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Evaluation of the polishing resistance characteristics of fine and coarse aggregate for asphalt pavement using Wehner/Schulze test

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HIGHLIGHTS

- Polishing resistance of various aggregate size fractions is tested using W/S.
- Polishing resistance of fine aggregate is greater than coarse one.
- Polishing resistance may not uniformly develop across all aggregate sizes.

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ABSTRACT

Traffic safety is influenced strongly by the skid resistance of pavements. Moreover, the long-term skid resistance of pavements depends mainly on the polishing resistance of the specific aggregate present on the surface. The polishing resistance is a measure which describes the roughness of aggregate after a polishing load has been induced by traffic loads. Specifications for the polishing resistance of aggregate are given only for coarse aggregate. However, given the various mixture types it is questionable if the fraction of fine aggregate (up to 55 M.-%) ought to be neglected, particularly since the polishing resistance of fine aggregate is higher than that of coarse aggregate. This paper aims to quantify the polishing resistance of various aggregate size fractions with particular focus on the properties of fine aggregate, and to demonstrate the suitability of the Wehner/Schulze test (W/S) in this regard. The results show that the initial skid resistance and the polishing resistance of fine aggregate are generally greater than that of coarse aggregate. It is notable that the initial skid resistance decrease is far more pronounced for fine aggregate. The polishing resistance does not exhibit a uniform development across all aggregate sizes. It is to be expected that fine aggregate may play a significant role for the skid resistance of asphalt pavements; however only coarse aggregate is considered in the design process. Further research is needed to precisely determine the effect of fine aggregate to allow for more economically feasible pavement designs.

1. Introduction

Due to the high mass fraction in asphalt, aggregate has a considerable influence on the mechanical performance of asphalt pavements [1,2]. Moreover, the long-term skid resistance of pavements depends mainly on the polishing resistance of the specific aggregate present on the surface. The polishing resistance is a measure which describes the roughness of aggregate after a polishing load has been induced by traffic loads [3–5]. Therefore, to ensure the safety of motorists, the polishing resistance of aggregate must be determined and verified in a laboratory with several test methods before being applied on pavement surface layers [6].

The polishing resistance is characterized as the skid resistances after a defined polishing process. According to common international practice, the polishing resistance may be determined experimentally with the polished stone value (PSV) according to EN 1097-8 [7–9]. A sample consists of coarse aggregate (for example 8/11 mm in Germany) and is mounted in convex mould segments and polished with emery powder for six hours, this simulates the polishing load. Hereafter the skid resistance is determined with a device such as the British Pendulum Tester (BPT) [10].

In recent years, the Wehner/Schulze test (W/S) in accordance with EN 12697-49 was applied in numerous research projects to investigate the polishing resistance of coarse aggregate [11–18].

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In this case, the polishing load is imposed by three conical rubber rollers under the addition of water and quartz powder, whereafter the skid resistance is measured in the same device. In contrast to the Pendulum Tester, which measures friction at low speeds (about 10 km/h), the friction measurement in the W/S is conducted at 60 km/h and reflects the applicability to reality more accurately.

Aggregate is commonly subdivided into coarse (>2 mm) and fine particles (<2 mm), which both have significantly different influences on the asphalt mixture [19–22]. Coarse aggregate is generally responsible for forming the granular structure and fine aggregate is added to the framework of coarse aggregate [14,23]. Table 1 gives a broad overview of commonly used asphalt mixture types used for federal highways in Germany; the respective aggregate composition is also given. Taking the span of approved aggregate gradations into account, the content of fine aggregate varies between 5 M.-% and 55 M.-% depending on the asphalt mixture type.

Specifications for the polishing resistance of aggregate are only given for coarse aggregate. However, given the various mixture types as seen in Table 1 it is questionable if the fraction of fine aggregate (up to 55 M.-%) ought to be neglected. Asphalt surfacing mix with nominal coarse aggregate size from 6 mm to 20 mm was tested by W/S test carried by Woodward [18]. And research on friction properties of fine aggregate was performed by Kirchmaier [24]. According to these studies, it is clear that the properties of fine aggregate differ from those of coarse aggregate and may significantly influence the skid resistance of asphalt pavements.

In conclusion, the customary practice of applying the PSV test is strongly limited in its practical applicability for pavements. On the one hand, it only includes the coarse fraction of aggregate to determine the skid resistance which may represent merely 45 M.-% of aggregate in certain cases; on the other hand, it conducts tests at low speeds which has little relevance regarding skid resistance properties and their implications on traffic safety. Only few studies have investigated and quantified the characteristics of fine aggregate roughness, and skid resistance characteristics [12–16].

This paper aims to quantify the polishing resistance of various aggregate size fractions with particular focus on the properties of fine aggregate, and to demonstrate the suitability of the W/S in this regard. Furthermore, the relationship between W/S friction coefficient ($\mu_{W/S}$) of the aggregate and the number of polishing cycles in the W/S is to be determined. The investigations are conducted on coarse aggregate as well to ensure comprehensive data. The change of texture characteristics and skid resistance is investigated for fine and coarse aggregates for further comparison.

2. Experimental methodology

Various aggregate sizes were individually tested to determine the polishing resistance and the development thereof under polishing with the W/S in seven stages (polishing cycles: 0; 5000; 10,000; 15,000; 30,000; 45,000; 90,000). The aggregate grain size fractions in [mm] were selected as follows: [0.2/0.4, 0.4/0.63, 0.63/1, 1/3.15, 2/5, 5/8, 8/11.2, 11.2/16]. Furthermore, two rock types with different mineral contents, Greywacke and Diabase, were included in the data set. The investigation of the respective mineralogical properties was conducted, as shown in Fig. 1.

An X-ray Diffraction (XRD) analysis was used to determine the composition of the aggregate (content ≥10 M.-%):

- Diabase (Crystal size 165 μm): Chlorite (Chl) 18.5%, Plagioclase (Pl) 13.0%, Albite 22.1%, Pyroxene (Px) 14.8% and Calcite (Cal) etc.
- Greywacke (Crystal size 45 μm): Quartz (Qtz) 50.3%, Muscovite (Ms) 22.4%

The crystal size as well as the description of the mineral structures of each aggregate type was determined on 30-μm thick segments. Thus, the effects of mineralogical composition and mineral structure could be determined with regard to the aggregate polishing resistance.

The W/S was applied to determine the development of the aggregate skid resistance after the respective polishing stages. The surface texture of the aggregate specimens was measured after the polishing test by the texture measurement tool ELATextur®.

The W/S device as seen in Fig. 2 (left) comprises two separate stations: One to allow for the simulation of an accelerated polishing processes and one for friction measurements. The polishing

Table 1
Commonly used asphalt mixture types used on federal highways in Germany and the respective composition of aggregate.

Mixture type	<2 mm	2/8 mm	8/11 mm	>11 mm
AC 11 (Asphalt Concrete)	40–50 M.-%	20–45 M.-%	5–30 M.-%	0–10 M.-%
SMA 11 (Stone Mastic Asphalt)	20–30 M.-%	20–45 M.-%	35–50 M.-%	0–10 M.-%
MA 11 (Mastic Asphalt)	45–55 M.-%	15–40 M.-%	5–30 M.-%	0–10 M.-%
PA 11 (Porous Asphalt)	5–10 M.-%	0–5 M.-%	75–95 M.-%	0–10 M.-%

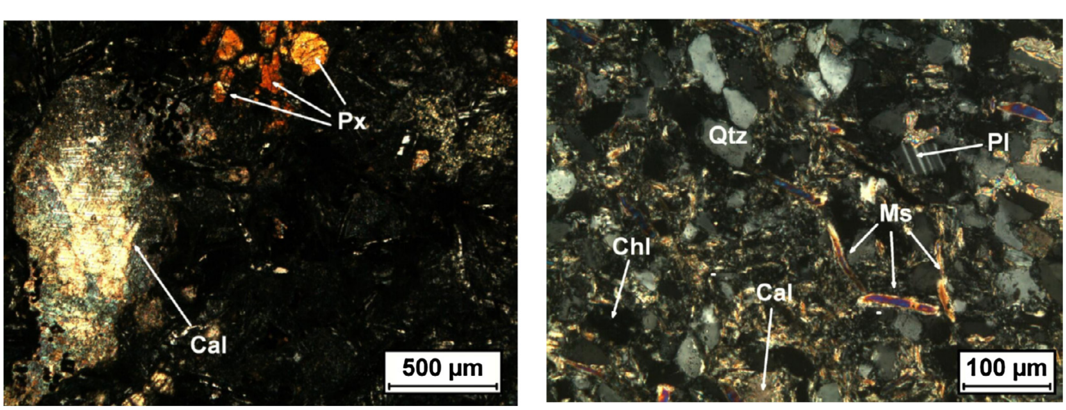

Fig. 1. Microstructure: Diabase (left) and Greywacke (right) [25].