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# Accurate detection method for compaction uniformity of asphalt pavement

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## HIGHLIGHTS

- The reasonable detection interval of PQI is determined.
- The detection points in the road can be divided into high, medium and low density regions where the core samples are took according to proportion.
- The void distribution characteristic on sectional image of core sample is analyzed by image processing technology.
- The coefficients $UC_N$ and $UC_R$ are put forward to evaluate quantitatively compaction uniformity of asphalt pavement from the microscopic structure.

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## ABSTRACT

To evaluate the compaction uniformity effectively, firstly, the feasibility of using density and void distribution as compaction uniformity evaluation index was demonstrated by laboratory test. Secondly, relying on the project of Tong-Xun Highway, reasonable detection interval of non-nuclear density gauge PQI was determined, and quantitative evaluation index of density distribution uniformity was also proposed. Next, core samples at representative density point were drilled and of which the voids distribution characteristic on sectional image of core sample was analyzed by image processing technology, and further on, the evaluation index of void distribution uniformity was put forward. Finally, the accurate detection method of compaction uniformity based on density and void distribution was exampled relying on entitative engineering. The results show that it is feasible to evaluate the compaction uniformity of asphalt pavement with its density and void distribution. The reasonable lateral detection interval of PQI is 1.5 m, and the reasonable longitudinal detection space is 50 m. Density statistical index such as $S_r$, $S_R$, $k$ and $h$ can reflect the density distribution uniformity on detection section. Voids number uniform coefficient $UC_N$ and voids ratio uniform coefficient $UC_R$ of core samples can reflect the compaction uniformity of asphalt pavement from the aspect of micro structure.



## 1. Introduction

Ensuring quality uniformity and stability is the technical requirements which any structures and materials must meet, so the asphalt pavement must meet them to prevent the asphalt pavement from non-uniformity phenomenon, such as gradation segregation, temperature segregation, uneven compaction etc. At present, the studies on non-uniformity of asphalt pavement mostly concern about the mixture design and production stage, and most study focused on the segregation effects on the performance of asphalt mixture using the laboratory simulation method, the causes of asphalt mixture segregation and improving segregation-resistance of the mixture and evaluating segregation of the mixture are also the research hotspots. China also lacks the evaluation standard of pavement construction uniformity in the quality inspection and acceptance of asphalt pavement construction. Khedaywi found that gradation segregation caused significant decrease of indirect tensile strength, rutting resistance and water sensitivity of asphalt mixture [1,2]. Sivilevičius simulated randomly the influence of aggregate gradation and the content of fine aggregate on the uniformity of asphalt mixture [3]. Liu studied the way to relieve the segregation in asphalt pavement compaction, and found that the compaction segregation can be controlled by some technical measures such as improving the operating characteristics of stalls paver and roller machine [4]. Yang studied the relativity between envelope area of segregation

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grading curve and design gradation curve and mixture performance deviation, and proposed that the envelope area of grading curve can be used to assess quantitatively the segregation of asphalt mixture [5].

Some scholars have tried to use advanced equipment and image processing technology, such as non-nuclear density meter PQI, laser texture meter, etc to evaluate the uniformity of asphalt pavement construction. Zhang analyzed the feasibility of detecting asphalt pavement by using non-nuclear density meter PQI [6]. Chang proposed that the compaction uniformity is controlled by Intelligent Compaction and IC technology measures ICMV (Intelligent Compaction Measure Value) and gives optimal pass count [7,8]. Bao proved the feasibility of using texture depth as the judgment index of asphalt pavement segregation, and established evaluation standard of the different levels of segregation [9].Wang used image processing technology to measure the texture depth of asphalt pavement, and found that the testing method of texture depth based on image processing was convenient and accurate [10].Song handled image of asphalt pavement, and evaluated the uniformity of texture distribution of asphalt pavement by calculating the variation coefficient of the concave area fraction under the road surface [11]. On the basis of previous studies, some scholars have tried to combine the density (compactness) with the texture depth to evaluate the construction uniformity of asphalt pavement [12,13]. However, above researches which evaluate construction quality of asphalt pavement based on the macroscopic indexes such as density and texture depth cannot fully reflect the uniformity of pavement construction, especially the compaction uniformity.

Compaction degree is very important to the asphalt mixture, which influence the performance and duration of the asphalt pavement.

For the asphalt mixture, With the increase of run times of compaction, mixture particles will become closer and closer, so, in a certain volume, the solid phase increase while air phase decrease according to the solid–liquid-air phase system theory, if the pavement is detected, the two detection parameters will show such a trend that the density of the pavement increases, void ratio decreases. So density and void ratio can be used to reflect the compaction degree of asphalt pavement.

Density can reflect the overall construction quality of asphalt pavement in certain areas, and void composition and distribution could reflect the fine structure of a certain road area. The two parameters characterized asphalt pavement construction quality integrally and partially respectively. From the density and the void distribution, precise method can be established to detect the compaction uniformity of asphalt pavement. The feasibility of using density and void distribution as compaction uniformity evaluation index was demonstrated by laboratory test in the paper. The non-nuclear density gauge PQI, industrial CT system combined with image processing technique were used to detect density distribution and internal void distribution of cored from asphalt pavement, and finally an accurate detection method of compaction uniformity were put forward based on density and void distribution. The research results could provide a reference for the testing and evaluation of asphalt pavement compaction uniformity.

## 2. Experimental apparatus and method

Industrial CT: Industrial CT is the abbreviation of industrial computed tomography. The utility model can display the inner structure, the composition, the material and the defect condition of the detected object clearly, accurately and visually in the form of a two-dimensional fault image or a three-dimensional image under the Nondestructive condition to the detected object.

IPP software: IPP software was commonly used in medical and biological fields, and it had powerful function in the image size measurement and counting, classification statistics and analysis . The IPP software was used to process the CT fault image and analyze the voids in two-dimensional section, therefore, parameters such as voids number and section void ratio in fault image of core sample were obtained.

Experimental method: Voids number and section void fraction of core can be processed by Methods of mathematical statistics analysis.

## 3. Analysis on the evaluation index of compaction uniformity

### 3.1. Density distribution

AC-13 and AC-20 asphalt mixture with different gradation and segregation degree were designed in the laboratory. Uneven compaction of asphalt pavement was simulated by different compaction temperature and wheel roller. AC-13 and AC-20 gradation composition of segregated mixture are shown in Table 1. SK90# base asphalt is used.

Ran 24 times by wheel mill, non-segregation slab of asphalt mixture of AC-13 and AC-20 were formed at a temperature of 155 °C, 140 °C, 125 C and 110 °C. The bulk volume density and void ratio of each sample were measured in laboratory were shown in Fig 1.

Fig 1 showed that under the same compaction condition, the bulk density of the slab specimen increased with the forming temperature. In the range of 110 °C–140 °C, the growth rate of bulk volume density was relatively fast, however, the growth rate of the bulk volume density became slow when the temperature exceeded 140 °C. In contrast to the change trend of the volume density, the void ratio of the specimen decreased rapidly with the forming temperature, and decreased slowly when the temperature exceeded 140 °C. When the temperature surpassed 140 °C, the void ratio of the slab specimen could reach the design requirement, which indicated that rising temperature over a certain temperature had slight effect on compaction characteristics of the mixture. It was because that as temperature exceeded 140 °C, the mixture was at stable condition, and the compaction of asphalt pavement would not be affected by different temperatures in this rang.

Asphalt mixture slab specimens with various segregation degrees were formed by different wheel run times 12, 18, 24, 30, 36 and 42 times respectively. The cylindrical samples were drilled from the slab specimen, and then the bulk volume density of each specimen was measured by submerged weight in water method, as shown in Fig 2.

It can be seen from Fig 2, for AC-13 and AC-20mixture, the density of asphalt mixture of different degrees of segregation showed the same trend with the rolling compaction times. With the increase of rolling times, asphalt mixture density first increased rapidly, then slowly increased to the peak, and then with the continued rolling times, the density of the mixture decreased slightly. It was because that, in a certain range, with the increase of rolling compacted times, voids of asphalt mixture decreased gradually which shown up as a mass increase in a certain volume of asphalt mixture. However, when the rolling times exceeded a certain times, the density would decrease.

In summary, the variation of compaction processes such as compaction temperature and rolling compaction times would significantly affect the asphalt pavement density. The asphalt pavement density could be used to characterize the construction quality of asphalt mixture in general, and it was feasible to evaluate the compaction uniformity of asphalt pavement with the density distribution.