Measurement 90 (2016) 151–157

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Effect of compaction procedure on air void structure of asphalt concrete

Rafiqul A. Tarefder, Mohiuddin Ahmad *

Department of Civil Engineering, University of New Mexico, MSC 01 1070, 1 University of New Mexico, Albuquerque, NM 87131, United States

ARTICLE INFO

Article history:
Received 23 September 2015
Received in revised form 1 March 2016
Accepted 25 April 2016
Available online 26 April 2016

Keywords:
Compaction
Gyratory
Kneading
Permeability
Pavements

ABSTRACT

Past studies found a significant difference of strength between laboratory and field compacted asphalt concrete (AC). This study evaluated the pore structure of AC compacted by gyratory compactor, linear kneading compactor (LKC) and field cores. The different components of pores were determined and compared for different compaction procedures. The variation of permeability as well as moisture damage of samples prepared by different compaction procedures was also compared. It was observed that the pore structure of field samples is totally different from linear kneading compacted and gyratory compacted samples. Permeability of field samples does not depend on the level of compaction as much as for laboratory compacted samples. The indirect tensile strength (IDT) of field samples is always less than gyratory samples and more than linear kneading compacted samples. Field samples and linear kneading compacted samples are more susceptible to moisture than the gyratory compacted samples.

1. Introduction

1.1. Evolution of laboratory compaction procedures

Asphalt materials have been used in pavements for more than 150 years. As the use of asphalt mixtures increased, the need for a mix design was necessary so that the pavement was safe, cost effective and good performing. Therefore, it was required to prepare samples in the laboratory. It was expected that laboratory samples would have the same properties (i.e. stiffness, fatigue resistance, permeability, etc.) as field compacted samples so that a mix design could be implemented properly in the field. To prepare samples in the laboratory that have the same property as field samples, different compaction procedures were developed by different researchers around the globe. They include the Hubbard-Field method, Marshal Method, Hveem Method, French Roller Method, etc. The most recent development is the Superpave gyratory compactor.

1.2. Precision of the methods available

The Marshal method uses impact load to densify the mix to a certain air void. However, because of the impact, same aggregate orientation as in the field cannot be obtained. The Superpave gyratory compactor tries to include shear movement of the particles by adding an angle of gyration as in the field due to the roller compactor. Also, it uses the same pressure as in the field by static roller [1]. Independent studies made by Consuegra et al. [2] and Button et al. [3] showed that a Texas gyratory compacted sample had strength indicators (resilient modulus, tensile strength, creep compliance, etc.) very close to field samples compared to other non-gyratory compactors. Khan et al. [4] evaluated the effect of the gyration angle and found that for the gyration angle of 1.25°, laboratory samples showed similar behavior to that of field samples. Peterson et al. [5] showed that a gyration angle of 1.5 produced samples with closer results to the field. Jonsson et al. [6] showed that none of the laboratory compaction methods could produce a sample where particles were evenly distributed as in the field. Very few studies have been made using the linear kneading compactor (LKC) [7,8]. Masad et al. showed that gyratory compacted samples have more air void near top and bottom surfaces [9]. For LKC, pores are more near the bottom surface. However, they didn't discuss the connectivity of the pore for different compaction effort.

Kok et al. showed that for the same air void content, laboratory compacted samples always show better performance than field compacted samples [10]. An independent study by Kekana and Steyn [11] and Cross and Lee [12] yielded same conclusions. Air void has a great influence on laboratory compacted tensile strength whereas tensile strength of field cores are not affected much by air voids. The reason may be that the orientation of particles is different from each other. The internal structure (volumetric and texture) of gyratory compacted and slab sample were compared by Pratico and Vaiana [13].

* Corresponding author.
E-mail addresses: tarefder@unm.edu (R.A. Tarefder), mahmad@unm.edu (M. Ahmad).

http://dx.doi.org/10.1016/j.measurement.2016.04.054
0263-2241/

1.3. Need for pore structure, permeability and moisture damage comparison

All the studies mainly focused on the mechanical properties immediately after compaction. However, other properties such as permeability pore structure and moisture damage for different compaction procedures have not been studied yet. Understanding these properties is very important to evaluate the long time performance of a pavement. A study made by Tarefder and Ahmad [14] showed that permeability affects moisture damage significantly. Pavements with higher permeability undergo higher moisture damage and vice versa. Therefore, permeability during mix design needs to be controlled. Pore structure is another factor that may affect permeability, aging, moisture intrusion and damage, etc. Study by Tarefder and Ahmad [15] evaluated that permeability is greatly affected by permeable pores. Tarefder et al. [16] show that moisture damage reduces the dynamic modulus of a pavement. Therefore, pore structure, permeability and moisture damage of laboratory compacted samples need to be compared with field samples to evaluate the compaction procedure.

1.4. Studies on pore structure

Pore structure of asphalt concrete was evaluated by several researchers. Ranieri et al. [17] used X-ray tomography, Liang et al. [18] used image processing, and Omari [19] used X-ray CT scan. All of these methods are expensive and time consuming. Tarefder and Ahmad [15] used tracer method and ASTM D6752 to evaluate pore structure and permeability together which is very quick and less expensive. Tracer method consists of a saltmeter attached to a permeameter and it is a very popular method to determine permeable pores in soil [20–22].

2. Definitions

2.1. Different type of pores

Different type of pores of asphalt concrete can be classified in the following categories:

- *Total pores:* The term total pore in this study is used to denote all type of pores together. Total pores do not include intra-particle pores.
- *Effective pores:* Pores that are permeable to water are termed as effective pores. Some of the effective pores are permeable to water but do not conduct water.
- *Permeable pores:* Pores that continue from top to the bottom of a sample. These pores are responsible to conduct water from one end to other end of the sample. This type of pore is determined by tracer method described later in this study.
- *Dead end pore:* Pores that start at one end, but do not continue to the other end. Holds water after precipitation until evaporation. It is the difference between effective and permeable pores.
- *Isolated pores:* These types of pores are not permeable to water. It is determined by subtracting effective pores from total pores.

Those type of pores are shown in Fig. 1.

2.2. Permeability

Permeability is the material's ability to conduct water from one side to other side of a sample. It is determined using Darcy's law by either falling head or constant head procedure.

3. Objectives

The objectives of this study are:

(1) To evaluate the difference of pore structure of laboratory compacted samples from field collected cores.
(2) To evaluate of effect of compaction procedure on permeability, tensile strength and moisture damage of asphalt concrete.

4. Methodology

Three compaction methods were considered during this study: (i) Superpave gyratory compaction, (ii) Linear kneading compaction (LKC), and (iii) Field compaction. Fig. 2 provides the brief description of the job performed during this study. Field mixes were used to prepare laboratory compacted samples. Gyratory compactor was used to prepare cylindrical sample and LKC was used to prepare slab samples. At the same time, samples were collected from 9 pavements from different Districts of New Mexico, instead of one location to get a wide range of air void. Cores were collected from shoulders so that it is not compacted by traffic. Total pore and air void were used interchangeably in this study. All samples were tested for total pore and effective pore using ASTM D6752 [23]. Permeability and permeable pores of each of the samples were determined using tracer method which is simply a saltmeter attached to a permeameter. Knowing total pore, effective pore and permeable pores, dead-end and isolated pores were easily determined. Indirect Tensile Strength (IDT) for a set of samples from all three compaction procedures was determined. Moisture conditioning of the samples was done using AASHTO T283 [24] and Moisture Induced Sensitivity Testing (MIST) procedures. Tensile strength of conditioned sample to dry sample was compared to find the degree of moisture damage.

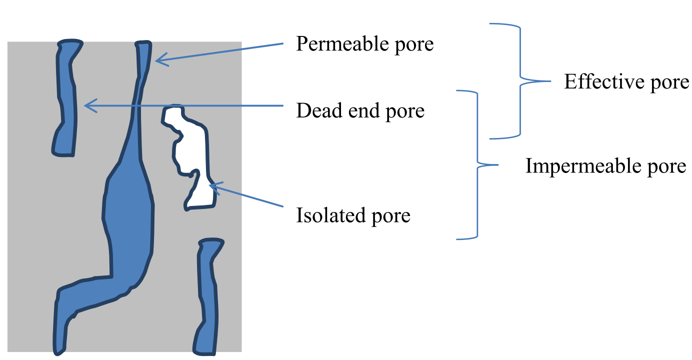

Fig. 1. Different type of pores in asphalt concrete.