Measurement and Characterization of Aggregate Surface Texture

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Abstract: The surface texture of aggregates has an important influence on the amount of aggregate adsorbed asphalt and the adhesion properties between asphalt and aggregates . The purpose of this paper is to select appropriate methods to characterize and measure the surface characteristics of aggregates. To this end, the Contour GT 3D laser profiler was used to measure the surface texture of aggregates, and the aggregate surface texture parameters and the 3D scanning images of 5 kinds of commonly used aggregates in road engineering were obtained. The results show that the contour arithmetic mean deviation R_a and the contour root mean square deviation R_q can be used to describe the surface roughness of aggregates, and the height of the contour unit (R_t) of aggregate texture is about 1.5μm, which belongs to the typical mesostructure.

Introduction

The surface texture of aggregates is an important factor affecting the performance of the mixture. On the one hand, The aggregate with rough surface has a larger friction resistance, which is more likely to form a larger internal friction angle after rolling, and the mixture tend to have better shear strength and high temperature performance. On the other hand, aggregates with roughened surfaces bond stronger with asphalt, and the adhesion performance and water stability is tend to be better. In addition, since aggregates with coarse textures can adsorb more asphalt, which affects the proportion of free asphalt in the asphalt mixture[1,2,3,4].

At present, in road engineering, the research on the properties of aggregates is mainly focused on its mineral composition, particle shape, and its mineral strength, and the research on asphalt is also focused on its mechanical properties and rheological properties, and very few people pay attention to their pore and texture structure[5,6,7,8,9]. To analyze the surface properties of aggregates and asphalt, it is necessary to select appropriate parameters to characterize the porosity and texture characteristics of aggregates. On the other hand, it is necessary to use accurate test methods to accurately measure the selected parameters.

In this paper, the Contour GT 3D laser profiler was used to measure the surface texture of aggregates, and the aggregate surface texture parameters and the 3D scanning images of 5 kinds of commonly used aggregates in road engineering were obtained.

Materials and Methods

Materials

The technique performance of the five adopted mineral aggregates was tested in accordance with the methods of Aggregate for Highway Engineering (JTG E42-2005) of China[10]; the test results are shown in Table 1.

Methods

Methods for Characterizing Aggregate Texture

Aggregate surface texture is depends on the rock types, diagenesis mechanism and crushing mechanism, et al. In general, aggregate made of rock with open-grain structure, isometric structure or mosaic structure, such as marble and granite, generally cube-like, and macro texture obvious.

Besides, other factors, such as the types of crushing machinery, also affect the aggregate surface texture, and aggregates crushed by a jaw crusher may have smoother surfaces[11].

Table 1 Technique performance of different aggregates

Lithology	Crushed value/%	Cohesion with asphalt /level	Water absorption/%	Apparent relative density	Gross volume relative density
Gabbro	17.63	4	0.723	3.063	2.997
Diabase	10.7	5	0.31	2.695	2.673
Limestone	16.9	4	1.03	2.749	2.687
Basalt	8.5	4	0.54	2.928	2.882
Granite	8.3	4	0.36	2.784	2.733

In the analysis of the solid surface profile, the contour curve of the solid surface can be obtained by the intersection of a plane and a solid surface, as shown in Fig. 1.
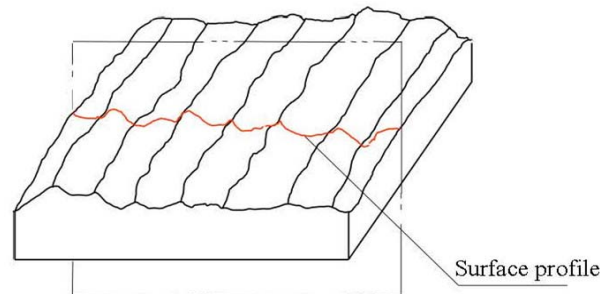

Figure 1. Schematic diagram of solid surface profile

Arithmetic median line was used to divide the surface profile into two parts of equal area. And with contour height as the vertical coordinate, the coordinate system of the surface profile curve can be established, as shown in Fig. 2.
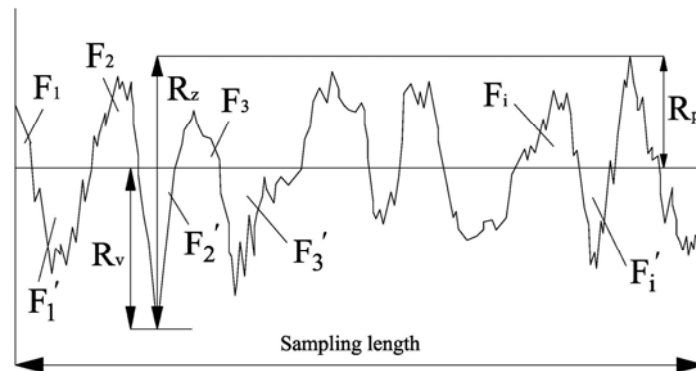

Figure 2. Schematic diagram of profile parameters

$$\sum_{i=1}^{n} F_i = \sum_{i=1}^{n} F_i' \tag{1}$$

Where Fi is the area of the i-th crest above the centerline, F_i' is the the area of the i-th trough below the midline.

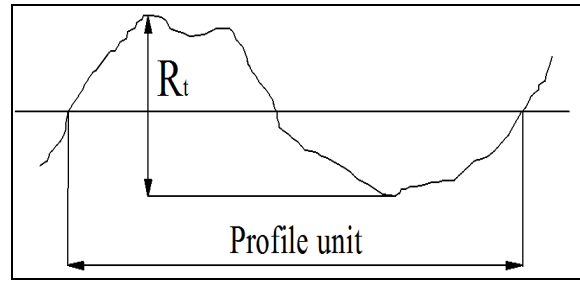A contour peak and a trough outline together is called a profile unit, as shown in Fig. 3.

Figure 3. Schematic diagram of profile unit

The parameters that can be used to characterize the solid surface profile are as follows:
(1) Maximum contour peak height (Rp)
In a sample length, the maximum contour peak height, as the Rp shown in Fig. 2.
(2) Maximum contour depth (Rv)
In a sample length, the Maximum contour depth, as the Rv shown in Fig. 2.
(3) Total height of the profile (Rz)
In a sample length, the sum of the maximum contour peak height and the maximum contour depth , as the Rz shown in Fig. 2.
(4) Height of profile unit (Rt)
Sum of the peak height and valley depth in a contour unit.
(5) Contour arithmetic mean deviation (Ra)
In a sampling length, the arithmetic mean of the absolute values of the ordinate, its continuous form is as shown in Eq. 2.

$$R_a = \frac{1}{l}\int_0^l |Z(x)| dx$$

（2）

Where l is the sampling length;
　　Z(x) is the contour height or profile depth in the x-position.
Its discrete form is as shown in Eq. 3.

$$R_a = \frac{1}{n}\sum_{i=1}^{n} |Z_i|$$

（3）

Where n is the number of sampling points；
　　Z(i) is the contour height or contour depth of the ith point
（6）Contour root mean square deviation (Rq)
In a sampling length, the root mean square value of the ordinate, as shown in Eq. 4.

$$R_q = \sqrt{\frac{1}{l}\int_0^l Z^2(x) dx}$$

（4）

In this paper, the contour arithmetic mean deviation (Ra) and root mean square deviation (Rq) were selected as parameters for characterization of the surface roughness of aggregates.

Methods for Measuring the Aggregate Surface Texture

The Contour GT 3D laser profiler was used to measure the contour parameters, and the relevant parameters are shown in Table 2.

Figure 4. Contour GT 3D laser profiler

Table 2. Operating parameters of Contour GT 3D laser profiler

Size of sample table	Light source	Objective	Measuring range	Maximum scan rate	Maximum sample quality
15cm×15cm,±6°	Dual LED light source	2.5X, 5X, 10X, 20X, 50X	0.1nm～ 10mm	2.81μm/s	4.5kg

Results and Discussion

The surface texture parameters of limestone, granite, diabase, gabbro and basalt were measured by Contour GT3D laser profiler, as shown in Table 3. The surface texture 3D scan images of the five aggregates are shown in Fig. 5.

In material engineering, generally, the structure can be divided into three levels according to the size. The size in the atomic, molecular weight (10-7 ~ 10-4cm), which is composed by the crystal structure and the molecular structure, is called the micro structure. The size range from the molecular dimension to the macroscopic size, the scale of the structural unit ranges from 10-4cm to a few centimeters, is called the mesostructure. Structures larger than a few centimeters, known as the macro structure. Table 3 and Fig. 5 show that, the Rt of 5 types of aggregates rang from 133722.544nm to 185804.592nm, belongs to the typical mesostructure. Besides, the order of the roughness of the 5 types of aggregate is that: limestone> gabbro> granite> basalt> diabase.

Table 3. Surface texture parameters of 5 types of aggregates

Types of aggregates	Limestone	Granite	Diabase	Gabbro	Basalt
Number of scanned data points	307200	307200	307200	307200	307200
R_a/nm	25604.908	21022.928	17797.36	25184.852	19891.248
R_p/nm	42822.724	45683.640	24689.118	55421.080	43742.456
R_q/nm	32061.350	29008.544	24461.092	33867.02	24837.392
R_t/nm	185804.592	173668.400	154894.96	181514.048	133722.544
R_v/nm	-142981.872	-127984.750	-130205.848	-126092.976	-89980.080
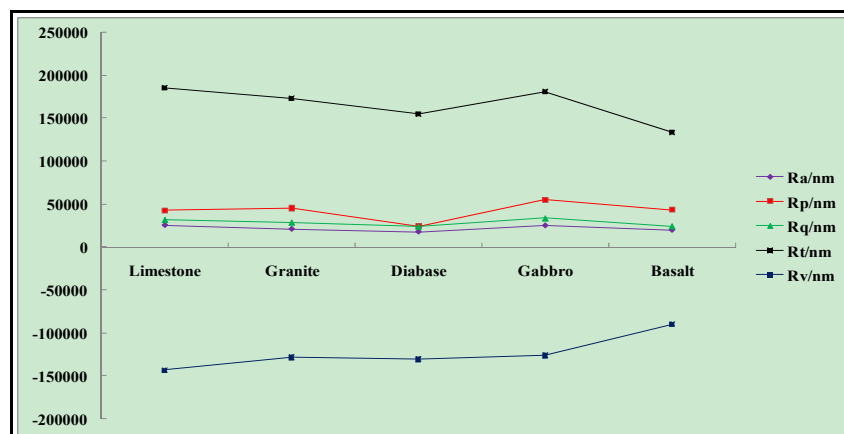
Figure 5. Surface texture parameters of 5 types of aggregates

(a) Limestone
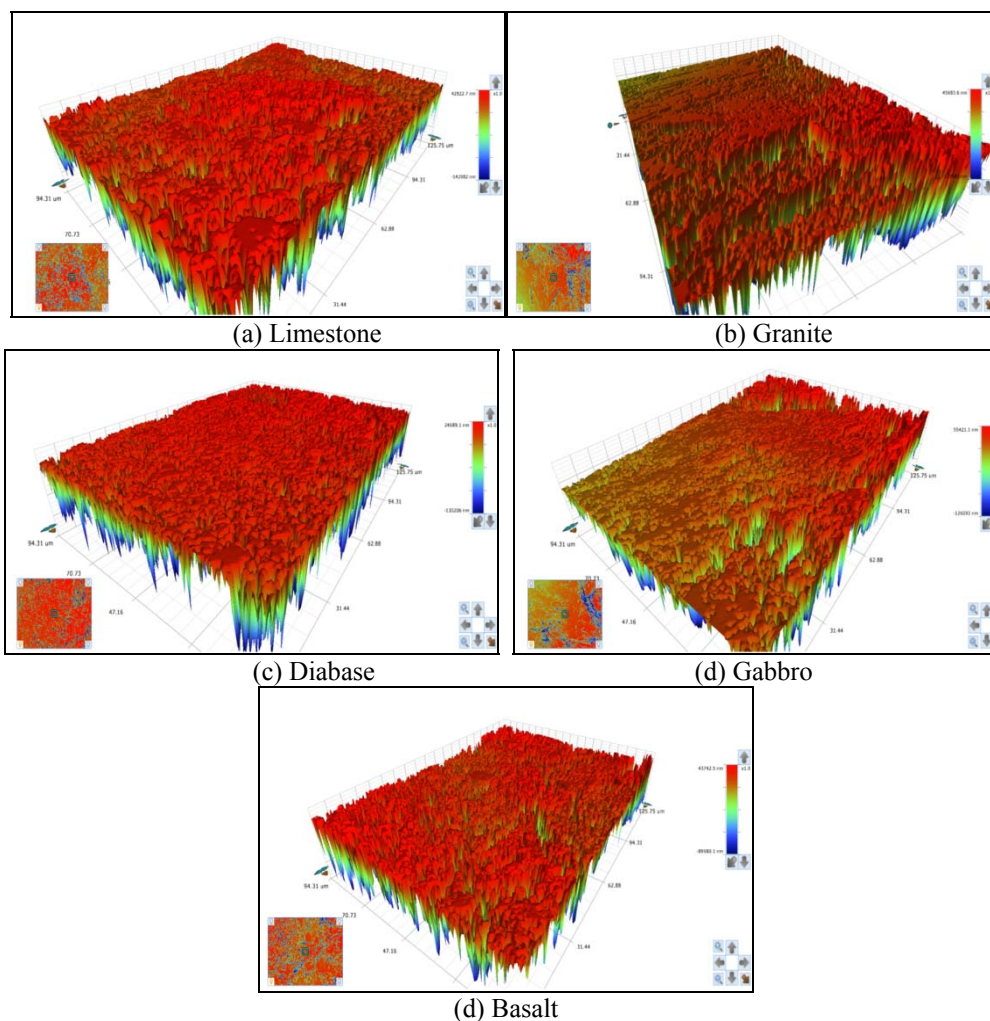
(b) Granite

(c) Diabase

(d) Gabbro

(d) Basalt

Figure 6. Scanning of aggregate surface

Conclusions

(1) The surface characteristics of aggregate affect its adhesion properties and the amount of asphalt adsorbed by aggregate, and thus affect the water stability of asphalt pavement.

(2) The contour arithmetic mean deviation Ra and the Contour root mean square deviation Rq can be used to describe the surface roughness of aggregates.

(3) The height of the contour unit (R_t) of aggregate texture is about 1.5μm, which belongs to the typical mesostructure.

(4) The measured roughness of the five kinds of aggregates is limestone> gabbro> granite> basalt> diabase.

Acknowledgment

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