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Investigating the effect of temperature variations on the measured airfield pavement skid resistance

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HIGHLIGHTS

- Sub-zero temperatures in skid resistance measuring and correction models are used.
- Pavements should be tested for their skid resistance at the same temperature.
- Simple procedures to measure skid resistance at below zero temperature are provided.
- Compaction direction affects the measured skid resistance values.
- Developed models are important to relate field and laboratory skid resistances.

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ABSTRACT

Airfield temperatures can range between −30 °C and +50 °C. Therefore, it is critical to correct the measured skid resistance values for field temperatures. To achieve this, several asphalt slabs were prepared and tested using the British Pendulum Tester. A special fluid was used to conduct skid resistance tests at below freezing temperatures. Test results were used to develop correction models for skid resistance under temperature variations, to be used by airfield operators. The results of this research are unique and important where it is the first time to include below freezing temperatures in skid resistance measurements and correction models.

1. Introduction

Safety on pavements is usually evaluated through several components; among them the skid resistance is one of the most important indicators. The lack of skid resistance may cause a serious safety hazard in specific situations especially when water exists in any form [1]. Adequate skid resistance of pavement surface is essential feature for highway safety [2]. Al-Mansour [3] emphasized the role of skid resistance to reduce the traffic accidents. It was found that lack of skid resistance was the reason or one of the factors of more than a quarter of wet-road vehicle accidents in the United Kingdom [4]. For airfield pavements, skid resistance of surface is extremely important. It influences the spin-up of the wheels, which is required to operate the electronically controlled antiskid braking systems installed in most modern aircrafts. In other words, adequate skid resistance of runway surface is essential to braking and deceleration operations. The national transportation safety board reported that runway conditions were a cause or factor in 115 aircraft accidents between 1983 and 1987. Other researchers concluded that conditions of runway surface and lack of skid resistance are factors in many aircraft accidents [5–7].

Many researchers have studied the effect of temperature variations on skid resistance of pavement surfaces. In general, a higher ambient/pavement temperature results in a lower skid resistance value [8,9]. Ahammed and Tighe [10] concluded that the British Pendulum Number (BPN) of wet pavement surface should decrease by 0.35 for each 1 °C increase in temperature.

MacLean and Shergold [11] conducted skid resistance tests at controlled temperatures between 5 °C and 45 °C, they found that;

$$SRV20 = [(100 + t)/120] \times SRVt \tag{1}$$

where; SRV20 = skid resistance value at 20 °C, SRVt = skid resistance value at t °C and t = air temperature in °C.

Oliver [12] concluded the following two equations;

$$SRV20 = SRVt/[1 - 0.00525 \times (t - 20)] \tag{2}$$

where; t = surface temperature in °C, and

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$$SRV20 = SRVt/[1 - 0.00816 \times (t - 20)] \quad (3)$$

where t = air temperature in °C.

Based on these equations, a relationship between pavement surface temperature (Tp) and air temperature (Ta) was obtained as [9];

$$Tp = 1.554Ta - 11.09 \quad (4)$$

DTMR [13] used a reference temperature of 30 °C and concluded that;

$$SRV30 = SRVt/[1 - 0.00525 \times (t - 30)] \quad (5)$$

where; SRV30 = skid resistance value at 30 °C, SRVt = skid resistance value at t °C and t = surface temperature in °C.

The following equation was developed by conducting skid resistance tests using the British Pendulum Tester (BPT) on prepared specimens to determine polished aggregate friction value [14];

$$SMVC = SMVt \times [(t + 100)/123] \quad (6)$$

where; SMVC = skid mean value corrected for temperature, SMVt = skid mean value at test temperature and t = air temperature in °C.

Bianchini et al. [15] studied the temperature influence on skid resistance measurements using locked-wheel trailer. They concluded that skid number should be corrected for temperature variations by an adjustment factor ranging from −2, at approximately 4.4 °C (40 °F), to 2 for temperature value of 32.2 °C (90 °F).

Although many researchers have studied the effect of temperature on the measured skid resistance of pavement surfaces, none of them has studied such effect below the freezing temperature. The main objective of this research is to correct the measured skid resistance values of airfield asphalt mixes for the wide variation of field temperatures including below freezing temperatures. This correction is essential to relate skid resistance values measured at any field temperature to a corresponding value at room/laboratory temperature for accurate comparisons between different airfield pavement skid resistances measured at different temperatures. In addition and for future development of statistical models predicting field skid resistance from laboratory data measured at room temperature, it is very important to investigate the effect of wide range of field temperatures on the measured skid resistance of airfield pavements.

2. Experimental program

2.1. General

To achieve the objective of this research, the experimental program consisted of testing of two different airfield asphalt surface mixes for their skid resistance in the laboratory. The field mixes were supplied by the Egyptian General Authority of Roads & Bridges and Land Transport. These mixes were referred to as Mix1 and Mix2. Fig. 1 illustrates aggregate gradations for the studied mixes. Crushed limestone aggregates, crushed sand, and limestone powder were used in aggregate blends. Asphalt cement 60/70-penetration asphalt was used with a content of 6% for both mixes. Skid resistance of the two asphalt mixes was measured using the BPT according to ASTM [16].

2.2. Methodology

For each asphalt mix, four slabs of dimensions 70 × 25 × 7.5 cm were prepared and compacted using plate compactor. A ramp was prepared at the end of the wooden forms to allow the compactor to move back and forth on top of the asphalt slabs without damaging the wooden edges of the forms. The compaction was completed after 10 passes per slab.

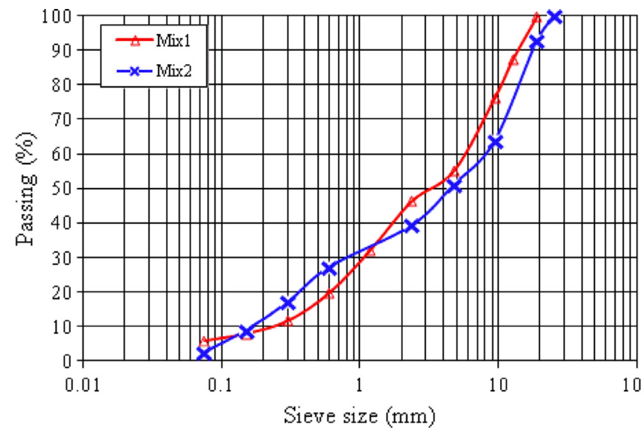

Fig. 1. Aggregate Gradation for Studied Mixes.

The slabs were labeled and tested for their skid resistance using the BPT [16]. Instrument was leveled and the pendulum was adjusted such that its free swing carried pointer to zero. Contact path length was adjusted using a marked ruler provided with the pendulum. Enough water was applied with a spray to cover the test area and the slider completely. One swing was executed but the reading was not recorded. After that four more swings were carried out with the surface rewetted each time and results were recorded. The test was performed at five different locations at distances of 7, 21, 35, 49, and 63 cm from the beginning of each slab.

All sliders were conditioned by the supplier. To control the variations of results due to wear in slider, one new slider was used for each slab after swinging five times across a dry slab surface. Wear of the slider edge was monitored such that it did not exceed 3.2 mm in the plane of the slider or 1.6 mm vertical to that plane [16].

Nine test temperatures were adopted during the testing program as follows: 50 °C, 40 °C 30 °C, room temperature (25 °C), 15 °C, 5 °C, −10 °C, −20 °C and −30 °C. The temperature was controlled utilizing an environmental chamber. The BPT (and the rubber sliders) were normally left at room temperature and then conditioned at test temperature for two hours before the test.

For temperatures below 0 °C, a special fluid (Clean Up, glass and surface cleaner produced by El-Manar Co. for Falcon Co., Egypt) was used to conduct the test. The fluid is used for car glass cleaning in winter season. Visual inspection of slabs did not show any reaction with asphalt surface.

To adjust skid resistance values for fluid usage, one slab of each mix was tested using the fluid at temperatures of 50 °C 40 °C 30 °C, 25 °C, 15 °C and 5 °C. At each temperature, the ratio between average skid resistance measured using water and average skid resistance measured utilizing the fluid was calculated. Then the correction factor for fluid usage (CF_f) was calculated as the average of these ratios. The corrected skid resistance for fluid usage was used to develop the correction factor for temperature variations (CF_t) by calculating the ratios of skid resistance measured at room temperature and those measured at different temperatures.

3. Laboratory test results

3.1. Skid resistance test results

This section presents the skid resistance test results for the laboratory compacted asphalt slabs. For each slab, the test was performed in the direction of compaction (longitudinal direction LOD). In order to investigate the effect of direction of compaction on skid resistance of asphalt mixes, the test was also performed in the transverse direction (TRD). For each mix, the average skid