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Development of permeability test method for porous concrete block pavement materials considering clogging

Wuguang Lin [a], Dae-Geun Park [b], Sung Woo Ryu [c], Byeong-Tae Lee [d,*], Yoon-Ho Cho [e]

[a] College of Transport and Communications, Shanghai Maritime Univ., 1550 Haigang Ave., Shanghai, PR China
[b] Pavement Research Center, Seoul Metropolitan Government Quality Inspection Office, 131 Taebong-ro, Seocho-gu, Seoul 137-900, Republic of Korea
[c] Korea Expressway Corporation Research Institute, 208-96, Dongbu-daero 922 beon-gil, Dongtan-myeon, Hwaseong-si, Gyeonggi-do, Republic of Korea
[d] Dept. of Civil and Environmental Engineering, Chung-Ang Univ., 84 Heukseok-Ro, Dongjak-Gu, Seoul 156-756, Republic of Korea
[e] Dept. of Civil and Environmental Engineering, Chung-Ang Univ., 84 Heukseok-Ro, Dongjak-Gu, Seoul, Republic of Korea

HIGHLIGHTS

- The causes of clogging were investigated and a clogging simulator was developed to evaluate the sustainable permeability of porous concrete block pavement.
- Furthermore, a test method for verifying the sustainability of infiltration which can predict and assess the permeability performance was proposed.
- It was found that the pores were easily clogged with the vibration frequency increased, but with the amount of contaminants increased to a degree clogging had less influence on vibration.

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ABSTRACT

Pervious pavement has been used widely due to efficient hydrological characteristics such as reduction of runoff during floods, providing delay of rainwater into sewer systems and ground water quality improvement. However, clogging prevents it from functioning properly due to sedimentation after a short period of service, which results to poor permeability and performance of pervious pavement. In this study, the causes of clogging were investigated and a clogging simulator was developed in order to evaluate the sustainable permeability of porous concrete block pavement in advance. Furthermore, a test method for verifying the sustainability of infiltration which can predict and assess the permeability performance by years of service was proposed. In addition, the penetration of contaminants also varies depending on vehicle vibration and the rainwater that permeates together with it. It was found that the pores were easily clogged with the vibration frequency increased, but with the amount of contaminants increased to a degree clogging had less influence on vibration. When various types of porous concrete block pavers were evaluated with the proposed sustainable permeability test method, the coefficient of permeability before and after the test have shown very high correlation.

1. Introduction

Pervious pavement has been widely used because of efficient hydrologic characteristics, such as driving safety during rainy days, runoff reduction and ground water quality improvement etc. The permeability of new pervious pavement is known to be at least 4500 mm/h (equivalent to 1.25 mm/s) before traffic opening, and the performance of some pervious pavement systems is 0.03 ~ 0.3 mm/h even after service for 15–20 years (Yong et al. 2013) [1]. The service life of pervious pavement is defined as the period until the pervious function of pavement drops due to clogging up to a level at which it cannot cope with the design storm and requires maintenance such as cleaning (Wong, 2006) [2].

Clogging phenomenon refers to the loss of permeable function due to the clogging of pores with various foreign particles on the road entering the pervious pavement after traffic opening, thus lowering the coefficient of permeability and hydraulic conductivity. Kayhanian et al. (2012) [3] took the images of core specimens using X-ray and found that most cases of clogging occurred on the

* Corresponding author.
E-mail addresses: wglin@shmtu.edu.cn (W. Lin), dgpark94@seoul.go.kr (D.-G. Park), honor.ryn@ex.co.kr (S.W. Ryu), humanlee@samsung.com (B.-T. Lee), yhcho@cau.ac.kr (Y.-H. Cho).

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surface of pavement. A majority of the specimens, which were collected from field were clogged from the surface down to 25 mm. and some of them were even clogged down to 100 mm. Pratt et al. (1995) [4] claimed that the accumulation of fine particles in the pores of pervious pavement caused clogging and the mass of the cumulative sediments was the most critical factor. Furthermore, the particle size of sediments can be another influencing factor because small sediment particles are locked by large particles, and the more small particles there are, the faster the pores get clogged (Colandini et al., 1995) [5]. According to the findings from the study by Kayhanian et al. (2012) [3], the content of dust with 38 μm or smaller particle diameter is the major influencing factor of clogging.

The test method of permeability for the porous medium is mainly divided into lab tests and field performance tests, but it is difficult to predict the permeability of the pervious pavement in-service by using these methods. Further, since it is difficult to simulate rainwater containing pollutants, the actual evolution of surface infiltration is unknown. A typical field permeability test methods for pervious pavement are introduced by the ASTM C 1701 [6] which is based on constant head permeability test. Another typical laboratory test method for permeable pavement materials is introduced by KS F 4419 [7]. The limitation of these test methods is that they cannot predict the permeability after it is open to traffic.

Unlike typical porous medium, traffic is loaded on the pervious pavement in most cases after construction. This means the process of contamination penetrating into the voids can vary due to traffic load, such as pressure by its weight and vibration by driving on the pavement. It will further be accelerated by the pore clogging caused by tire friction or compression forces. However, it was confirmed that there are no case studies on clogging of the porous medium by applying vibration. Therefore, the test method for evaluating the permeability of pervious pavement considering the characteristics of the traffic will be required. In this study, a method of evaluating the sustainable permeability of pervious pavement materials was proposed after simulating the clogging process through a lab test with contaminants on actual roads.

2. Dust contaminants collection and grain-size analysis

2.1. Dust contaminants collection

The movements of contaminants on the roads are classified into siltation, suspension, and creep. Siltation is the movement of small particles with a diameter of 70–500 μm, which fly from the surface of pavement and move along the shape of orbit under the influence of the resistance of air and the gravity. This consists of 55–72% of all movements. Suspension refers to the floating and moving of particles in air by wind at a distance before being precipitated. The diameter of these particles is smaller than 70 μm. Suspension accounts for 3–10% of all movements. Creep refers to the rolling or slow moving of sands and aggregate-sized particles under the influence of silting particles and accounts for 7–25% of all movements. Among these particles, large sand particles gather on the pervious pavement and the spaces between them are filled with dusts or fine particles generated from worn out pavement surface and vehicle tires, which decrease permeability and clog the pores, thereby making the pavement impervious (Amirjani, 2010) [8].

To identify the characteristics of fine dusts in roads, the contaminants on the roads were collected for two consecutive days with a road cleaning equipment that was being used by local government of Seoul city. The recommended operating speed of the vehicles was 10–15 km/h and the total length of the sections that were passed through was 45 km. The local roads investigated were constructed by typical asphalt pavement with 3.5 m width for each lane. Hence, the total investigating area concerned for collecting contaminants is 157,500 m^2. The roads in this area were cleaned each day.

2.2. Dust contaminants grain-size analysis

Table 1 shows the weight of the collected contaminants per day. The cleaning equipment automatically classifies large contaminants and fine dusts, and stores them separately. The weights of contaminants shown in Table 2 were calculated depending on distance and area of the cleaning equipment operated.

To examine the characteristics of road dusts affecting clogging, the average grain size of contaminants was analyzed using six samples that were collected each from large and fine dust bins. The grain sizes of the large contaminants and fine dusts following t-distribution at 95% confidence level are shown in Fig. 1. Most of the contaminants filtered through No. 4 sieve were leaves and cigarette butts which would not greatly affect clogging over time. The largest percentage of the contaminants was the grain sizes between No. 30 and No. 50 sieves, which are mainly sand and dust with the particle diameters between 0.60 and 0.36 mm. They were regarded as causing clogging as they come in contact with water and became agglomerated. The collected large contaminants and fine dusts were combined at 56:44 ratios in the laboratory and the gradation was shown in Fig. 2.

The permeability of pervious pavement decreases as the service period increases. The correlations between permeability and service period were analyzed on the basis of the amount of collected contaminants. As a result of the analysis of the contaminants collected by cleaning equipment in Eupyeong-gu, Seoul, the variation of the amount of contaminants was not significant. Therefore, it was assumed that the same amount of contaminants was generated every year. The amount of daily contaminants per unit area was calculated as 332 mg/m^2/day.

3. Clogging simulator and test method

3.1. Clogging simulator

The clogging simulator was developed to simulate the event in which the pores of pervious pavement can be clogged by contaminants in water initially. Furthermore, a motor was attached to simulate the vibration of the vehicle on the road and early clogging. A mold of a certain size was used to evaluate the pervious pavement as shown in Fig. 3 that indicates the details of the clogging simulator.

On the asphalt road at a constant vehicle speed of 60 km/h, torsion resonance of the tire exhibits a large peak around the frequency of 40 Hz (Umeno, 2002) [9]. The vibration motor can simulate the vehicle movement in the vertical direction, which can be controlled to 0–60 Hz with the increment of 0.1 Hz. The main body and table were fixed with springs to minimize the test error when the table is vibrated. The size of the mold to mount pervious material is 200 × 200 × 150 mm, and the porous blocks which are sold in large numbers at present in Korea can be tested. Sponge was attached to an iron plate so as to prevent gaps between

Table 1
Comparison of weights of contaminants collected at local road in Seoul.

1st Day (kg)		2nd Day (kg)		Average (kg)
Large contaminants	27.60	Large contaminants	30.70	29.15
Fine dusts	9.45	Fine dusts	17.15	23.18
	10.45		9.30	
Total contaminants	47.50	Total contaminants	57.15	52.33