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Influence of temperature on polishing behaviour of asphalt road surfaces

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ABSTRACT

The skid resistance of road surfaces is crucial for traffic safety and varies due to the polishing effect of the traffic loads. Numerous prediction models for the skid resistance of asphalt pavements have been developed based on three standard polishing methods in accordance to regulations; Polished Stone Value (PSV), Micro-Deval (MD) and Wehner/Schulze machine (W/S). However, the aforementioned tests can only be carried out for given conditions such as under constant temperature. This does not fully represent real conditions on road surfaces, because asphalt exhibits a strongly temperature-dependent performance due to the viscosity of bitumen. In this paper, the polishing effect due to traffic and weathering was simulated with a self-developed device, the Harbin Accelerated Polishing Machine (HAPM). It is equipped with real tires and allows for the precise control of the testing temperature. The British pendulum number (BPN) and mean texture depth (MTD) were determined to describe skid resistance development during polishing process. Prediction models of skid resistance are created and the model parameters are calculated by means of a regression analysis. The influences of the temperature during polishing on the long-term evolution of skid resistance are studied.

1. Introduction

Skid resistance of road surfaces is an absolutely essential factor contributing and ensuring traffic safety. Properties of the binder (e.g., cement or bitumen) and the aggregate determine the skid resistance [1–6]. During the service life of a pavement, bitumen is removed from the crests of the aggragate and the uncovered aggragate is polished under influences of traffic loading and weathering. In this case, the skid resistance decreases continually upto an equilibrium phase [1]. A number of prediction models have been developed for asphalt pavements based on standard polishing methods, e.g., the polished stone value (PSV, EN 1097–8:2009) [1,7–12], Micro-Deval test (MD, EN 1097–1) [13,14] and the Wehner/Schulze machine (W/S, EN 12697–49) [1,15–25] which are conducted under laboratory conditions.

Research indicates that the skid resistance follows a cyclical seasonal variation which is caused by the following aspects:

- duration and intensity of acid rain (Acid rain will erode mineral contents in aggregate such as limestone with relatively high calcium carbonate content.) [2,5]
- traffic flow (The traffic composition and intensity in winter and summer differ significantly.) [1,2,5]
- load and contact pressure (The heavy-duty vehicles and passenger cars have greatly different influences on the polishing effect as well as on the development of skid resistance of the road surface.) [18–20]
- self-sharpening effect of the road surfacing aggregates [21]
- wetness conditions and water content (On dry road surfaces, a thin deposition containing a mixture of road dust and rubber abrasion is formed on the surface, which prevents the aggregate from further polishing and simultaneously fills the cavities of the texture. For wet road surfaces, rubber abrasion is rare. The abrasion of binder material and minerals are strongly increased by water.) [22]
- size, composition and hardness of road dust (The road dust can be considered as a polishing agent, whereby different mineral contents, such as quartz and silicon dioxide, resulting in different abrasivity and thus influencing the polishing effect.) [2,7,22–25]
- application of gritting material for the winter services (For example, the sand and salt used to de-ice road surfaces in the winter significantly affect the polishing effect and thus the skid resistance.) [2,22]
- influence of freeze-thaw cycles on the aggregates [26].

In the aforementioned standard laboratory test procedures (PSV, MTD and WS) the temperature of the specimens is kept constant at

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Table 1
Volumetric properties and composition of the asphalt.

Asphalt mixture			AC 13	SMA 13
Aggregate	Grain size and mass percentage	< 0.075 mm	5.5 M.-%	10.0 M.-%
		0.075 – 2.36 mm	28.3 M.-%	10.5 M.-%
		2.36 – 4.75 mm	15.5.8 M.-%	6.5 M.-%
		4.75 – 9.5 mm	25.1 M.-%	35.5 M.-%
		9.5 –13.2 mm	19.4 M.-%	32.5 M.-%
		13.2 – 16.0 mm	6.2 M.-%	5.0 M.-%
	Stone type		andesite (albite 91.3 M.-% and quartz 8.7 M.-%)	
Binder	SBS modified asphalt		5.7%, 6.2%, 6.7%	4.5%, 5%, 5.5%
Mixture	Air void percentage		4.4 vol.-%	4.3 vol.-%

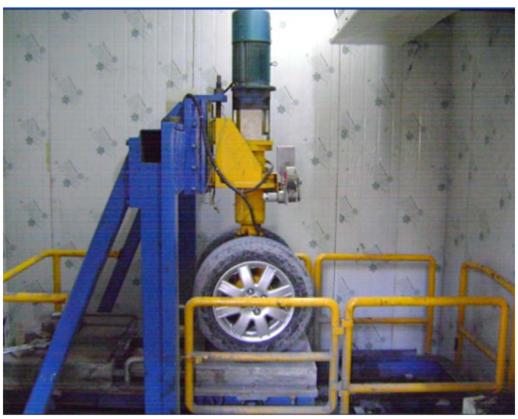


Fig. 1. The Harbin Accelerated Polishing Machine (HAPM).

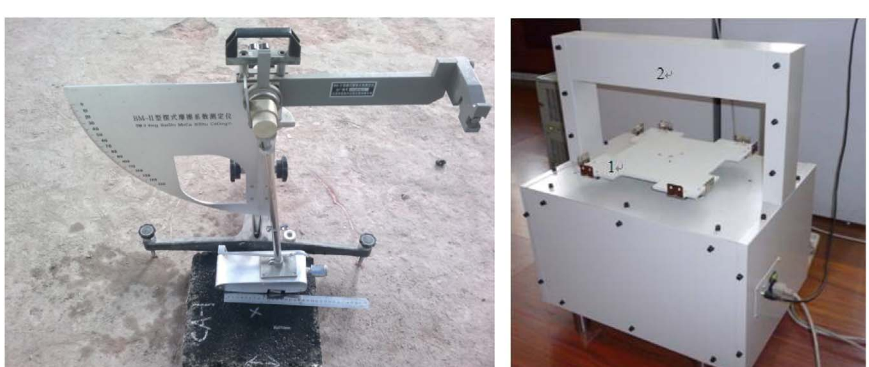
room temperature during the polishing process. It is widely known, that the friction of pavement was contributed by two major components, which are adhesion and hysteresis [27,28]. During the polishing process, a huge quantity of heat can be produced by the tire-pavement interaction, where a thin film of melting asphalt and rubber can be generated and dramatically decreases the adhesion property [29]. In this case, the hysteresis becomes the main factor dominating the tire-pavement friction, which highly depends on the temperature [28,30]. Furthermore, the material properties of asphalt mixtures (e.g., viscosity of bitumen, elastic modulus of mixture, affinity between bitumen and aggregates.) are temperature-dependent; thus the mechanical performance of the asphalt pavement should differ under different temperatures as well. As a result, polishing conditions with constant temperatures do not fully represent conditions in reality. The impact of temperature on the development of skid resistance on asphalt surfaces cannot be sufficiently determined under such laboratory conditions.

Fig. 3. Binder-free surface of SMA sample after polishing test.

In this paper, the polishing stress imposed by traffic and weathering was applied to the asphalt road surfaces continuously and simultaneously. The Harbin Accelerated Polishing Machine (HAPM), developed by the School of Transportation Science & Engineering at Harbin Institute of Technology (HIT), simulates the polishing process with real tires under controlled testing temperature. Since the skid resistance depends on both marco- and micro-texture, following indices were used to determine the skid resistance during polishing process:

- British pendulum number (BPN), indicating the micro-texture (EN 13036–4)
- Mean texture depth (MTD), indicating the macro-texture and drainage capacity of road surface (EN 13036–1)

Prediction models for skid resistance are created and the model parameters are calculated by means of a regression analysis. The influences of temperature during polishing on the long-term evolution of skid resistance are studied. The comprehensive conclusions contribute to increase the accuracy of the skid resistances prediction to ultimately ensure increased traffic safety.



(a) **British Pendulum Skid Resistance Tester** (b) **Optical profilometer**

Fig. 2. Measuring devices.