Journal of Environmental Management 160 (2015) 297–305

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Infiltration performance of engineered surfaces commonly used for distributed stormwater management

N.A. Valinski, D.G. Chandler*

Department of Civil and Environmental Engineering, Syracuse University, United States

ARTICLE INFO

Article history:
Received 7 January 2015
Received in revised form
17 June 2015
Accepted 19 June 2015
Available online 2 July 2015

Keywords:
Porous pavement
Engineered soil
Infiltration
Low impact development (LID)
Urban runoff

ABSTRACT

Engineered porous media are commonly used in low impact development (LID) structures to mitigate excess stormwater in urban environments. Differences in infiltrability of these LID systems arise from the wide variety of materials used to create porous surfaces and subsequent maintenance, debris loading, and physical damage. In this study, the infiltration capacity of six common materials was tested by multiple replicate experiments with automated mini-disk infiltrometers. The tested materials included porous asphalt, porous concrete, porous brick pavers, flexible porous pavement, engineered soils, and native soils. Porous asphalt, large porous brick pavers, and curb cutout rain gardens showed the greatest infiltration rates. Most engineered porous pavements and soils performed better than the native silt loam soils. Infiltration performance was found to be related more to site design and environmental factors than material choice. Sediment trap zones in both pavements and engineered soil rain gardens were found to be beneficial to the whole site performance. Winter chloride application had a large negative impact on poured in place concrete, making it a poor choice for heavily salted areas.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Urban land cover is often classified as highly impervious and the negative impacts on urban hydrographs are well documented (Shuster and Rhea, 2013). Porous pavement, rain gardens, and other low-impact development (LID) strategies have become increasingly popular for reducing runoff and flashy urban hydrographs (Montalto et al., 2013; Hood et al., 2007). These LID development strategies have been particularly useful in cities where combined sewers are subject to frequent overflow events and have been used as viable alternatives to typical gray infrastructure remediation (DeSousa et al., 2012).

Infiltration capacity is an important measure of LID performance where the design goal is to reduce runoff from impervious sources. In hardscape sites such as porous parking lots, a subsurface gravel storage bed can be developed below the pervious surface to store infiltrated precipitation. This is a common approach for sites with low permeability soils. Surfaces with low intrinsic permeability or those clogged by sediment or surface debris can limit stormwater capture, especially during periods of intense precipitation or on sloping sites where concentrated flow reduces residence time. Pavement clogging can be effectively reduced by routine vacuuming and power washing to help remove sediment resulting from winter maintenance, braking, and debris loading (Chopra et al., 2010).

Previous research has addressed both short term and long term hydraulic performance of porous pavements and LID projects, primarily through measurement of saturated permeability with various types of ring infiltrometers. Although ring infiltrometers are a standard method for determining hydraulic conductivity, these devices require substantial set up time, often at a fixed location within the site, which practically limits the number of experimental replicates (Chopra et al., 2010; Al-Rubaei et al., 2013). Some novel studies have relied on embedded systems such as time domain reflectometers, but the requirement that monitoring systems are installed at the time of construction limits this approach (Brown and Borst, 2013). These methodological limitations to broad replication of infiltration measurements limits the statistical power of comparative analyses across sites and does not support an understanding of spatial variability within sites. Furthermore, ring infiltrometer methods create a positive head condition above the surface which is often not representative of the depth of water normally associated with sheet flow and shallow concentrated flow during a rain event. This study resolves these issues by using a

* Corresponding author.
E-mail address: dgchandl@syr.edu (D.G. Chandler).

http://dx.doi.org/10.1016/j.jenvman.2015.06.032
0301-4797/© 2015 Elsevier Ltd. All rights reserved.

survey instrument that supports measurement replication and applies a process-appropriate head at the surface boundary condition.

Automated disk infiltrometers have been widely used to characterize infiltration properties of soils and other porous media and were used in this study (Ankeny et al., 1991; Casey and Derby, 2002; Madsen and Chandler, 2007). Disk infiltrometers provide a constant positive or negative head at the surface. The cumulative infiltration record can be analyzed to determine the short term effects of sorptivity and the long term, steady state infiltration capacity at the field conditions (Wooding, 1968; Perroux and White, 1988). Unsaturated hydrophilic porous media typically exhibits early time dominance of processes contributing to sorptivity, followed by a decline in the infiltration rate as the distance to the axisymmetric wetting front increases and the permeability of the field saturated media at the applied head is approached. Automated disk infiltrometers operated at a short time step provide detailed data sufficient to analyze both early time sorptivity and steady state infiltration properties, and several instruments can be operated simultaneously to leverage time in the field. One uncertainty shared by both surface mounted ring and disk infiltrometers is the time variant diameter of the wetting front in the subsurface, which is governed by capillary diffusivity in highly sorptive soils and distorted by macropores and cracks in dual permeability media at high positive heads (Haverkamp et al., 1994).

The goal of this study is to compare the relative infiltration capacity across an array of LID projects and document spatial variability within several types of engineered porous surfaces. The surveyed sites were mostly constructed within a three year period and provide an opportunity to compare *in situ* performance in a single city following typical use, seasonal weather, and routine maintenance.

2. Materials and methods

2.1. Sites

Syracuse, New York was the central focus of Onondaga County's Save the Rain program between 2010 and 2013, and more than 50 sites with recently installed engineered porous surfaces were available for infiltration surveys in the summer of 2013. Fifteen locations were selected to represent the various porous materials, including porous asphalt, porous concrete, porous brick pavers, flexible porous pavement, engineered soils, and native soils (Table 1). Detailed descriptions of material depth profiles for each porous surface type are available as supplemental material. Thirteen of these locations were a part of the Onondaga County Save the Rain program; Harrison Street Parking Lot and R2 Parking Lot are sites owned and maintained separately by Syracuse University. Infiltration surveys were made in June and July 2013, midway between biannual maintenance routines to provide a measurement of typical performance. Additional measurements were made in July and August of 2014 to support statistical analysis and better define spatial patterns of infiltration.

Porous asphalt is a common surface replacement for parking lots and curbside parking. Four parking lots were selected to represent different fractions of porous surface area to total site area (Table 1). Otherwise the sites are generally similar in construction. None of the tested sites have a curb to limit runoff or runon, and are nearly level with the exception of the Harrison Parking Lot. The land cover and surface material bordering the lots varies among sites. Pearl Street Parking Lot is bordered by dense vegetation which serves as a seasonal source of organic litter to the lot. City Lot #4 has a 45 cm porous concrete aesthetic border and bioretention gardens along two sides. Harrison Parking Lot has a 1 m strip of porous asphalt along the base of the 58 m, 3% sloped sealed asphalt surface (Fig. 1b). These sites are represented by a total of 130 infiltration tests.

In Syracuse, porous concrete pavement was installed primarily in curbside parking zones and parking lot edges as a means to delineate parking areas from traffic lanes, with typical construction bed depths of approximately 76 cm. A few sidewalks were constructed of porous concrete. The concrete was cast in place at City Lot #3, East Genesee curbside parking, the R2 Parking Lot, and University Avenue curbside parking. Precast porous concrete was installed at City Lot #4 and at the East Water Street sidewalk. The R2 Parking Lot was studied extensively to identify differences in infiltration among the center traffic lane, parking spots, and near curb areas (Fig. 1a). A total of 178 successful tests were performed at the R2 Parking Lot. The lot has an approximate 4% grade. All other porous concrete surfaces were surveyed with a total of 105 successful tests.

Flexible porous pavements were installed as walkways within Syracuse city parks. The material is a pavement composed of recycled shredded tires (Flexi-Pave, KBI Industries, Largo FL). At Skiddy Park 15 tests were performed on a path with a negligible grade near the entrance of the park.

Several surfaces paved with a variety of porous brick types were tested. Porous brick pavers were used in road details and parallel parking spaces at University Avenue and the Water Street Gateway. Bricks on University Avenue were small (4.5 cm × 23 cm) with a smaller aggregate size used to fill the 0.6 cm gap between bricks.

Table 1
Overview of study sites by surface type age and porous area.

Site	Surface	Age (yr)	Site porous area (%)
City Lot #4	Porous Asphalt	1	91
Harrison Parking Lot		~4	0.9
Pearl Street Parking Lot		3	65
Skiddy Park Court		2	100
City Lot #3	Porous Concrete	3	21
East Genesee Street		2	16
R2 Parking Lot		2	100
University Avenue		2	32
City Lot #4 Edging	Precast Porous Concrete	1	91
East Water Street Sidewalk		<1	100
Skiddy Park Walkway	Flexible Porous Pavement	2	100
University Avenue	Porous Brick Pavers	2	30
Water Street Gateway		2	30
East Genesee Rain Garden	Engineered Soil	2	20
Concord Place	Native Soil	2	100

Download English Version:

https://daneshyari.com/en/article/7481905

Download Persian Version:

https://daneshyari.com/article/7481905

Daneshyari.com