are measured before any polishing using ASTM E-303-93 [3]. Afterwards, specimen is subjected to an accelerated rate of polishing by a polishing shoe

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while being pressed against the specimen's surface at a constant load. Friction measurements are taken at intervals of 60 min to determine the surface's friction deterioration curve and residual friction value.

Despite the many available procedures for screening asphalt mixtures in terms of frictional characteristics to ensure acceptable surface characteristics and to control skid-related accidents, they are time consuming and somewhat labor-intensive. Some attempts were made to reduce experimentation time, yet it is still somewhat lengthy. Therefore, it is imperative to improve these procedures to meaningfully shorten test duration to be more practical as viewed by the industry and state and federal agencies as well. This study aims at addressing the development of a new predictive tool to reduce experimentation time for the investigation of frictional properties deterioration of asphalt pavement surfaces.

2. Literature review

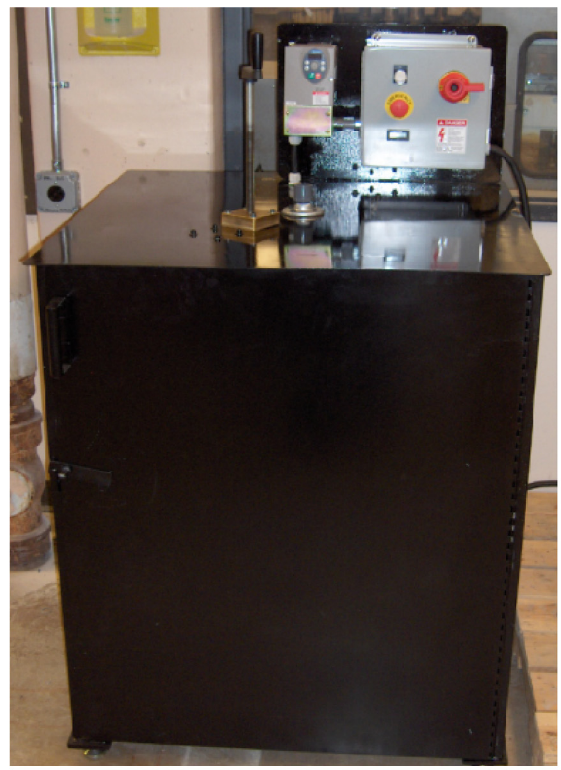
Pavement friction or skid resistance, which is the force that resists sliding on pavement surfaces, is an essential part of the interaction between automobile tires and pavement surfaces. Not only does friction allow a vehicle to accelerate and maneuver, but also it exerts a major determining factor in the ability to stop a vehicle. The factors influencing asphalt pavements' friction include the pavement surface texture, vehicle speed, and whether the surface is wet.

Aggregate polishing is defined as the reduction in microtexture, which results in the smoothing and rounding of exposed aggregates. Wearing, on the other hand, is the loss of macrotexture or surface irregularities. Polishing and wearing mainly vary only in the degree and rate of material loss. Skid resistance (or friction) and texture are two parameters usually measured during the life cycle of the pavement to ensure that they meet safety requirements.

Pavement texture often controls most tire-pavement interactions; such as wet friction, splash, noise, rolling resistance, and tire wear [4]. Pavement texture has been divided into four categories based on the wavelength of its components: microtexture, macrotexture, megatexture, and roughness or evenness. Microtexture and macrotexture are the two features affecting wet pavement friction, as can be seen in [5–9]. Microtexture and macrotexture should be selected wisely since pavements designed with high friction values may adversely affect noise, splash and tire wear. In details, tiny grains of fine aggregate and features that make up the surface of coarse aggregate provide what is known as the pavement microtexture. Microtexture describes wavelength that ranges from 0.1 mm to 0.5 mm and it is correlated to low speed friction. Features of the pavement surface that range from approximately 0.5 mm to 50 mm in length are classified as macrotexture. Macrotexture was shown to be the primary determining factor of high speed wet skid resistance. Macrotexture is a result of the large aggregate particles in the mixture and it is a function of aggregate type. Both the microtexture and macrotexture of asphalt concrete pavements are influenced by the properties of the coarse aggregates exposed at the wear surface since the coarse aggregate in bituminous mixtures is more influential than other mix constituents in determining skid resistance [10–13].

Over the years, different procedures have been utilized to accomplish polishing on aggregate and Hot Mix Asphalt (HMA) specimens in an accelerated manner. These test procedures were designed to suit laboratory scale specimens. Furthermore, friction and texture quantification of asphalt pavement surfaces to monitor deterioration of surface friction over time and to take remedial actions as needed were also included in these test procedures [14]. Several accelerated polishing devices are available and can be used in a laboratory setting to produce asphalt concrete surfaces with different frictional properties. Essentially, these polishing devices facilitate the tire-pavement interaction to mimic the actual in-situ abrasion action. In addition, friction-measuring techniques and texture-measuring techniques are also available and must be used together with polishing devices to complete the polishing and wearing process in the lab. Typically, the British Pendulum Tester (BPT) and the Sand Patch Method are used to measure friction and texture values.

The laboratory polishing and wearing simulation process could take from 24 h to fairly a few days, this includes specimen preparation. To reduce testing time, an attempt was done by Khasawneh [15] in which a torque-measuring device was installed on the polishing machine to enable the direct observation of power required



(a) General view of the accelerated polishing machine

(b) Close-up of the rubber shoe-specimen interface

Fig. 1. Accelerated polishing machine using rubber shoes for testing HMA specimens.