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Consistent distribution of air voids and asphalt and random orientation of aggregates by flipping specimens during gyratory compaction process

Ashkan Bozorgzad, Hosin "David" Lee *

Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, IA 52242, United States

HIGHLIGHTS

- Uniform vertical distribution of air void in asphalt mixture by filliping ample during compaction.
- Better orientation of aggregate in asphalt mixture by new method of compaction.
- Better vertical distribution of bitumen in asphalt mixture by flipping samples in gyratory compaction proses.

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ABSTRACT

The current Superpave mix design determines the optimum asphalt content that would produce asphalt specimens with total air voids of 4.0% without considering their sizes and distribution within the specimens. In addition, the current Superpave gyratory compaction equipment may produce inconsistent specimens with higher air voids on the top layer than the middle and bottom layers of the specimen. To produce more consistent gyratory specimens, a new approach of compacting both ends of the specimen, rather than the one side, is presented. Based on the automated image analysis of twenty-four specimens, the difference in air voids between top and bottom layers decreased when specimens were compacted on both ends. In addition, the standard deviations of both air voids and asphalt contents throughout the specimen decreased when the specimens were compacted on both ends. Therefore, it can be concluded that the air voids and asphalt contents were more uniformly distributed throughout the specimen when the gyratory specimens were compacted on both ends. Based on the angles between major axes of aggregates and horizontal plane, the aggregates were more randomly oriented when compacted on the both ends.

1. Introduction

The internal structure of asphalt mixtures, which consists of aggregates, air voids and asphalt, plays an important role in the performance of asphalt pavements [5] [13]. The main purpose of the asphalt mix design is to identify optimum aggregate structure, asphalt content and air voids. The current Superpave mix design procedure determines a total asphalt content to achieve total air voids of 4.0%. However, it does not ensure a consistent internal structure of the asphalt mixtures with uniform distribution of asphalt content and air voids and the random orientation of aggregates [11]. Distributions of asphalt contents and air voids within asphalt mixtures are significantly affected by a compaction procedure. In the past, an X-ray computed tomography (X-ray CT) system was used to identify the effect of various compaction levels on distribution of large air voids and aggregate orientation [7] [12,10]. The effect of compaction methods, such as gyratory and vibratory equipment, on the aggregate orientation within asphalt mixtures has been also studied [9]. In another study, the gamma-densitometer was used to measure a distribution of air voids of field and laboratory compacted specimens [8]. There are a number of researchers that have used numerical methods to predict and model internal structure. In these studies the non-uniform internal structure of mixture was major assumption [3,4,7]. In other studies, the effects of non-uniform internal structure on mechanical properties of mixtures were investigated by numerical modeling [1,2].

In the past, a significant research effort has been made on identifying a distribution of air voids and an aggregate orientation within a gyratory compacted specimen. However, none of them addressed specific means to produce a compacted specimen with

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* Corresponding author.
E-mail addresses: ashkan-bozorgzad@uiowa.edu (A. Bozorgzad), hlee@enginering.uiowa.edu (H."David" Lee).

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more uniformly distributed air voids and randomly oriented aggregates. In this paper, a comprehensive analysis of a compacted specimen's internal structure is presented along with a means to improve an internal structure by flipping it in the middle of gyratory compaction process.

Distributions of large and small air voids and the orientation of aggregates, with and without flipping the specimens, were automatically measured using an image analysis system. For detecting air voids, X-ray CT was used and, distributions of asphalt contents, with and without flipping a specimen, were measured using a burn-off oven.

2. Superpave gyratory compacted specimens

Fig. 1 shows a gradation plot of limestone aggregates with a maximum size of 0.5 in. and the bulk specific gravity of 2.71. Fig. 2 shows a plot of air voids versus asphalt content and the volumetric properties corresponding to 4.0% air voids are summarized in Table 1. To determine the optimum asphalt content, a Superpave mix design was performed using PG 64-22 asphalt and the optimum asphalt content was determined as 5.67% under a medium traffic level of 76 gyrations.

Using a normal one-side compaction procedure, two specimens were prepared for each combination of three asphalt contents of 5.17%, 5.67% and 6.17% (optimum asphalt content and ±%0.5) and two gyration levels for medium and high traffic levels of 76 and 96 gyrations. Additional twelve samples were prepared by flipping after reaching to a half gyration level, 38 and 48 gyrations, then, the compaction process was repeated (both-side compaction). To minimize a heat loss during the flipping process, as shown in Fig. 3 two separate molds were used. During the first half of gyration, the second mold was placed in the oven in order to maintain the compaction temperature. After finishing the first half of gyration, as shown in Fig. 3, the specimen was extracted into the second mold and compacted for the second half of gyration.

Air voids of twenty four samples are summarized in Table 2. As shown in Fig. 4, as expected, the air void decreased as both the number of gyration and the asphalt content was increased. It should be noted that, in most cases (five out of six), air voids decreased when the samples were compacted on both sides.

2.1. Preparation of samples

The main objective of this research is to identify the differences in air voids distribution, aggregate orientation and asphalt distribution between one-side and both-side gyratory compacted asphalt mix specimens. The following steps were made in order to prepare samples for air void, aggregate orientation and asphalt distribution analysis:

1 As shown in Fig. 5, each specimen was then sawed vertically into four sections. Two 2-cm thin parts in the middle were used for analysis.
2 The gyratory specimens, with heights ranging between 155 and 160 mm (Average height of the specimens were 156 mm and 158 mm for 96 and 76 gyrations, respectively), were sawed at each end to obtain a consistent height of 145 mm. The height of 145 mm was chosen to ensure that the heights of all specimens would be same.
3 As shown in Fig. 6, each sample was divided into nine regions that is a combination of three horizontal layers and three vertical columns.
4 One sample was used for analyzing a distribution of large air voids (larger than 0.5 mm in diameter) and measuring an aggregate orientation. The other sample was used for analyzing distributions of asphalt contents.

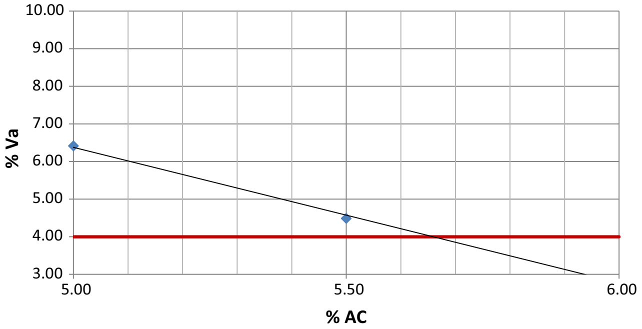

Fig. 2. Air void percent versus asphalt binder content.

Table 1
Mix design volumetric properties.

Mixture property	Value	Specification
Target air voids (%)	4.00%	–
Optimum asphalt content (%)	5.78%	–
VMA (%)	18.9	14.0% Min.
VFA (%)	78.8	65%–78%
Dust-binder ratio	0.61	0.6–1.4
Film thickness, μm	13.00	8.0–15.0
Compaction temperature	145 °C	–
Specimen height	155 mm-160 mm	–

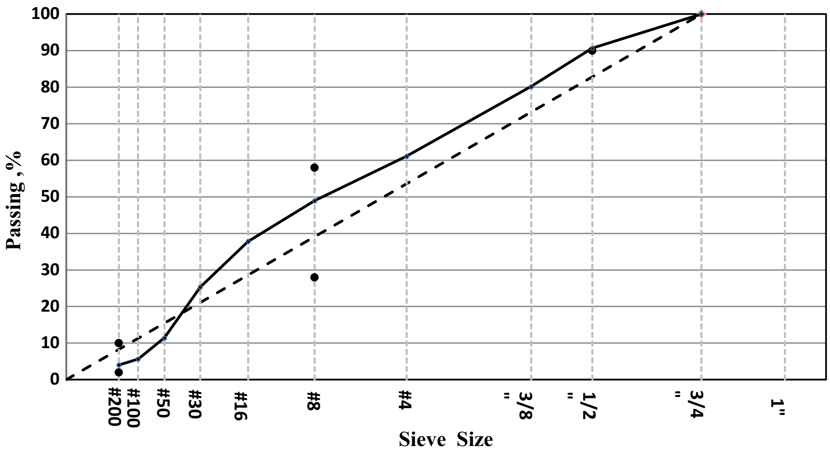

Fig. 1. Gradation of aggregates for a medium traffic level.