Journal of Environmental Management 230 (2019) 212–220

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Effects of OASIS® phenolic foam on hydraulic behaviour of permeable pavement systems

Mohamed Heweidak[a], Shohel Amin[b,*]

[a] School of Energy, Construction and Environment, Coventry University, Priory St, Coventry, West Midlands, CV1 5FB, United Kingdom
[b] School of Energy, Construction and Environment, Sir John Laing Building, Room No. JL136, Coventry University, Priory St, Coventry, West Midlands, CV1 5FB, United Kingdom

ARTICLE INFO

Keywords:
Stormwater
Permeable pavement system
Geotextile material
Infiltration rate
Optimal thickness

ABSTRACT

Sustainable drainage is a major challenge for highway and environmental agencies to mitigate flooding and understand the optimum design parameters of pavement structure. This paper experiments the hydraulic properties of OASIS® phenolic foam material examining infiltration rate and steady-state behaviour, water storage capacity of different thicknesses of OASIS® material, and the effect of OASIS® material in deferring the water peak flow during rainfall intensities of 100 mm/h, 243 mm/h, 400 mm/h, and 563 mm/h. This paper designs an application programme that estimates the optimal thickness of OASIS® layer to retain 100% of stormwater for a duration of 15 min. The results from laboratory tests corroborate the performance efficiency of OASIS® material to delay peak stormwater flow and mitigate flooding. The OASIS® materials not only increase the ability of permeable pavement system to absorb and retain stormwater up to a saturation limit but also retain the nutrient contaminants infiltrate to groundwater. The designed application programme will help the designers and constructors to increases the drainage efficiency of pavement structure by estimating the optimal thickness of OASIS® layer required to delay peak stormwater flow during maximum rainfall intensities.

1. Introduction

Impermeable pavement surfaces increase the volume of stormwater runoff that overburdens the capacity of drainage networks and eventually causing floods particularly in urban areas (Scholz, 2013). Sustainable drainage system (SuDS) is a contemporary challenge that considers permeable pavement system (PPS) as the environmentally and economically beneficial approach for minimising flood risks (Scholz and Grabowiecki, 2009; Wardynski et al., 2012). Application of PPS as a SuDS method implements source control, prevention, detention, infiltration and biodegradation techniques (Woods-Ballard et al., 2007). The retention of excessive stormwater at the PPS layers minimises the flooding risks and can be used for irrigation needs after removing pollutants (Nnadi, 2009; Nnadi et al., 2014; Wilson et al., 2004).

Two decades ago, there was no specific design for PPS in the United Kingdom (UK) as PPS constructions were rare, but it is now regularly used in parking lots, compounds, and residential areas (Wilson et al., 2004). The most common design for PPS in the UK is a geotextile layer beneath the surface layer because geotextile materials retain stormwater pollutants and enhance the process of biodegradation within permeable pavement (Nnadi, 2009; Wilson et al., 2004; Newman et al., 2011). The geotextile material is provided to separate backing geotextile layers from sand/aggregate bedding layers and aggregate or geocellular sub-base (Wilson et al., 2004). Several materials such as polyethylene, polypropylene and polyester are used to manufacture the geotextile layer but there is no scientific evidence on compromising attenuation and filtration attributes (Nnadi et al., 2014; Wilson et al., 2004). The three-dimensional structure of OASIS® phenolic foam characterised by highly porous cells that increase the material ability to absorb and attain stormwater up to a saturation limit. Yong et al. (2008) observed that geotextile layer increased the probability of voids clogging affecting the total performance of PPS. Nnadi (2009) observed the performance of PPS with a geotextile layer composed of Inbitex Composite® and silts, and identified that geotextile layer improved the filtering and attenuating stormwater. Lowe et al. (2010) invented a 3D structure module that contains phenolic foam material for irrigation and filtering system purposes. Nnadi et al. (2014) studied the hydraulic properties of OASIS® material with 1.3 cm and 2 cm thicknesses under rainfall intensities of 100 mm/hr, 200 mm/h and 400 mm/h and determined the positive performance of PPS for retaining stormwater within the pavement structure. Nnadi et al. (2014) identified that 1-cm

* Corresponding author.
E-mail addresses: heweidam@uni.coventry.ac.uk (M. Heweidak), Shohel.Amin@coventry.ac.uk (S. Amin).

https://doi.org/10.1016/j.jenvman.2018.09.084
Received 11 June 2018; Received in revised form 20 September 2018; Accepted 22 September 2018
0301-4797/

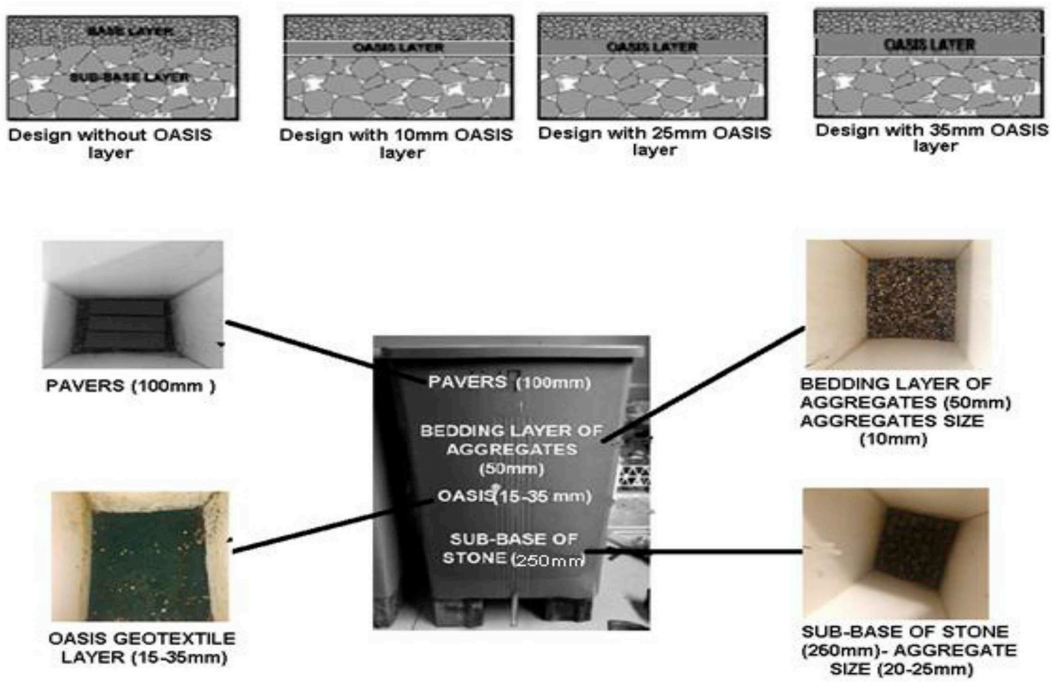

Fig. 1. Scheme of the control and OASIS® rigs.

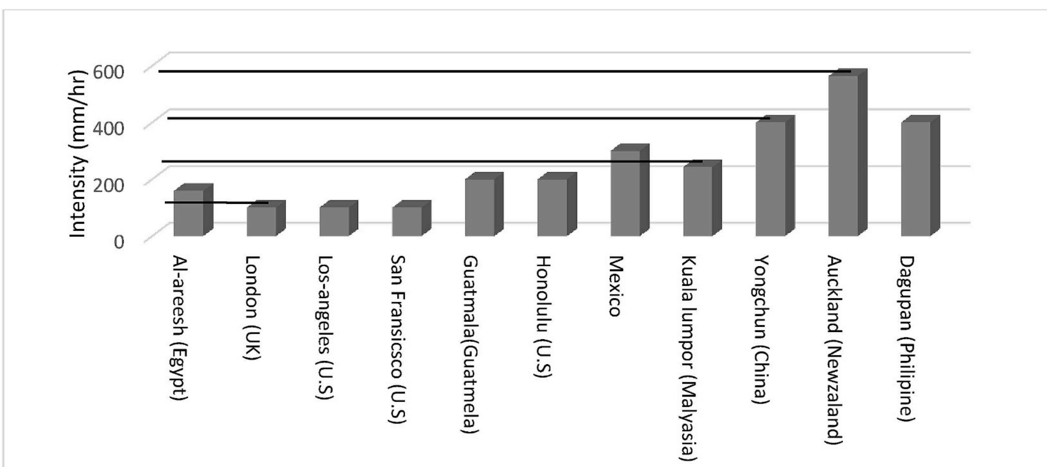

Fig. 2. Maximum rainfall intensities for different cities with 100-year return period for 15 mins (Campos–Aranda, 2010; Daniell and Tabios, 2008).

increase in OASIS material would increase its stormwater storage capacity by 37%. However, the experimental results by Nnadi et al. (2014) require to be validated by different thicknesses of OASIS® material subjected to different rainfall intensities.

This paper experiments the hydraulic properties of OASIS® material examining infiltration rate and steady-state behaviour, water storage capacity of different thicknesses of OASIS® material, and the effect of OASIS® material in deferring the water peak flow during rainfall intensities of 100 mm/h, 243 mm/h, 400 mm/h, and 563 mm/h. This paper designs an application programme that estimates the optimal thickness of OASIS® layer to retain 100% of stormwater for a duration of 15 mins.

2. . Experimental Methodology

2.1. Test rigs design

The control rig was designed with 250 mm sub-base, 50 mm base, and 100 mm paver layers without a geotextile layer. The control rig was replicated three times under each rainfall intensity attaining the required time for initial infiltration rate, and constant rate of water flow. Three rigs were designed with 15 mm, 25 mm, and 35 mm thicknesses of OASIS® material (Fig. 1). A 5-mm diameter hole was made at the bottom of rig to drain out the water. To simulate the rainfall event, water was flowed evenly through a funnel connected with a sprinkler for a duration of 15 mins over the surface of PPS model. The process was replicated three times for four maximum rainfall intensities. The same type of bucket was used but without a hole in the base to prevent water drainage outside the bucket and study the likelihood of flooding during 15 mins of rainfall intensities.

2.2. Extreme rainfall intensity analysis

To study the hydraulic properties of the OASIS® material, four extreme rainfall intensities were chosen for different cities. Maximum rainfall intensities were selected within the range of 100 mm/h to