Optimising the hydraulic performance of Permeable Pavement Systems: Novel materials as water barrier/treatment systems

Optimisation de la performance hydraulique des systèmes de pavés drainants : utilisation de nouveaux matériaux comme barrière hydraulique et traitement de l'eau

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RÉSUMÉ

Cette étude explore la combinaison de la mousse phénolique OASIS® aux systèmes de pavage perméables en vue d´améliorer les performances hydrauliques ou de servir d´alternative aux géotextiles conventionnels. Ce nouveau système est comparé à un système de pavage perméable associé au géotextile de type Inbitex® et un système sans dispositif de barrière d´eau. La performance hydraulique de notre système a été testée en laboratoire sur une durée de 9 semaines, en mesurant la capacité d´infiltration, le temps de latence du premier écoulement et le volume total écoulé pour des évènements pluvieux de 45mm/h d´intensité pendant une heure. Les résultats suggèrent qu'avant saturation, notre système de drainage comparativement aux systèmes conventionnels, améliore la capacité de rétention et contribue à retarder le pic de crue. De plus, avant saturation, la mousse phénolique OASIS stocke les volumes infiltrés constituant ainsi une source réutilisable. Cependant des analyses complémentaires sous différentes intensités de pluies sont nécessaires pour une meilleure compréhension des processus influençant la capacité de rétention de la mousse phénolique OASIS en zone d´absorption en vue d´optimiser son utilisation.

ABSTRACT

This research reports the application of OASIS® phenolic foam to Permeable Pavement Systems (PPS) as a replacement or enhancement to the hydrological performance provided by conventional geotextiles. This performance of PPS containing OASIS was tested in comparison with PPS utilising Inbitex® geotextile and designs with no barrier systems. To evaluate the hydraulic response of PPS, infiltration rates, time to first discharge and total discharged volume were studied at a laboratory scale under 45mm/hr rain events of 1hr duration over the course of 9 weeks. Results showed that PPS designs containing OASIS, prior to saturation, improved the water storage capacity of the systems and provided an additional delay to reach the peak flow when compared to those PPS designs utilising Inbitex. OASIS, prior to saturation, retains all absorbed water volume resulting in high levels of readily available water for reuse. Further testing under various rainfall regimes is needed to fully understand the parameters influencing the water retention capacity of OASIS in the so-called absorption zone and how OASIS retention capacity could be optimised.

KEYWORDS

Geotextile; Infiltration behaviour; Permeable Pavement Systems; SuDS; Water barrier/treatment

systems

1 INTRODUCTION

Permeable Pavement Systems (PPS) have always been designed according to the specific needs for water management through the years and have been influenced by factors such as climatic conditions and topography (Woods-Ballard et al. 2015). The increase of impervious surfaces due to urbanisation as well as the changes in climatic conditions, demand the implementation of measures for better water management. Extra storage capacity for extreme rain events and the availability of this water in drought is now necessary (Woods-Ballard et al. 2015). A novel material to act as a water barrier/treatment system was developed at Coventry University (patent number WO2006077421A1), based on a material commercially available as OASIS® flower foam with the potential to increase the water storage capacity of PPS when used as a replacement or enhancement to geotextiles (Nnadi et al. 2014, Sañudo Fontaneda 2014). The placement of geotextile most commonly below the laying course can provide benefits such as separation of aggregate, stability and improvement of water quality as reported by Coupe et al., 2006; Newman et al., 2006; Gomez-Ullate et al., 2010 and Sañudo-Fontaneda et al., 2014 pinpointing its importance in PPS designs. This investigation aims to evaluate the OASIS phenolic foam potential as a barrier system compared with Inbitex®, which is a non-woven geotextile widely used in the engineering sector. The hydraulic performance of the PPS designs will be evaluated by measuring water retention and infiltration rates at laboratory scale.

2 METHODS

2.1 Experimental design

Seven testing rigs were installed under the same laboratory settings for the purpose of this investigation. The rigs consisted of 3 PPS designs with different installed water barrier/treatment systems and a Control rig with no barrier system. A surface area of 35cm x 37cm was covered with Permeable Concrete Paving Blocks (PCPB) placed in a pattern with empty joints and seams filled with crushed limestone (figure 1). For the purpose of statistical analysis, 3 replicates of each design with barrier system were constructed. The water barrier/treatment systems under investigation were namely, OASIS and Inbitex (figure 1). A detailed layout of the test rigs is given in figure 1.

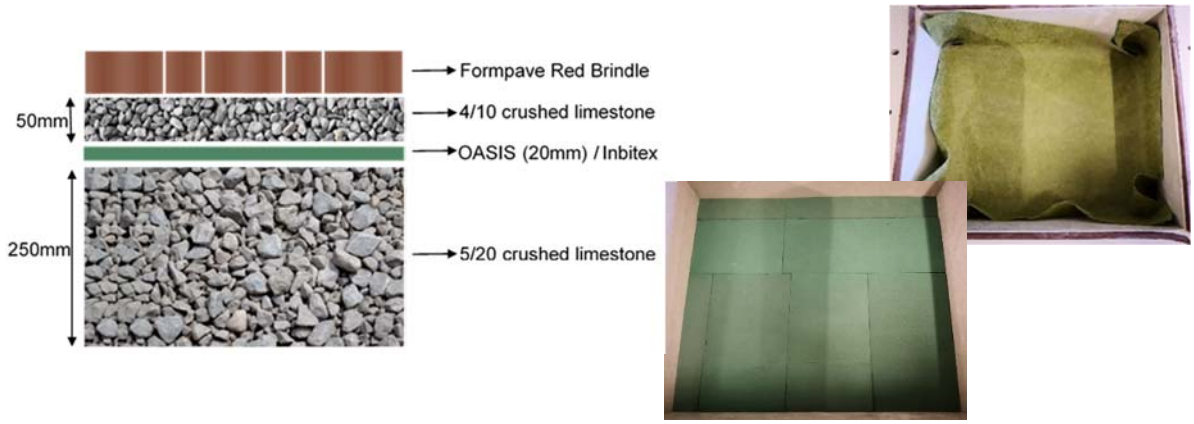

Figure 1. Schematic layout of PPS designs (left), installation of water barrier/treatment systems (Inbitex (top right), OASIS (bottom right))

2.2 Rainfall regime and simulation

The simulated rainfall regime was decided based on hourly rainfall data taken from Met Office Integrated Data Archive system (MIDAS) corresponding to the UK West Midlands region in the UK. Available data for the period 1992-2017 indicated that the highest rain event (Rank 1) was observed at 125mm/hr and a Rank 2 event at 45mm/hr (Met Office 2012). The decision on rainfall intensities was based upon previously observed performance under simulation of low rainfall intensities of 10mm/hr. A rainfall delivery system with the capacity to generate rainfall intensities from 10mm/hr to 125mm/hr was designed, constructed and calibrated. The rainfall delivery system consisted of an overflow tank, a flowmeter, and a layout of rigid hosepipes with nozzles. The test rigs were subjected to rainfall events of 45mm/hr intensity and duration of 60 minutes with an antecedent drying period of 7 days. This

scenario resulted in the simulation of 9 rainfall events over a period of 9 weeks.

2.3 Experimental method

The quantities of interest for this investigation were the time to first discharge (lag time), discharge rate and total discharged volume. The first flow was measured, and the discharge rate curves were developed in 1-minute intervals by taking mass measurements utilising a weighing balance and a beaker at the bottom outlet of each rig. Once the discharge was over, the total discharged mass was noted. The volume of retained water in the test rigs was calculated by deducting the total discharged volume to the total received volume of rainfall.

3 RESULTS AND DISCUSSION

3.1 Water attenuation

OASIS retained all of the captured rainfall volume prior to local saturation. The discharge rate curves of the first rainfall simulation, showed a delay to the first discharge of 20 minutes and 13 minutes in OASIS and Inbitex, respectively, in comparison with the no barrier system, where discharge occurred after 2 minutes since the beginning of the simulated rain event. OASIS additional delay in discharge can be attributed to the already observed performance zones (referring to the absorption zone) by Nnadi et al. (2014) and Sañudo Fontaneda (2014). In all cases, after the end of each rain event, OASIS exhibited discharge curves with short and steep slopes similar to Control rigs but in contrast with the gradually decreasing discharge rate of Inbitex (figure 2). This difference in performance translates into higher attenuation from OASIS rigs prior to saturation (as seen in first rain event) and upon saturation (last rain event) similar retained volumes to Inbitex but with the disadvantage of delivering water with very high flow rates.

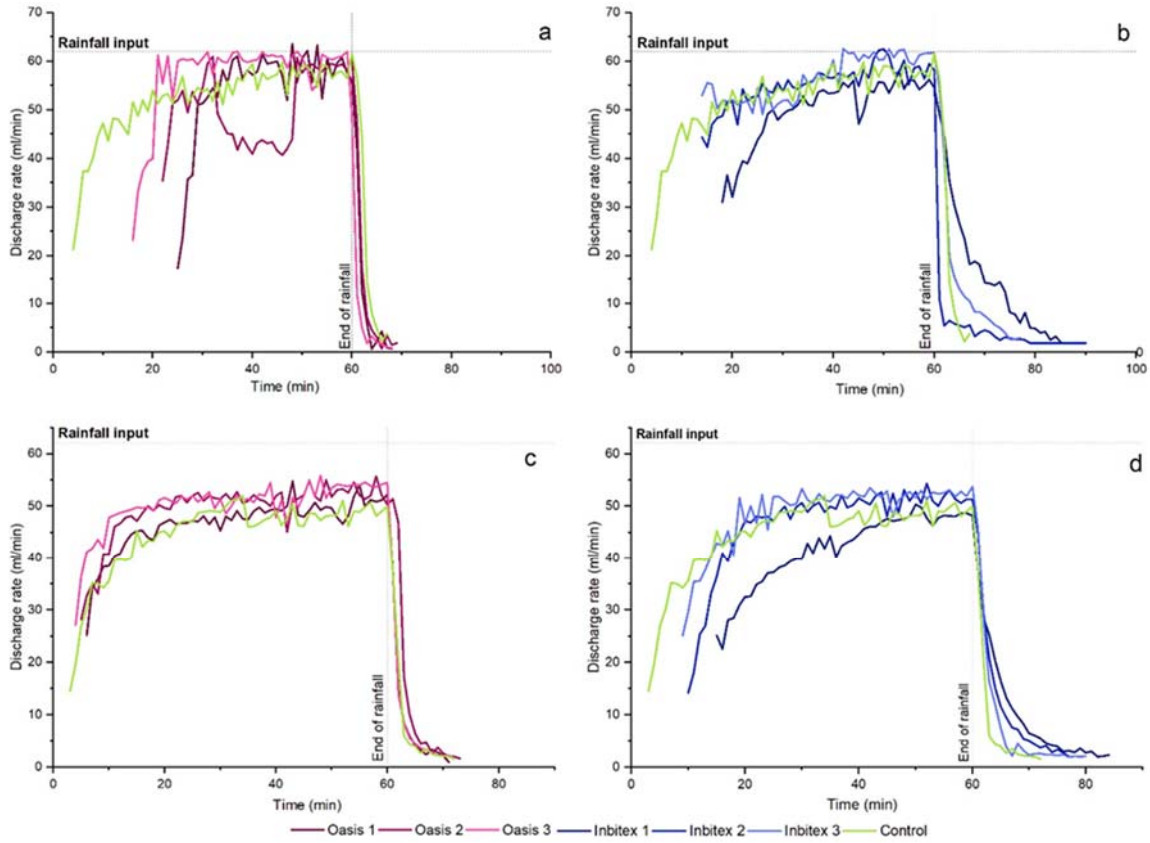

Figure 2.Discharge rate curve. (a, c) OASIS 1st and 9th event. (b, d) Inbitex 1st and 9th event

3.2 Water retention

OASIS showed an advantage on retention performance in comparison with Inbitex and Control rigs, retaining a mean of 40% of an hour rain event of 45mm/hr, following by Inbitex with 27% and Control with 16% (figure 3). Although results were in agreement with Nnadi et al. (2014) reports of OASIS enhanced retention performance compared with the near zero retention performance of traditional PPS,

the calculated storage capacity per m^2 was distinctively different. The mean water retention capacity at absorption zone of OASIS was estimated at ≈10l/m^2 almost one third of the estimated 27.17 l/m^2 by Nnadi et al. (2014). The disagreement on the estimated water storage capacity of OASIS at absorption zone implies that other factors may influence OASIS water retention prior to any infiltration.

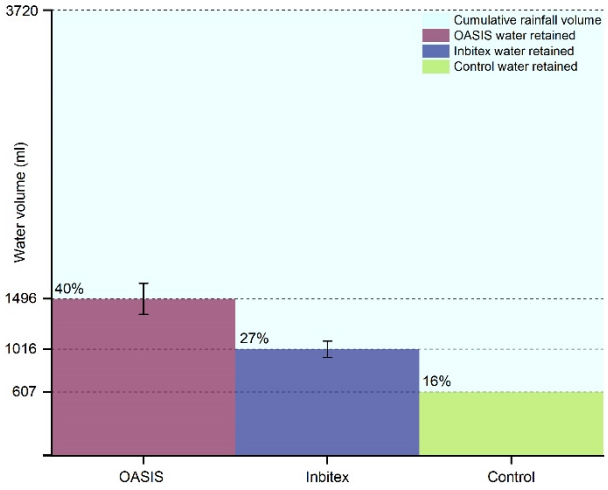

Figure 3. Water retention performance of OASIS, Inbitex and Control rigs

4 CONCLUSIONS

OASIS showed a benefit on retention performance compared to Inbitex and traditional PPS with no barrier systems, which lasted up to the total saturation of the sample. Upon reaching saturation OASIS systems exhibited similar retention behaviour to Inbitex and Control rigs. OASIS and Inbitex exhibited a delay of peak flow in comparison to traditional PPS systems. The OASIS additional delay of peak flow when compared to Inbitex was due to its three-dimensional structure and the capacity to store water prior to infiltration (absorption zone). OASIS does not drain any of the retained water prior to saturation, and this ability to retain water in the PPS structure could be beneficial in specific climate settings where water is needed during dry seasons. Results of OASIS water retention per m^2 obtained from these tests were particularly different from previously reported from Nnadi et al. (2014) and Sañudo Fontaneda (2014). Therefore, further research is required to identify any parameters correlated with water retention performance of OASIS. Testing under varying rainfall regimes is recommended.

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