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# A study of the laboratory polishing behavior of granite as road surfacing aggregate

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## HIGHLIGHTS

- We determined skid resistance and abrasion in process of polishing test of the granites.
- The aggregates with the same skid resistance/polishing resistance may exhibit different wear resistances.
- The change of the texture was taken as a link between the polishing effect and the skid resistance development course.
- We related the polishing/wearing behavior to the mineralogical composition and structure of the granites.

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## ABSTRACT

Four sources of granite aggregates with different mineralogical properties were investigated. They were formed into test plates with a flat surface and polished with the Aachen Polishing Machine using quartz powder and quartz sand as the polishing agent respectively. Changes of the texture were studied on the basis of both texture measurements and skid resistance measurements measured by the Pendulum Test and the Wehner/Schulze device. By comparison of the four granites, the influence of mineral composition and crystal size on micro-texture and skid resistance changes of the aggregates is determined. The polishing and wearing resistance can be described with functions of the mineralogical parameters.



## 1. Introduction

Skid resistance of road surfaces is essential to ensure traffic safety [1,2]. Skid resistance mainly depends on the micro-texture and macro-texture of the road surface and is influenced by the roughness, choice, grain size, arrangement and grading of the aggregates [1–5]. The skid resistance of roads generally decreases with the polishing process of aggregates due to traffic loads [1,5]. It then achieves a state of equilibrium which depends on many factors during the in-service life of roads. During the polishing process, the angularity and texture of aggregates changes due to a gradual removal of mineral components [6,7]. Different test methods, for example the polished stone value (PSV) according to EN 1097-8 and the Wehner/Schulze test (W/S) according to the EN 12697-49, are applied to determine the polishing resistance of the aggregates. The changes of aggregate textures due to the polishing action in PSV or W/S tests have been investigated quantitatively with different texture parameters [6,8–11]. Based on these aggregate tests and roughness parameters for a given set of laboratory conditions, several prediction models for asphalt roads have been developed [6,12–17].

With regard to the polishing resistance of aggregates certain factors play a decisive role. These include the composition of the aggregates and the petrographical parameters of the single minerals, which include the fissility, hardness, sharpness and potentially

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the hardness contrast between different minerals [1,7,14,18–20]. Principally, an irregular texture is favored in comparison to a texture with parallel or layered elements (for example mica) [1,20]. The average hardness and hardness contract of crystals on aggregate maintain good skid resistance under polishing [7,19,20]. With smaller crystal size the mineral can have a higher angularity whereby the sharpness of the surface increases [1,20]. In [21], the polishing resistance of the various groups of aggregates has been studied in dependence on those petrological features. For the igneous rocks, variation in hardness between the minerals, the proportion of soft minerals and cracks and fractures present in the individual mineral grains, affect polishing resistance significantly. More finely grained allotriomorphic igneous aggregates present a tough, cohesive surface which polishes considerably.

Based on the previous research results, the exact mechanism as to why and how the mineralogical properties like the mineral compositions and mineral sizes of the aggregates influence the polishing behaviors quantitatively will be described and identified in this paper. The polishing behavior is described not only by the polishing resistance, but also by the wearing resistance. Especially the latter is not taken into consideration in current polishing tests such as PSV or W/S. This parameter describes the amount of pavement wear and is closely related to urban dust and $PM_{10}$ production (i.e. particulate matter with an aerodynamic diameter of less than 10 μm) [21–24].

Four sources of granites with great variation in their mineralogical properties were chosen for this study. The selected granites are prepared in the shape of plates measuring 26 × 32 × 4 cm and polished with the Aachen Polishing Machine (APM) using different polishing agents. The polishing resistance is studied on the basis of skid resistance measurements using the Pendulum Tester (PT) and the Wehner/Schulze device (W/S). The surface topography of the specimen is measured with a profilometer to calculate the parameter “abrasion” which describes the amount of minerals that have been worn out from the surface in the course of polishing. Finally, the influences of the polishing condition and the mineralogical properties of the polishing resistance and abrasion are evaluated using multiple regression analysis.

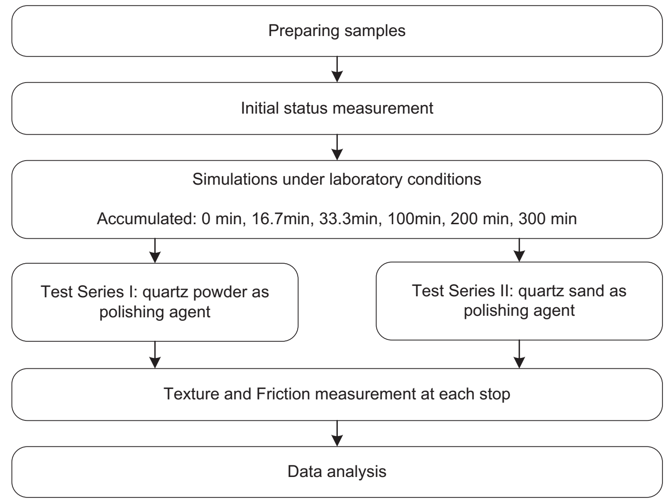


**Fig. 1.** Methodology of evaluation on the aggregates.

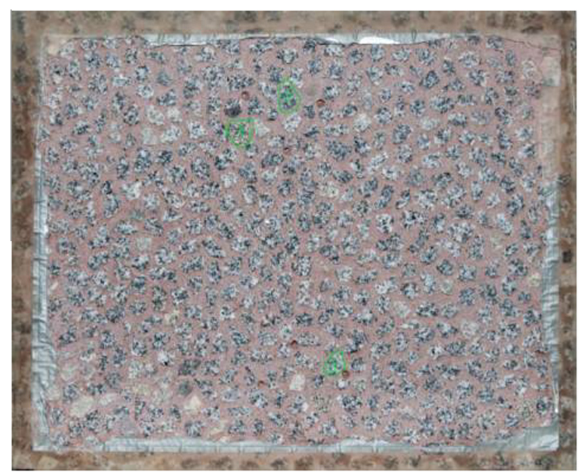

**Fig. 2.** Test plate of the aggregates with a grain size of 8/11 mm.

## 2. Investigation method

### 2.1. Test procedure

The strategy of this research is illustrated in Fig. 1.

Considering that different types of aggregates are not comparable in terms of origin, structure and compositions, four granites typically used for surface layers on highways were chosen from major granite quarries in Germany. These granites have three advantages: firstly, granites have a crystal size of 0.1–3 mm, which, in comparison to aggregates with very fine grains (crystal size ⩽ 0.1 mm) such as greywacke or diabase, is large enough for the analysis with the aid of stereo microscopy. Secondly, it does not have a coadunate or interlinked structure which allows for the differentiation of every mineral. Finally, granites are clearly classifiable by the QAPF diagram in dependence of their mineral composition (quartz, alkali feldspar, plagioclase and feldspathoid). The great variation in its mineral composition makes granite very favorable for studying the influence of different minerals on the polishing and friction behavior.

The polishing and wearing resistance of the granites used is determined with different test methods. First of all, plates with a dimension of 32 × 26 × 4 cm are produced in mosaic-laying method with a grain size of 8/11 mm. The arrangement of the aggregates is similar to that specified for the polishing test in EN 1097-8 and EN 12697-49: the aggregates are laid out by manually placing the aggregates in a single layer over the entire surface of the test plates. Quartz sand is sprinkled into the gaps between the individual grains and concrete is poured over the whole plate. The cement level was significantly lower than the crests of the grains (>3 mm); thus the tires do not come into contact with the cement. A centimeter-wide rim of the plate is covered with epoxy resin to ensure the stability of the edges (see Fig. 2).

In this research, the samples are polished with the Aachen Polishing Machine (APM) [17,25,26]. Two kinds of quartz of different grain sizes are applied as polishing agents: quartz powder (QP, maximum grain size: 0.2 mm, average grain size: 0.04 mm) and quartz sand (QS, maximum grain size: 1.0 mm, average grain size: 0.42 mm). Therefore, a total of 16 specimens (4 granites, two test series (I: with quartz powder, II: with quartz sand), two plates of each variant to obtain reliable results) were prepared. The polishing load is exerted in five stages, which are equivalent to an accumulated polishing duration of 16 min and 40 s, 33 min and 20 s, 100, 200 and 300 min. With the aid of a non-contact, high-resolution profilometer from Fries Research & Technology GmbH the surface topography of the samples' surfaces is measured at the end of each polishing stage. The skid resistance is measured using the Pendulum Tester and the Wehner/Schulze device. In order to describe the polishing behavior, the following parameters were defined (see Fig. 3):

- Polishing resistance: characterizes the roughness of the texture of aggregates after the polishing and represents the final skid resistances measured with PT and W/S.
- Wearing resistance: defined as abrasion calculated from the average height change on the measured area of the samples. This parameter describes the average wear of the specimen surface in the course of polishing.

The influence of polishing action and mineralogical properties on polishing resistance and abrasion was studied using multiple regression analysis.

### 2.2. Polishing test using the Aachen Polishing Machine (APM)

The polishing effect of tires is not simulated by W/S, but by the Aachen Polishing Machine (Fig. 4). In comparison to the W/S the APM uses real vehicle tires (type: Vanco-8, 165/75 R 14 C 8PR 97/95 R TL from Continental). Two test specimens are subjected to shear stress from a superimposed translational and rotational motion. The translational motion is realized by a horizontally movable sled onto which the test plates are fixed, while the rotational motion is realized by rotating a vertical axle with two wheels. Polishing is caused by a tire with an inner pressure