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Evaluating skid resistance of different asphalt concrete mixes

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Abstract

At all stages of pavement life, the highway surface should have some sort of roughness to facilitate friction between car wheels and pavement surface. Skid resistance is a measure of the resistance of pavement surface to sliding or skidding of the vehicle. It is a relationship between the vertical force and the horizontal force developed as a tire slides along the pavement surface. The texture of the pavement surface and its ability to resist the polishing effect of traffic is of prime importance in providing skidding resistance. Polishing of the aggregate is the reduction in microtexture, resulting in the smoothing and rounding of exposed aggregates. This process is caused by particle wear on a microscopic scale. It is a common fact that the lower the skid resistance value, the higher the percentage of the traffic accidents, especially during the wet seasons. Having a low skid resistance value at an asphalt concrete surface might be attributed to one or more of the following reasons: (1) use of higher asphalt content than recommended by the mix design procedure, (2) the Marshall mix design procedure itself, (3) used aggregate gradation, and (4) aggregate quality. To evaluate these factors, a comparative study was performed to find the British Pendulum Skid Resistance Number for a number of mixes. These mixes included, an asphalt concrete mix using local aggregate at the optimum Marshall asphalt content, mixes with 0.5% and 1.0% asphalt contents higher than Marshall optimum asphalt content, a mix designed using Superpave design procedure, a mix with steel slag to replace 30% of limestone aggregate, and a mix with stone matrix aggregate gradation. It was found that the mix with 30% slag has the highest skid number followed by Superpave, SMA, and Marshall mixes, respectively. It was also observed that increasing the asphalt content above the optimal asphalt content value decreases the skid resistance of these mixes.

Keywords: Skid resistance; British Pendulum; Skid number; Superpave; Stone matrix aggregate; Slag; Microtexture

1. Introduction

Worldwide, more than 1 million person is killed yearly due to traffic accidents. Although high percentage of these accidents is due to drivers errors, but highways have a significant effect on this high percentage of traffic accidents. The most important factor in the highways affecting traffic accident rates is the skid resistance. Accident rates increase in the rainy season especially after the initial rain showers. One of the main reasons for this increase is attributed to the low skid resistance of the highway surfaces. In addition, a number of the drivers do not give much attention to the depth of the grooves in their tires treads, and their driving habits do not change much during the rain period.

In general, the highway surface should have some sort of roughness to facilitate friction between the car wheel and pavement surface. Skid resistance is the force developed when a tire that is prevented from rotating slides along the pavement surface [1]. Skid resistance is a measure of the resistance of the pavement surface to sliding or skidding of the vehicle. It is a relationship between the vertical force and the horizontal force developed as a tire slides along the pavement surface. Therefore, the texture of the pavement surface and its ability to resist the polishing effect of traffic is of prime importance in providing skidding resistance.

Skid resistance is an important pavement evaluation parameter because:

- Inadequate skid resistance will lead to higher incidences of skid related accidents.
- Most agencies have an obligation to provide users with a roadway that is ‘‘reasonably’’ safe.

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- Skid resistance measurements can be used to evaluate various types of materials and construction practices.

Skid resistance depends on a pavement surface's microtexture and macrotexture [2]. Microtexture refers to the small-scale texture of the pavement aggregate component (which controls contact between the tire rubber and the pavement surface); therefore, it is produced from the coarse aggregate. Macrotexture 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) [1]. Therefore, macrotexture is controlled by the shape, size, gap width, layout, and gradation of the coarse aggregates [3]. Skid resistance changes over time. Typically, it increases in the first two years following construction as the roadway is worn away by traffic and rough aggregate surfaces become exposed, and then decreases over the remaining pavement life as aggregates become more polished. Skid resistance is also typically higher in the fall and winter and lower in the spring and summer. This seasonal variation is quite significant and can severely skew skid resistance data if not compensated for [1]. Bazlamit and Reza [4] reported that skid resistance is also affected by temperature, it decreases with increased temperature.

Polishing of the aggregate is the reduction in microtexture, resulting in the smoothing and rounding of exposed aggregates. This process is caused by particle wear on a microscopic scale and is difficult to quantify. Low-speed friction measurements, such as the British Portable Friction Tester, have been used in an attempt to quantify polishing.

Coefficient of friction, μ is calculated by dividing the motion frictional resistance, F, by the load acting perpendicular to the interface, L [2]. Therefore, μ is dependent on the pavement surface properties, wheel properties, and loading conditions, in addition to factors affecting those properties. Another factor which is usually used is the friction factor, f which is equal to F/L. ASTM in test method E274 introduced the skid number, SN which is equal to $100*f$.

Most skid resistance measuring techniques involve measuring the force required to drag a non-rotating tire over a wet pavement. One of the most popular procedures which are used to evaluate the friction resistance of the road surfaces is the Portable British Pendulum Tester. This test procedure is standardized in ASTM E303 test method. The British Pendulum Tester is a dynamic pendulum impact type tester which is based on the energy loss occurring when a rubber slider edge is propelled across a test surface. The apparatus may be used for both laboratory and field tests on flat surfaces, and also for polished stone value (PSV) measurements on curved laboratory specimens from accelerated polishing wheel tests. The values measured are referred to as British Pendulum (tester) numbers (BPN) for flat surfaces, and PSVs for specimens subjected to accelerated polishing.

Locked-wheel trailer methods are also used to evaluate skid resistance of highway surfaces according to ASTM E274 procedure. In this method, a bias-ply tire is towed at 40 mph. The wheel is locked and allowed to slide for a certain distance. From the measured resistance force, the skid number, SN, is calculated. Another skid resistance evaluation procedure is by the use of the yaw mode system. In this system, the wheels are turned at some angle to the direction of motion. The side or cornering forces are measured and transformed into skid numbers. In addition, other measuring systems use surface texture analysis, like the TRRL Texture meter, to evaluate skidding properties.

The Skid Number does not indicate the stopping characteristics of the vehicle, driver, or climatic condition, but it is a useful tool that can be used in evaluating the surface friction properties depending on aggregate types, asphalt mix design, and pavement construction methods. Although higher Skid Numbers are preferable to lower Skid Numbers, it is not possible to select a single value which can be considered adequate for all sites and traffic conditions [5].

Another variable which is used to evaluate aggregate resistance against polishing is the PSV. PSV of aggregate gives a measure of resistance to the polishing action of vehicle tires under conditions similar to those occurring on the surface of a road.

The PSV test is carried out in two stages, accelerated polishing of test specimens followed by measurement of their state of polish by a friction test. The PSV test is standardized as a BS 812 test.

Some of the factors affecting road skidding resistance properties are [2]:

1. surface porosity of the pavement layers,
2. surface wear due to studded tires and aggregate,
3. polishing of surface aggregate,
4. rutting due to compaction, lateral distortion or studded tire wear,
5. bleeding and flushing of bituminous binder to the surface,
6. contamination (rubber, oil, water, etc.).

Skidding resistance of roads can be improved by mechanical methods of retexturing using high pressured water jets which is analogous to sand blasting. It can also be improved by milling and resurfacing. In addition, road surface can be roughened or dressed by chipseal, overlay, slurry seal or microsurface, or by making grooves in it [6,7].

2. Study objectives

This investigation was undertaken to compare the skid resistance of different asphalt concrete mixes that included an asphalt concrete mix using local aggregate at the optimum Marshall asphalt content, mixes with 0.5% and 1.0% asphalt contents higher than Marshall optimum asphalt content, a mix designed using Superpave design