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Proceeding Paper

Intervention Time of Porous Asphalt Mixture Evaluation to Prevent Clogging †

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Abstract: Porous pavements are considered an alternative to increasing the city's permeable surfaces with great potential for rainwater harvesting. Over time, the surface layer clogs, limiting porous pavement application and use. This study aims to evaluate the maximum time for an intervention of a porous surface to recover its permeable properties before clogging. Through a constant load permeameter, rainwater runoff simulations were performed to measure the permeability coefficient of porous asphalt mixtures. Void content and interconnected voids were also evaluated. The permeability showed a good indicator for determining to clog and, by regular measurements, the necessary intervention time to prevent it can be established. The designed porous mixture surface intervention should occur every year.

Keywords: porous asphalt mixture; clogging; intervention time

1. Introduction

The growing urbanization process of the cities led to an increase in impermeable areas, generating changes in the natural characteristics of watersheds. Consequently, the recharge of springs and groundwater was compromised, and with the volume of surface runoff increased, risks of floods and inundations occurred. An alternative for integrated rainwater management is using porous pavements and surfaces.

The porous pavement surface is mainly composed of porous asphalt mixtures, produced with small or no fines to form an open-graded structure and allow water to flow through it. The open gradation results in higher voids (18–25%) content as compared to dense-graded mixtures [1,2]. On the other hand, fine aggregates contribute to mixture strength and durability but increasing its proportion compromises the permeability, which is negligible if the void content is less than 14% [3].

Zhang et al. asserted that studies had shown porous mixtures' benefits related to dense ones. Due to the interconnected porosity, the water flows out of the pavement during rainfall, avoiding accumulating on the surface. The road safety improvements include more skid resistance and hydroplaning reduction [4].

The infrastructure can introduce low-impact development models through increasing permeable areas such as green spaces, porous pavements, and water systems. These models allow rainwater to be absorbed, retained and released to reduce runoff volume and peak flow, slow down runoff speed, replenish groundwater, and filter rainwater pollutants [5,6]. However, the water precipitated on the pavement surface carries contaminants and powdery materials (runoff), which, over time, lead to the progressive clogging of the voids.

Due to clogging, functionality is affected, and the porous pavement (or surface) cannot propitiate drainage. Also, the porous surface suffers damage due to water stagnation inside. The rate of clogging depends on factors such as pavement surface, voids content,

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traffic load, pavement slope, maintenance measures adopted, and environmental and local conditions [7]. The clogging progression evaluation can be performed in the field or the laboratory using permeameters.

Porous surface pavement layers contribute to stormwater management, reducing surface runoff and representing a benefit. On the other hand, the voids of porous layers clog over time, and the permeable characteristics decrease. Because of this, many road agencies averted the pavement porous surface layer applications.

In order to contribute to advancing the use of porous mixtures as a pavement surface layer, the primary motivation of this study was to evaluate the clogging by simple permeability tests. Thus, permeability reduction enabled establishing the needed intervention time to restore porous mixture permeable characteristics. This study aims to evaluate the maximum time for an intervention of a porous mixture to recover its permeable properties before clogging.

2. Methodology

In this study, the clogging progression of a porous asphalt mixture was measured in the laboratory to evaluate the maximum intervention time for recovery of the permeable properties. The porous asphalt mixtures were produced with asphalt rubber fabricated at the Brazilian refinery (terminal blend) with 15% incorporated rubber. Aggregates of granitic origin from southern Brazil were used, whose gradation curve is shown in Figure 1.

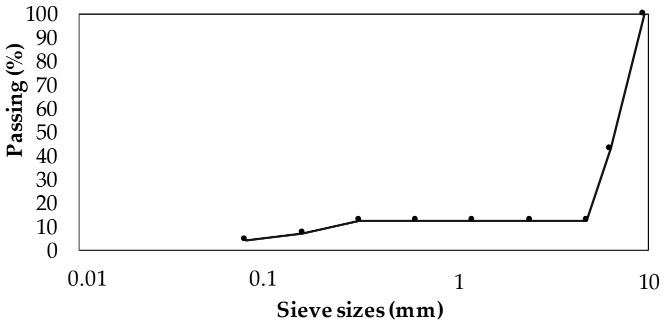


Figure 1. Mixture gradation curve.

The mixture design was performed according to the ASTM D 7064 standard [8] in the CGS (660 kPa, angle 1.25°, 50 gyrations) and resulted in an asphalt content of 5.0% and void volume of 24.2%. Figure 2 presents the experimental methodology procedure.

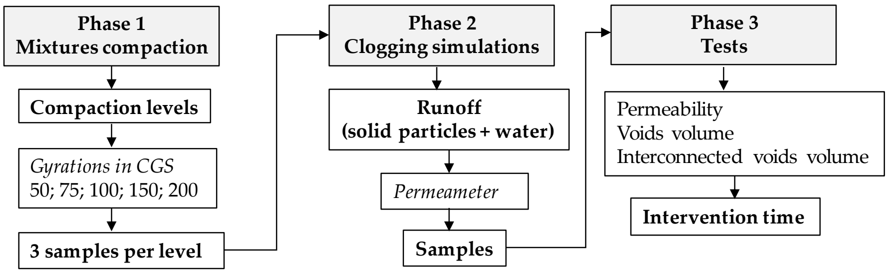


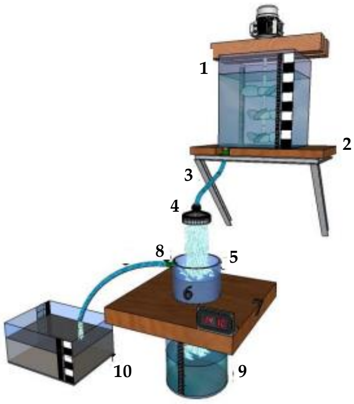
Figure 2. Experimental procedure.

To simulate the traffic influence on the mixture air voids reduction, in Phase 1, the samples (100 mm in diameter; 63.5 in height on average) were molded at different compaction levels in the Superior Performing Asphalt Pavements (SUPERPAVE) gyratory compactor (CGS) through increasing gyrations number (50—reference, 75, 100, 150 and 200). Three samples per level were produced to perform the tests.

The solid material accumulated under an overpass on a medium-traffic road was collected to compose the solid particles of runoff. After drying in an oven, the solid material was selected by sieving, and the fraction retained on sieve No. 100 (0.149 mm) was used, according to the study by Fwa et al. [9]. Adjustments were made to the amount of material for the sample dimensions of this study, resulting in 3.53 grammes. In the runoff solution to promote the sample clogging, 3.53 grammes of the solid material was added in one water litre. The runoff solution was introduced into the reservoir (Figure 3), and the samples were submitted to simulation cycles in a constant head permeameter developed by the authors in this study (Figure 3). The permeability coefficient was calculated through Equation (1). For porous materials, Fwa et al. [9] defined a constant (n of 0.70) to minimize the significant error between readings in tests with in-laboratory permeameters, which was also adopted in this study.

The initial permeability coefficient (k_i) was determined using water, and after five simulations with runoff solution, the final permeability coefficient (k_f) was measured. For each sample, the voids volume and the interconnected voids volume were evaluated before and after the simulations. It was used as a criterion; that means the sample was considered clogged when the interconnected voids volume reached 12%.

For each sample group, the permeability coefficient reduction (kr)was calculated as a function of the mean values distribution (Equation (4)) and the uncertainty range (Equation (5)). The maximum intervention time in months was established from the number of simulations to reach the criteria, considering the annual precipitation average of Florianópolis (1570 mm). In this way, for this precipitation, each simulation cycle represents 261.67 mm, and one cycle corresponds to two months.



Legend

1. Reservoir (volume 5 litres)
2. Reservoir support elevated 50 cm from the sample
3. Hose (diameter of 10 mm)
4. Plastic shower for water flow control
5. Plastic mould in which the sample is inserted
6. Sample with lateral waterproofed by silicone
7. Support to fixed the sample
8. Spillway (3/8″ gauge) to keep the water level above the sample
9. Water collector from the spillway

Figure 3. Constant-head permeameter developed in the study.

$$k = V/i^{n} \quad (1)$$

$$V = Q/t \times A \quad (2)$$

$$i = H/L \quad (3)$$

$$kr = a \times e^{-bN} \quad (4)$$

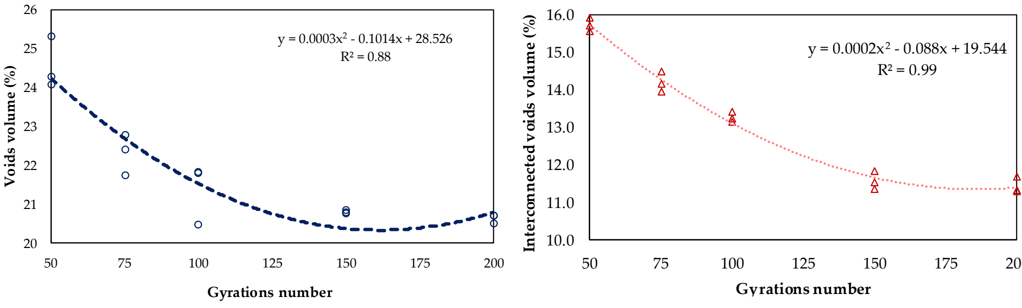
$$u = \mu + u \quad (5)$$

where k is the permeability coefficient (mm/s); V is the runoff speed (mm/s), given by Equation (2); i is the hydraulic gradient (dimensionless), given by Equation (3); n is the constant [9] equal to 0.7; Q is the drained volume mm^3); t is each cycle simulation time (s); A is the top surface area of the sample (mm^2); H is the height of water layer (mm); L is the sample height (mm); kr is the permeability coefficient reduction (mm/s); a and b are regression coefficients; N is the number of simulations; u is the uncertainty range; μ is the mean of permeability coefficient (mm/s); u is the standard deviation (mm/s).

3. Results and Discussion

3.1. Influence of Compaction Effort in the Voids Reduction

In function of the gyrations number, Figure 4a presents the voids volume reduction and Figure 4b for the interconnected voids volume.



(**a**) (**b**)

Figure 4. Voids reduction in function of gyrations number. (**a**) Voids volume; (**b**) Interconnected voids.

In Figure 4, it can be observed that as the level of compaction effort increased, the voids decreased. After 100 gyrations, the voids volume tended to stabilize with average values of 21.34%, 20.76% and 20.62% for 100, 150 and 200 gyrations, respectively (Figure 4a). The interconnected voids volume reduction with the compaction effort increase indicated a decrease in permeability (Figure 4b). Similarly, there was a tendency for values to stabilize after 100 gyrations, being, on average, 13.25%, 12.63% and 12.23% for 100, 150 and 200 gyrations, respectively.

3.2. Influence of Compaction Effort in the Permeability Coefficient Reduction

Table 1 shows the initial permeability coefficients (ki) measured before and the final one (kf), evaluated after simulations. The values were normalised for the permeability coefficient reduction (kr) analysis through the obtained average (Figure 5). The uncertainty range admitted presented a reliability of 68.3%. In Figure 5, the compaction effort increase, representing the traffic load along the time, is reflected in the permeability coefficient reduction.

Table 1. Permeability coefficients.

Gyrations Number	ki (mm/s) [1]	kf (mm/s) [2]
50	2.95	1.53
75	2.26	0.84
100	1.98	0.64
150	1.01	0.15
200	1.15	0.10

[1] Initial permeability coefficient; [2] Final permeability coefficient.

In the literature, there is a lack of studies that evaluated clogging at samples submitted to different compaction efforts. Samples submitted in simulation cycles using a permeameter with more than 20% voids were less affected by clogging [9]. Lin et al. [10] asserted that the initial permeability coefficient of samples was 0.56 mm/s, and after simulations, when it reached 0.49 mm/s, the surfaces were clogged. These studies corroborated that permeability tests help estimate voids reduction by clogging.

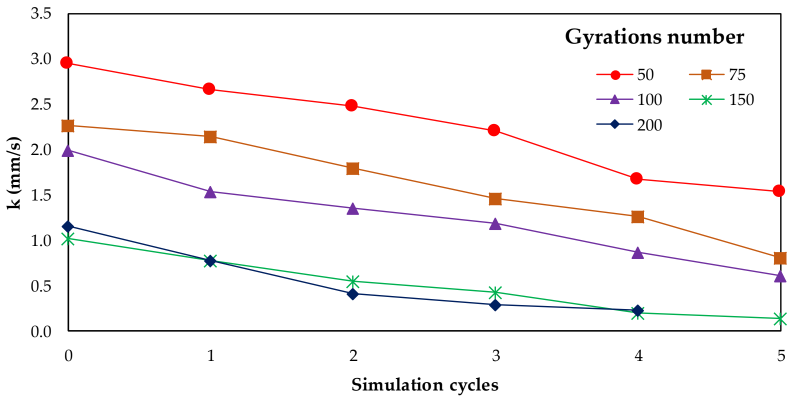


Figure 5. Voids reduction in function of gyrations number.

3.3. Intervention Time

Table 2 presents the regression coefficients obtained (Equation (2)) for each group of samples (gyrations number). Table 3 shows the obtained values, on average, of voids volume, interconnected voids volume and permeability coefficients for the samples group in the function of gyrations number. The permeability coefficient reduction (kr) was calculated by Equation (2) when the interconnected voids volume reached a value of 12%, and then the intervention time can be estimated.

The intervention time for the porous asphalt mixture recovers its permeable properties was proportional to the gyrations number, reflecting that the traffic effort contributes to the permeability reduction. For example, in Table 3, the intervention time was fourteen months for the compaction with 50 gyrations, while for the 200 gyrations, it was more than seven months. To prevent clogging progression, the intervention by surface cleaning for the porous mixture studied should occur at least every year.

Table 2. Regression coefficients.

Gyrations Number	a	b
50	3.0786	0.137
75	2.5136	0.199
100	2.0386	0.223
150	1.1594	0.425
200	1.1013	0.429

Table 3. Regression coefficients.

Gyrations number	Vv [1] (%)	IVv [2] (%)	k_{mean} [3] (mm/s)	k_{min} [4] (mm/s)	IT [5] (months)	Precipitation (mm)
50	24.54	15.73	1.53	1.16	14.16	1853
75	22.28	14.19	0.80	0.68	13.15	1720
100	21.34	13.25	0.60	0.49	12.64	1654
150	20.79	12.63	1.01	0.12	10.66	1395
200	20.68	12.23	0.22	0.21	7.59	994

[1] Voids volume; [2] Interconnected voids volume; [3] Mean of permeability coefficient; [4] Minimum permeability coefficient; [5] Intervention time.

4. Conclusions

A porous asphalt mixture was produced to estimate the necessary intervention time for permeable characteristics maintenance. In order to evaluate the traffic effect over time, the samples were submitted of different compaction efforts in the CGS by gyrations number increase (50, 75, 100, 150, 200 gyrations).

The samples were tested in the laboratory by rainwater (runoff solution) cycles through a constant head permeameter developed in the study. Before and after simulations, the voids volume, interconnected voids and permeability coefficient were measured. A stabilization of voids volume and interconnected voids volume values were observed from 100 gyrations, indicating that higher compaction levels present slight variations. The permeability reduction of each set of samples was evaluated statistically through the uncertainty range and analysis of experimental data.

A minimum value of 12% of the interconnected voids volume was established, considering that the porous mixture was clogged. The intervention time was estimated after the pavement surface layer was open to traffic. The permeability reduction was proportional to the gyrations increase. For samples subjected to 50 gyrations, the maximum intervention time was 14 months. On the other hand, for 200 gyrations, considering the effect of traffic, the intervention time was shorter, approximately 7.6 months.

Considering the porous asphalt mixture of this study and the local annual rainfall (1570 mm), based on the evaluated parameters, it is recommended that the intervention time by surface cleaning (with water and air jets) be carried out at least each year. Moreover, it is essential for future studies that the mixture's internal structure will be analyzed to estimate the intervention time and permeable parameters measurement. Also, experimental stretches must be constructed and monitored for data validation. The study limitations were using the same solid material amount at the laboratory tests and just one porous mixture type. The following research steps involve the development of a stormwater simulator and analysis by tomography.

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