Wear 318 (2014) 1–11

Contents lists available at ScienceDirect

Wear

journal homepage: www.elsevier.com/locate/wear

Study of micro-texture and skid resistance change of granite slabs during the polishing with the Aachen Polishing Machine

Dawei Wang [a,*], Xianhua Chen [b], Markus Oeser [a], Helge Stanjek [c], Bernhard Steinauer [a]

[a] Institute of Road and Traffic Engineering, RWTH Aachen University, D52074 Aachen, Germany
[b] School of Transportation, Southeast University, Nanjing 210096, China
[c] Institute of Clay and Interface Mineralogy, RWTH Aachen University, D52072 Aachen, Germany

ARTICLE INFO

Article history:
Received 16 December 2013
Received in revised form
21 March 2014
Accepted 4 June 2014
Available online 19 June 2014

Keywords:
Skid resistance of road surface
Micro-texture
Aggregates
Spectral analysis
Mineralogical composition
Granite slabs

ABSTRACT

In this paper, massive granite slabs were cut from lumps of rock using a diamond saw. The surface of the stone slabs was then retreated so that the slabs were characterized by different degrees of roughness. On the other hand, the slabs had no macro-texture, so that the skid resistance depended exclusively on the micro-texture. The prepared slabs were polished under various polishing conditions using the Aachen Polishing Machine. Changes of the micro-texture were studied on the basis of both texture level measured by spectral analysis and skid resistance measurements measured by the British pendulum tester. The results showed that micro-texture and skid resistance changes of the slabs are related to the applied polishing agent, initial roughness and mineralogical compositions of the granite slabs. The contribution of micro-texture to the skid resistance can be described with a function of the two texture parameters.

1. Introduction

Skid resistance of road surfaces is essential to ensure traffic safety. Statistics show that the risk of skidding crashes decreases with an improvement of skid resistance [1]. Skid resistance mainly depends on the road surface texture, which is characterized by two scale levels: micro-texture and macro-texture. Micro-texture is defined as “the amplitude of deviations from the surface plane with wavelengths less than or equal to 0.5 mm in length and depth” [1,2]. Furthermore, the roughness of an aggregate has a decisive influence on the magnitude of micro-texture of a road surface [1,2]. The macro-texture is characterized by surface irregularities whose dimensions range between 0.5 and 50 mm horizontally and between 0.1 and 20 mm vertically [1,2]. The micro- and macro-texture of a road, which have a significant impact on the activation of the frictional force between vehicle tires and road under wet condition, are influenced by the roughness, choice, grain size, arrangement and grading of the aggregates [2–5].

The skid resistance of roads generally decreases with the polishing process of aggregates due to traffic loads [2,5]. During the polishing process, the micro-texture of aggregates changes due to a gradual removal of mineral components [6,7]. Different test methods, for example the polished stone value (PSV, EN 1097-8:2009) [2,8–11], were applied to determine the polishing resistance of coarse aggregates (for example 8/11 mm in Germany). Furthermore, with the Wehner/Schulze test [12,13] the friction after the polishing test can be measured for the grain sizes 0/2 mm, 2/5 mm, 5/8 mm and 8/11 mm at a velocity of 60 km/h according to the draft EN 12697-49. Based on these aggregate tests for a given set of laboratory conditions, many prediction models for asphalt roads have been developed [14–19].

The changes of aggregate surface textures due to the rubber tire polishing action in PSV or W/S tests have been investigated quantitatively to micrometer level [6,20–23]. In order to characterize the roughness of a road surface, different texture parameters were developed which describe how a tire interacts with different types of asphalt surface. However, experiences have shown that the roughness parameters are scale-dependent [6,23–24]. Chen et al. have studied the development of aggregate-surface height profiles in the polishing process with the W/S machine using fractal and spectral analysis [6,23]. It has been demonstrated in [24,25] that the development of the power spectrum for the surface roughness could be directly correlated with the development of skid resistance.

In the standard tests to determine the polishing resistance of aggregates, such as the PSV and W/S tests, the samples are made

* Corresponding author. Tel.: +49 241 8026742; fax: +49 241 8022141.
E-mail address: wang@isac.rwth-aachen.de (D. Wang).

http://dx.doi.org/10.1016/j.wear.2014.06.005
0043-1648/

with aggregates that are chosen and placed in a single layer on the bottom of a mold by the laboratory assistant (Fig. 2). Concerning the wide differences in shape, size, angularity and texture of natural aggregates [26], the polishing behavior and the measurement results of the texture and skid resistance may be influenced by the choice, arrangement and orientation of the aggregates. As already proved in [2,9,20], the experience and proficiency of the laboratory assistant is of great importance for accuracy, repeatability and reproducibility of the test.

As a result, in this paper an additional study is developed accessorily to the standardized test methods such as PSV and W/S. For this purpose, massive granite slabs were cut from lumps of rock using a diamond saw. In the hope of minimizing the uncertainties due to the production procedure, different initial roughnesses of the granite slabs should thus be generated. A significant advantage of the slabs is that they have no macro-texture and thus the skid resistance depends exclusively on the magnitude of micro-texture. The fabricated slabs were polished under various polishing conditions using the Aachen Polishing Machine (APM) developed by the Institute of Road and Traffic Engineering (ISAC) at the RWTH Aachen University [19,20]. The changes of micro-texture and polishing resistance were studied on the basis of texture and skid resistance measurements using the British pendulum tester (BPT). The changes of the micro-texture will be characterized by two parameters with spectral analysis. Furthermore, a function which describes the contribution of micro-texture to skid resistance is to be developed with these two spectral parameters.

2. Investigation method

2.1. Selection and property of the aggregate

For this paper, a granite was chosen based on the results in [20]. This granite has two advantages: firstly, the crystal size (0.1–3 mm, Fig. 1) is in comparison with fine to very fine grains (crystal size ≤ 0.1 mm) large enough for the analysis with stereo microscopy. Secondly, it does not have a coadunate or networked structure so that every single mineral is clearly differentiable. The composition of the granite is determined by means of XRF analysis: quartz (31.4%), feldspar (51.4%) and mica (9.6%).

For the used granite, the polishing resistance was determined with different test methods on grains with a size of 8/11 mm. A PSV-value of 56 was determined with the PSV test (Fig. 2) [20].

Furthermore, six circular plates of 22.5 cm diameter are prepared. They are obtained by manually placing the aggregates of 8/11 mm in a single layer, lying with their flat test faces on the bottom of a circular mold, and then filling the mold with concrete. Three plates were tested with the standardized W/S. The other three were first polished with the Aachen Polishing Machine (APM, s. Chapter 2.4). After the polishing, their skid resistance was then measured with the British pendulum tester and W/S:

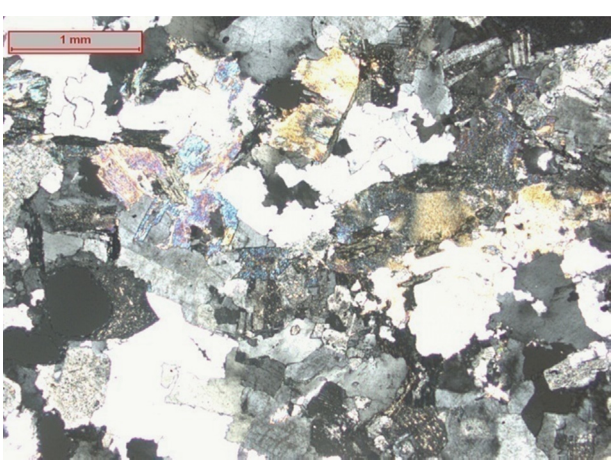

Fig. 1. Microstructure of granite aggregate 8/11 mm using a thin section [20].

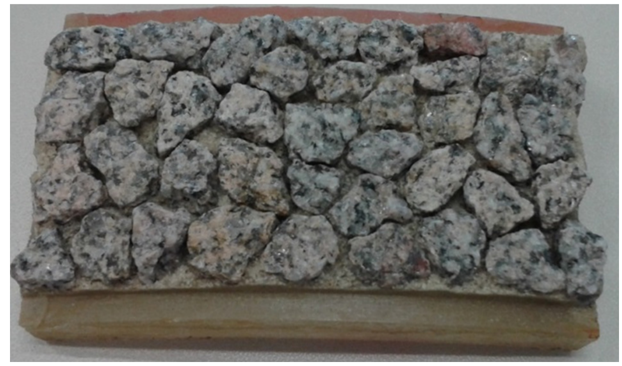

Fig. 2. The sample for the PSV test was produced with a grain size of 8/11 mm.

- Standardized W/S-values are 0.46.
- BPN after polishing in APM: 49 (quartz powder as the polishing agent) or 54 (quartz sand as the polishing agent).
- W/S after polishing in APM: 0.34 (quartz powder as the polishing agent) or 0.37 (quartz sand as the polishing agent).

2.2. Test specimens

It has been demonstrated in [20] that during the polishing test in APM, which uses real vehicle tires, only a small amount of aggregates from the top of the sample were polished, as shown by the red contour lines in Fig. 3. Therefore, the choice, arrangement and orientation of the aggregates influenced the surface texture and slider penetration depth, which in turn affected the result of the polishing tests and skid resistance measurements.

Given this, the samples used for this paper were chosen to be massive granite slabs having uniform initial roughness and typography conditions (Fig. 4). In comparison to the samples for the PSV or W/S tests, the granite slabs have one significant advantage: the effects due to the production procedure are negligible. The choice, arrangement and orientation of the aggregates would not extensively influence the measurement result of the texture and skid resistance. Moreover, the matrix (resin), cavities and voids embedded between the aggregates would not affect the polishing result and skid resistance measurement. Therefore, the polishing resistance will only be material-related.

In order to investigate the micro-texture and its influence on the skid resistance in a better way, an attempt to eliminate the influence of the macro-texture on the skid resistance has been done so that the skid resistance depends exclusively on the magnitude of the micro-texture.

In the measurements of real road surfaces by the Institute of Road and Traffic Engineering (ISAC), a relationship was found between outflow time (according to EN 13036-3: 2003) and the parameter of the macro-texture, MTD (Mean Texture Depth determined by the sand patch method according to EN 13036-1) [3], as shown in Fig. 5. As proved in ISO 12473-1, when the MTD approaches 0.1 mm, the outflow time of the sample approaches infinity, resulting in a lack of macro-texture and drainage capacity of the sample.

Based on the results in Fig. 5, three types of slabs were made, each consisting of a different roughness. The MTDs (calculated from the three-dimensional texture data) are all below 0.1 mm,