How reliable are Laboratory-based PICP Clogging Results?

Quelle est la fiabilité de résultats de colmatage sur PICP en laboratoire ?

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RÉSUMÉ

Il a été démontré que le colmatage des pavés perméables autobloquants en béton (PICP) par le dépôt des sédiments contenus dans les eaux de ruissellement réduit considérablement leur capacité d'infiltration au fil du temps. De nombreuses études ont utilisé des modèles de PICP en laboratoire et des eaux pluviales synthétiques afin de tenter de reproduire et de prédire les processus de colmatage qui se produisent sur le terrain dans les installations de PICP. Une variété de types et tailles de sédiments, et divers taux d'application des eaux pluviales ont été utilisés dans ces études avec des résultats mitigés. La présente étude a étudié les effets que divers types de sédiments, différentes distributions de tailles de particule et différentes durées de test avaient sur le colmatage des modèles de PICP. Dix-huit modèles de PICP spécialement construits ont été testés en laboratoire en utilisant la technique de simulation accélérée des eaux pluviales semi-synthétiques. Les résultats de l'étude ont révélé de nouvelles perspectives sur la fiabilité et la validité des résultats des tests de laboratoire sur le colmatage des PICP et sur la manière dont les résultats doivent être considérés.

ABSTRACT

Clogging of permeable interlocking concrete pavements (PICP) due to the sediment contained in stormwater runoff has been shown to significantly reduce their infiltration capacity over time. Numerous studies have used laboratory-based PICP models and synthetic stormwater in an attempt to replicate and predict the clogging processes that occur in PICP field installations. A variety of sediment types and sizes, and stormwater application rates have been used in these studies with mixed results. The current study investigated the effects that varying sediment types, varying particle size distributions and varying testing durations had on clogging of PICP models. Eighteen specially-constructed PICP models were tested in the laboratory using the accelerated semi-synthetic stormwater simulation technique. The study results have revealed new insights into the reliability and validity of laboratory-based PICP clogging testing results and how the results should be viewed.

KEYWORDS

Permeable Interlocking Concrete Pavers (PICP), Infiltration, Stormwater Pollution, Sediment, Clogging

1 INTRODUCTION

Permeable pavements are one type of SUDS treatment device that is becoming increasingly popular globally due to the many stormwater management and environmental benefits they provide. The most common type of permeable pavement is the permeable interlocking concrete paving (PICP) system (Lucke & Beecham, 2011). PICPs are specifically designed to remove sediment, total suspended solids (TSS) and other pollutants from stormwater runoff during the filtration processes that occur within the pavement structure. Over time, this can lead to a reduction of the infiltration capacity of the PICP system and clogging (Borgwardt, 2006; Bean et al., 2007; Yong et al. 2011). Clogging is a result of fines, organic matter and traffic-caused abraded particles, blocking the gaps and surfaces of PICPs due to physical, biological and chemical processes (Siriwardene et al. 2007). Clogging decreases the infiltration rate of a PICP system over time. The degree that particle deposition onto pavement surfaces impacts on the infiltration performance of a system depends on the particle size distribution of the sediment and the permeability of the system (Deo et al. 2010).

2 PURPOSE

A number of previous research studies have used laboratory-based, accelerated testing methods using simulated stormwater to predict the long-term clogging behaviour of PICP field installations. Natural rainfall intensity and durations are difficult to replicate in the laboratory, and accelerated testing methods are often used in laboratory-based studies in order to provide timely study results under controlled conditions. Accelerated testing can be defined as using annual rainfall volumes over shorter durations during testing in order to provide timely results.

The various simulated rainfall intensities and durations used in laboratory-based, accelerated testing methods are known to affect measured PICP surface infiltration results (Yong & Deletic, 2012; Yong et al., 2013). Sediment mass, size and type (Borgwardt, 2006: Siriwardene et al., 2007; Lucke & Beecham, 2011), and intermittent drying times between tests (Yong et al., 2011, Fassman & Blackbourn 2010; Yong & Deletic, 2012) also affect the PICP infiltration results obtained using accelerated testing methods. The results and subsequent conclusions drawn from each of these studies appear to have been strongly influenced by the different techniques used in the study to measure and predict clogging and its effects on PICP surface infiltration.

This study investigated the effects that different sediment types (natural and silica), and different simulated rainfall intensities and testing durations, had on the observed clogging processes, and on the measured surface infiltration results of laboratory-based, accelerated PICP testing studies.

3 APPROACH

This study used semi-synthetic stormwater (Hatt et al., 2006; Siriwardene et al., 2007; Bratieres et al., 2008; Yong et al., 2013) to investigate how different sediment types and testing durations affected clogging of PICP models under accelerated testing procedures. Three different sediment types were used to prepare the semi-synthetic stormwater in the study:

- Coarse Sediment (real sediment < 1.18 mm in diameter);
- Adjusted Fine Sediment (AFS- real sediment < 300 µm in diameter); and
- Synthetic Silica (Type 60G).

In this study, real stormwater sediment was collected from a number of local stormwater pits. Litter and gross pollutants were first removed from the collected sediment, which was then was placed in an oven to dry. The dried sample was then passed through a 1.18 mm sieve to remove excessively large sediment particles. The particles in the real sediment collected for this study were found to be larger than those reported by Duncan (1999). However, this sediment was still tested in the study and was labelled “Coarse Sediment.”

In order to allow a realistic comparison of clogging behaviour between real sediment and silica sediment, a quantity of the Coarse Sediment was passed through a 300 µm sieve to produce “Fine” sediment. However, the characteristics of this sediment were not sufficiently similar to those of the 60G silica. Therefore, another sediment type was prepared, namely “Adjusted Fine Sediment” (AFS). The AFS was prepared by adding appropriate amounts and sizes of real sediment to match the PSD of the 60G as closely as possible.

A purpose-built testing rig (Figure 1) was used to perform the accelerated stormwater simulations.

Eighteen laboratory PICP models (Figure 1b) were tested in this study with prepared semi-synthetic stormwater using accelerated rainfall simulation techniques. The models were 440 mm long and 330 mm wide, providing a test surface area of 0.145 m^2 each. Hydrapave™ pavers (80 mm thick) were used in the models and these were laid in a standard herringbone configuration on a 50 mm thick layer of 2/5 mm bedding aggregate. The bedding aggregate was held in place by a geofabric laid on a galvanized steel mesh set inside a steel frame base. The test pavers were confined within transparent acrylic sheeting and sealed internally around the perimeter using plumbers' putty (Figure 1b).

Figure 1. Accelerated Stormwater Simulation Testing Setup

The Sunshine Coast in Australia has an average annual rainfall depth of 1,620 mm and this value was used to calculate the stormwater volume required for the testing. An inflow volume of 235 L (1,620 mm*0.145 m^2) was required to deliver the equivalent of one year's rainfall to the PICP test models. Average total suspended sediment (TSS) concentration of 150 mg/L (35.3 g/235 L) was used in this experimental study to replicate urban runoff sediment load as recommended by Duncan (1999). As the purpose of the study was to investigate the long-term clogging, and subsequent infiltration capacity reduction effects in the PICP models, the equivalent of 10 years' worth of sediment (353 g) was added to one year's equivalent rainfall (235 L) for each of the tests.

Table 1. 18 Accelerated Stormwater Simulation Tests Performed

Test #	**Simulation duration (h)**	**Equivalent rainfall intensity (mm/h)**	**Sediment type used in simulation tests**
1	0.5	3,237	Silica 60G
2	2	809	
3	3	550	
4	4	405	
5	6	270	
6	12	135	
7	0.5	3,237	Adjusted Fine (< 300 µm)
8	2	809	
9	3	550	
10	4	405	
11	6	270	
12	12	135	
13	0.5	3,237	Coarse (< 1.18mm)
14	2	809	
15	3	550	
16	4	405	
17	6	270	
18	12	135	

Six different simulated rainfall durations were used in the accelerated tests, namely: 0.5; 2.0; 3.0; 4.0; 6.0 and 12 hours. These durations corresponded to equivalent infiltration rates of 3,237; 809; 550; 405; 270 and 135 mm/h respectively, over the PICP test models' surfaces (Table 1). The surface infiltration rate of each model (both before and after treatment) was determined using a constant-head method. By measuring the flow rate required to maintain a 20 mm high water level above the pavers inside the models, the surface infiltration rate of the individual PICP models was accurately determined.

4 RESULTS AND CONCLUSIONS

This study investigated the effects that different sediment types (natural and silica), and different simulated rainfall intensities and testing durations had on the observed clogging processes, and on the measured surface infiltration results of laboratory-based, accelerated PICP testing studies. The study found that:

- Surface infiltration rates increased (i.e. less clogging) for test durations up to 6.0 h when using silica sediment in the semi-synthetic stormwater. Testing durations longer than 6.0 h produced only minimal change between initial and final infiltration rates;
- Surface infiltration rates decreased (i.e. more clogging) as test durations increased when using the adjusted fine sediment in the semi-synthetic stormwater.
- Surface infiltration rates were generally unaffected by the application rate of semi-synthetic stormwater containing coarse sediment. The average change between initial and final infiltration rates was 96% (high clogging), irrespective of the testing duration used.
- Further research is needed to better understand the clogging processes of laboratory-based PICP studies using accelerated testing methods.

The results of this study may have implications for the reliability of results and conclusions of past PICP clogging studies that used accelerated testing methods and semi-synthetic stormwater. Caution is therefore advised when basing the design of permeable pavement systems on results of past research studies. It is recommended to only use results of studies using natural sediment.

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