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Comparison of methods for measuring porosity of porous paving mixtures

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HIGHLIGHTS

- The method used to test porosity in porous pavements has a measurable impact.
- The largest difference between two methods was approximately 3–5%.
- The measurement of the sample's volume contributes significantly to differences.

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ABSTRACT

The porosity of porous paving mixtures is critical to their performance and is a commonly measured parameter. However, as there are a number of methods to measure the porosity of a specimen, this research addressed how these different methods compared to one another and identified where differences in measurements arose. The four methods tested were the Corelok, Montes et al., vacuum, and image analysis methods (listed in order of increasing porosity measurements for the same specimens). All four methods, as well as variations of methods, were found to be statistically different except for the vacuum and image analysis methods. The Corelok method measured lower porosity values than the soak/tap and vacuum methods due to how the total specimen volume was measured, though once the difference in volume was accounted for, it fell between those two methods. The soak/tap and vacuum methods measured similar porosities for higher porosity samples (>25%), but due to the efficiency of the vacuum at removing entrapped air pockets from smaller voids, the vacuum method recorded higher porosity values for specimens that had lower porosity (<25%).

1. Introduction

Porous pavements are often used as an alternative to conventional pavements due to their higher porosity and permeability. Allowing stormwater to drain through the pavement instead of across it reduces runoff quantity, thereby reducing flooding conditions downstream and increasing ground water recharge, and improves runoff quality [3,4,5,6]. Introduction of such material to a project can potentially cut construction costs by eliminating the need for larger storm sewers, catch basins and curbs [15]. Additionally, porous pavement has a significant safety impact as they reduce both hydroplaning and visibility issues such as splash and spray [8,14].

Porosity is a material property that is critical to the proper function of porous pavements. The hydraulic conductivity and clogging characteristics are both strongly dependent on porosity. Porous pavement materials actually have two porosity values. The first is the total porosity or the fraction of the volume of all the voids divided by the total volume of a pavement. The second is the effective porosity, which is the fraction of the volume of the voids that are accessible divided by the total volume. The effective porosity is often the controlling value for hydraulic behavior, since the inaccessible voids cannot contribute to water storage or flow.

There are a number of different porosity measurement methods that are commonly used or have been proposed for use. While the different methods all are trying to measure the porosity, because they measure the volume of voids or the total volume of the specimens differently, the method used will have an impact on the measured porosity value. The objective of this research was to quantify how four different porosity testing methods compare to each other and how the results of each method were correlated. The four methods studied were:

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- Corelok – The Corelok method measures the effective porosity and is based on the vacuum sealing method outlined in ASTM D7063/D7063M [2]. It is primarily for bituminous pavement mixes, but its scope does cover other materials including concrete cylinders.
- Montes et al. [11] – The Montes et al. [11] method was developed specifically to measure the effective porosity of porous pavement and is based off of the basic theory of porosity. It uses direct measurement of the specimen dimensions to calculate the total specimen volume and a water bath to determine the volume of voids.
- Vacuum – The vacuum method is similar to the Montes et al. [11] method, except that a vacuum is used to remove any entrapped air from the specimen prior to the water bath.
- Image analysis – This is the most different of the four methods as it uses a 2-dimensional image of the pavement specimen to calculate an areal porosity to approximate the spatial porosity.

2. Experimental materials and methods

To achieve the objectives of this study, the porosity of 230 porous paving mixture specimens from seven different projects were measured using the four different methods. The porous paving mixture types evaluated in this study included porous asphalt, pervious concrete, and porous rubber pavement material as indicated in Table 1. The specimens included both field cores and lab produced specimens.

The four different methods that were used to measure the porosity of porous paving mixture specimens in this study were the Corelok method (ASTM D7063), Montes et al. method (soak and soak/tap versions), vacuum method, and image analysis method.

2.1. Corelok method

The first method was the vacuum sealing method outlined in ASTM D7063 [1]. The specimen was vacuum sealed, using the Corelok® vacuum sealer, inside a bag having a mass, B, and then submerged underwater and weighed both sealed, E, and unsealed, C. The porosity, Φ, was found as

$$\Phi = \frac{SG2 - SG1}{SG2} \times 100 \quad (1)$$

$$\text{Bulk specific gravity} = SG1 = \frac{A}{B - E - \frac{B-A}{F_T}} \quad (2)$$

$$\text{Apparent specific gravity} = SG2 = \frac{A}{B - C - \frac{B-A}{F_{T1}}} \quad (3)$$

where A is the dry mass of the specimen and F_T and F_{T1} are the apparent specific gravity of the plastic sealing material when sealed and unsealed, respectively.

This method was originally developed to determine the effective porosity and air void content of bituminous paving mixtures and has been recommended for measuring the porosity of porous pavement.

2.2. Montes et al. [11] method

The Montes et al. [11] method was developed specifically for porous pavement and is based on the basic theory of porosity. First, the dry weight, W_{dry}, and the volume, V, of the specimen is recorded. The volume was calculated for the specimens by measuring the height, H, in four different locations and the diameter, D, in three different locations on the top and bottom (six total

Table 1
Description of porous paving mixture specimens.

ID	Material	Number of specimens	Description
PA 1	Porous Asphalt	12	150-mm diameter by approximately 115-mm tall specimens were compacted in the lab with plant produced mix using 50 gyrations of a Superpave gyratory compactor. The mix was used in the construction of a porous asphalt pavement at Parris Island, SC
PA 2	Porous Asphalt	24	150-mm diameter cores drilled from porous asphalt pavement sections constructed in Aiken, SC
PA 3	Porous Asphalt	30	150-mm diameter by approximately 115-mm tall specimens were compacted in the lab with lab produced mix using 50 gyrations of a Superpave gyratory compactor. Three specimens were compacted for each of ten aggregate gradations as part of another study [9]
PC 1	Pervious Concrete	59	150-mm diameter specimens having variable heights. The specimens were a mix of cylinders that were cast at the time of placement and cores that were cut from cured pervious concrete pavements in Aiken, SC and August, GA. The 300-mm tall cylinders were cut into 75-mm thick slices. The cast cylinders were also compacted using different methods [13]
PC 2	Pervious Concrete	14	Cores that were cut from a pervious concrete pavement in Conway, SC. The cores had diameters of 50, 75, 100, and 150-mm and were cut in half vertically prior to porosity measurement
PC 3	Pervious Concrete	92	150-mm diameter by 150-mm tall specimens cast in the lab and compacted using twenty blows with a standard Proctor hammer
RP 1	Rubber Pavement	6	150-mm diameter specimens having heights ranging from 50 to 85-mm of a rubber paving material. Three of the specimens were cast in the lab and three were cored from an existing paved area in Columbia, SC