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Study of movement of coarse aggregates in the formation process of asphalt mixture in the laboratory

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HIGHLIGHTS

- Use real coarse aggregate three dimensional size to generate the model.
- Study indoor hot asphalt mixture forming mechanism using two-dimensional image processing technology.
- Find the coarse aggregate crushing compaction of between 40 and 60 times.

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ABSTRACT

In this paper, attempts have been made to build an equivalent-sphere mathematical model with respect to length, width, and thickness, in order to describe the coarse aggregates of asphalt mixture in the laboratory. The values of diameters calculated separately based on lengths, widths, and thicknesses have been compared to the model with actual values, which were obtained by two-dimensional digital image processing technique. Certain characteristics of movements were observed during the formation process. The results indicate that an increase of compaction time is accompanied by an increase in average diameter of 2D coarse aggregates and its standard deviation. This shows that the rotations of the coarse aggregates and their better packing effect increase with compaction time. The results also imply that there may be a considerable breaking of coarse aggregates between compaction of 40 and 60 times.

1. Introduction

A typical asphalt pavement is made up of 86% of aggregates, 10% of asphalt cement, and 4% air-voids by volume. Generally, the morphological characters of coarse aggregates are described by the following aspects: shape, size, angularity, and surface texture. Digital image processing technique has been applied for the study of micro-structures of bituminous mixture, since the 1990s [1]. A substantially large number of researches now focus on digital image processing for two aspects, one is a two-dimensional method (2-D), the other one is a three dimensional method (3-D) [2–4]. The former approach is more cost-effective. However, the captured features and quantified parameters used to evaluate the angularity and surface texture of coarse aggregates, through 2-D imaging techniques, are in most of the published researches, just employed to study the relatively simple aggregate structure [5–11]. A few of them are applied for studying complex structures. 3-D imaging technique employs X-ray computed tomography, which is a technology using computer-processed X-ray data to reproduce images of fault areas of the scanned object, which allow the user to detect the common internal structures in a non-destructive manner. Fig. 1 is a typical CT scanning system. However, the cost of the CT is high and the 3D algorithm is complex, and even if the construction of a three-dimensional specimen is completed, the next mechanical test next would not be so satisfactory.

Another kind of recent computer simulation technology, which is based on discrete elements, such as PFC3D, provides a useful method to obtain virtual coarse aggregates. However, it is too idealistic to describe the real form of the coarse aggregates completely through a mathematical model. For a long time, researchers have been trying to clarify the changes in coarse aggregates, during the shaping process, which include location, movement, and rotation. Despite its advantage over other technologies in the research, the discrete element method is based on ideal assumptions to a great extent, to be real and feasible [12].

Compared to this method, image processing has the advantage of being reliable and to the point. To study the mechanism of

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Fig. 1. X-ray CT process during the 3-D imaging technique.

formation of the asphalt mixture indoors, the image processing technique is applied to have an in-depth understanding of the movement of the coarse aggregates in the mixture forming process.

2. Mathematical model

The main focus was on the cutting process, in order to obtain the statistical distribution of the two-dimensional equivalent diameter of coarse aggregates, assuming that the mixture was completely homogenized. Even valuable information about changes in coarse aggregates, which could not be homogenized, due to different aggregate shapes, constraints in forming space, forming methods, and so on, could still be obtained. Coarse aggregates in asphalt mixture were composed of different particles and each particle was irregular and hard to describe. Geometric description of coarse aggregate particles is a hotpot also. Researches have shown that the feasible way to establish a model is to describe the asphalt mixture based on particle size [13]. Fig. 2 shows the basic model of the sphere method and the rounds cut from it. The spheres in this model represent the sizes of the mineral particles in the mixture.

Plane diameter exist mathematical expectation, when a ball of radius R is cut. The radius of the ball is divided into n segments. Thus the radius of the plane is n possible lengths correspondingly, with a probability value of $1/n$. The definition of mathematical expectation gives Eq. (1), which can be simplified to Eq. (2).

$$E(2R) = 2\lim_{n\to\infty}\frac{1}{n}\sqrt{R^2 - \sum_{m=1}^{n}\left(\frac{m}{n}R\right)^2} \tag{1}$$

$$E(2R) = 2\sqrt{\frac{2}{3}}R \tag{2}$$

Assuming that the size of the asphalt mixture is large enough, there will be a distribution for the aspect of particle diameter. The distance from center of the sphere to cut-section is r, radius of sphere is R, and the radius of the cut-circle is $d(r)$ (see Fig. 3).

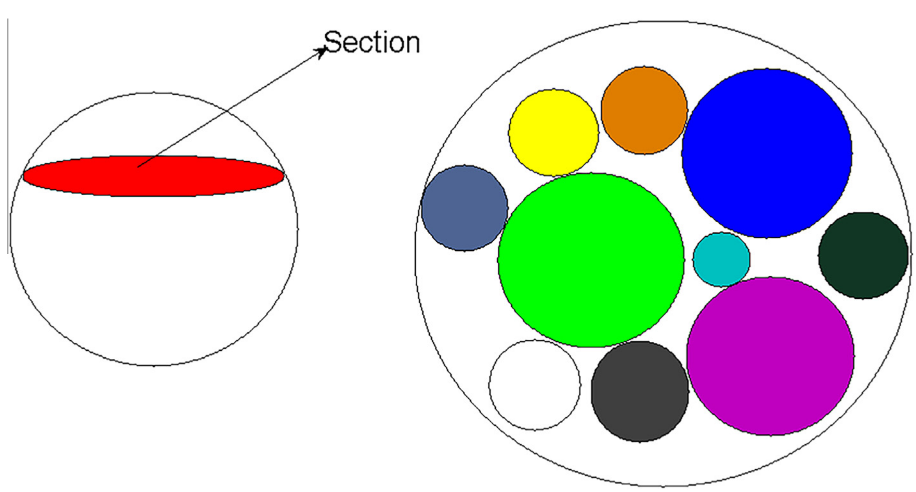

Fig. 2. Particle spheres model and cut rounds.