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Evaluation of morphological characteristics of fine aggregate in asphalt pavement

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HIGHLIGHTS

- 10 fine aggregate groups with different grain sizes are evaluated with regard to angularity characteristics.
- Fine particles (<2 mm) were characterized by digital image processing.
- Sphericity, texture, and angularity were compared to sand flow test (SFT) and Uncompacted Void Content Test (UVCT).

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ABSTRACT

Aggregate makes up a high mass fraction in asphalt pavements. The morphological characteristics of aggregate (i.e., shape factors, angularity, and surface texture) significantly affect the mechanical performance of asphalt pavement. Extensive investigations of aggregate morphology have been conducted on coarse aggregate in recent years; however the analysis of fine aggregate has not been carried out up to date. Commonly used methods to extrapolate information on the morphology of fine aggregate such as sand flow test (SFT) and Uncompacted Void Content Test (UVCT) give a general characterization of the aggregate morphology without allowing for differentiated conclusions regarding the respective morphological factors. In this study digital image processing (DIP) is used to determine morphological index values of fine aggregate. Data from DIP is compared with results from UVCT and SFT by means of correlation analyses to investigate the applicability and precision of the respective methods. UVCT and SFT are found to be strongly reliable on the absolute grain size rendering the methods less resilient. DIP is very well suited to determine specific morphological indices of fine aggregates and is a useful tool for the design of asphalt mixtures.

1. Introduction

Aggregate makes up a high mass fraction in asphalt pavements. Therefore the characteristics of aggregate have a considerable influence on the construction process and the quality of the pavement [1–3]. The morphological characteristics of aggregate (i.e., shape factors, angularity, and surface texture) significantly affect the mechanical performance of asphalt pavement [4–6]

- Mixture stability [7,8];
- Resistance against fatigue cracking [9,10];
- Resistance against rutting [11,12];
- Texture and friction of asphalt pavement [13,14,2].

Furthermore, the morphological characteristics of aggregate have been proved as a vital factor in different pavement modelling methods, such as FEM [15,16] and DEM [17].

Aggregate consists of coarse (>2 mm) and fine particles (<2 mm), which both have significantly different influences on the asphalt mixture. With regard to the internal structure, coarse aggregate are generally responsible for the interlocking of aggregate, thus forming the granular structure which enhances the stability and loading/bearing capacity of asphalt mixtures [18–20]. To ensure the integrity of asphalt mixture, fine aggregate is added to the framework of coarse aggregate, which have crucial effect on the shear resistance of asphalt [20,21]. The content and the morphological characteristics of fine aggregate also directly influence the micro texture of the pavement surface, strongly influencing

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the skid resistance [22–24]. The coarse aggregate content and morphological characteristics thereof define the macro texture and the ensuing drainage capacity of the pavement surface.

Due to the particle size of coarse aggregate certain morphological characteristics can be measured by simple means such as a sphericity vernier caliper or by means of a visual analysis according to DIN EN 93-4 [4–6]. However, only a few studies investigate and quantify the characteristics of fine aggregate angularity and roughness. The two methods recommended can only evaluate the morphological characteristics of fine aggregate indirectly: Sand Flow Test (SFT, according to EN 933-6) and Uncompacted Void Content Test (UVCT, according to AASHTO T304).

Recently, Digital Imaging Process (DIP) has gained popularity and is now widely used to investigate morphological properties of coarse aggregates; the method exhibits a high accuracy accurate and is efficient. Based on captured 2D images the aggregate form [25–27,22], angularity [28–30] and texture [30,31] can be quantified. Furthermore, modifications of the investigations to include 3D morphological characteristics by means of a Fourier Transform Interferometry system [31] and X-ray Computed Tomography [4–6,32] have been realized.

In this paper, the morphological characteristics of fine aggregate are quantified with both conventional tests (SFT and UVCT) and the DIP. Based on investigations on 10 different types of aggregate, different morphological index values are calculated and the correlations between parameters are evaluated.

2. Experimental methodology/program

2.1. Selection and properties of the aggregates

Samples with different variety of rock types (Ceramic, Sand, Andesite and Limestone) and mineral contents were selected from 10 aggregate groups.

Table 1 outlines the apparent relative densities of the different fine aggregates and the respective grain sizes. According to the German guideline [35] and the former research in Austria [36], three different levels of particle sizes, 1.18 mm, 0.6 mm and 0.3 mm can be used to evaluate and classify the fine aggregate. Hence, the present tests were performed on particles separately with size: 1.18 mm, 0.6 mm and 0.3 mm.

2.2. Sand Flow Test (SFT)

According to EN 933-6, the SFT (see Fig. 1) is an indirect measurement of the morphological characteristics. It reflects the surface texture of fine aggregate by measuring the time required for a defined volume of aggregate passing through a standardized metal funnel with 12 mm diameter and 60° falling angle. By simply letting different fine aggregate groups pass throng the funnel, the morphological characteristics can be roughly evaluated by the time consumed for fully infiltration The more time taken from the test, the more friction angle can be assumed, and the more morphological characteristics of aggregate can be concluded. The average values of five tests were used in this research project.

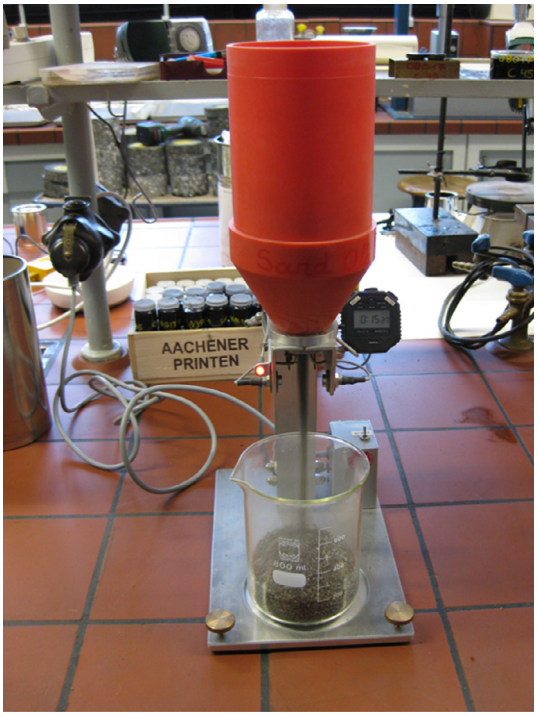

Fig. 1. Sand Flow test.

2.3. Uncompacted Void Content Test (UVCT)

The UVCT, according to AASHTO T304 is a method implemented in Superpave™ to control the pavement quality, by means of regulating fine aggregate.

The UVCT estimates morphological characteristics of fine aggregate by measuring the loose uncompacted void content of fine aggregate particles. Based on the known gradation of samples, the loose uncompacted void content can give indications about

Table 1
The apparent relative density of fine aggregate.

Aggregate type	Apparent relative density 10^3[kg/m^3]		
	Grain size 1.18 mm	Grain size 0.6 mm	Grain size 0.3 mm
1#Sand	2.646	2.667	2.663
2#Ceramic	1.561	1.732	2.016
3#Andesite-1	2.657	2.653	2.674
4# Andesite-2	2.766	2.776	2.781
5#Andesite-3	2.774	2.677	2.751
6#Andesite-4	2.854	2.800	2.805
7#Andesite-5	2.759	2.808	2.764
8#Limestone-1	2.798	2.821	2.768
9#Limestone-2	2.887	2.894	2.881
10#Limestone-3	2.807	2.771	2.771

Fig. 2. Stereomicroscope by Harbin Institute of Technology.