proceedings

Proceedings

Thermal Performance of Wet Swales Designed as Multifunctional Green Infrastructure Systems for Water Management and Energy Saving [†]

Valerio C. Andrés-Valeri [1,2], Luis A. Sañudo-Fontaneda [3,4,*], Carlos Rey-Mahía [3], Stephen J. Coupe [4] and Felipe P. Alvarez-Rabanal [3]

[1] Instituto de Obras Civiles, Universidad Austral de Chile, General Lagos 2085, Campus de Miraflores, 5090000 Valdivia, Chile; valerio.andres@uach.cl
[2] GITECO, School of Civil Engineering, University of Cantabria, Avenida de los Castros s/n, 39005 Santander, Spain
[3] Department of Construction and Manufacturing Engineering, Polytechnic School of Mieres, Campus of Mieres, University of Oviedo Stormwater Engineering Research Team (UOStormwater), 33600 Mieres, Spain; UO236881@uniovi.es (C.R.-M.); alvarezfelipe@uniovi.es (F.P.A.-R.)
[4] Centre for Agroecology, Water and Resilience (CAWR), Coventry University, Ryton Gardens, Wolston Lane, Coventry CV8 3LG, UK; Stephen.coupe@coventry.ac.uk
* Correspondence: sanudoluis@uniovi.es; Tel.: +34985458196

[†] Presented at the 2nd International Research Conference on Sustainable Energy, Engineering, Materials and Environment (IRCSEEME), Mieres, Spain, 25–27 September 2018.

Published: 5 November 2018

Abstract: Lack of city space and conventional drainage systems failures have derived in the need to implement Green Stormwater Infrastructure (GSI) techniques which provide multifunctional areas capable of managing stormwater, treating the pollutants present in the runoff, bringing back biodiversity to the urban environment, and providing amenity whilst improving livability. In this context, swales were studied as a potential multifunctional GSI for water management and energy saving. This research successfully proposed the combination of a wet swale with a Ground Source Heat Pump (GSHP) system. The materials used within the cross section of a standard wet swale provided good isolation properties within the temperature performance ranges (20–50 °C), showing great potential for a swale to be developed together with GSHP elements, opening a new research area for water management and energy saving.

Keywords: GSHP; stormwater BMPs; SUDS; WSUD

1. Introduction

Climate change and anthropogenic impacts have worsened flooding and drought problems in urban areas. Green Infrastructure (GI) has arisen as a relevant tool to improve city resilience against extreme events, being supported by the European Union (EU) as well as other international institutions [1]. Sustainable Urban Drainage Systems (SUDS) have been at the forefront of techniques designed and implemented to decrease flooding problems across the world, becoming the preferred GI. SUDS are also well-known for providing multiple benefits like runoff control and pollution treatment whilst bringing biodiversity back to the built environment and improving livability conditions in cities [2].

Many countries no longer accept inefficient urban design and poor land-use. Thus, they are looking into multifunctional spaces capable of providing several functionalities such as robust water management infrastructure, technology to provide resilient food and water systems, and energy saving devices, amongst others. Permeable Pavement Systems (PPS) were the first SUDS technique designed alongside Ground Source Heat Pump (GSHP), becoming the first multifunctional SUDS for urban environments. It showed a good performance to help saving energy in buildings [3] and larger areas in cities [4]. However, further development in this technology was necessary before it could become a reliable multifunctional technology. Following up from that, further experiments carried out at a laboratory scale focused in the analysis of the thermal performance of several materials included in the structure of various PPS when combined with GSHP [5].

The research presented in this article introduces, for the first time, the application of greener SUDS like wet swales which could help in improving livability conditions and biodiversity at a higher level when introduced in urban areas [6]. The main aim of this study was to find out whether the design and construction of wet swales could be liable to be developed in combination with geothermal energy elements such as GSHP. With this aim, a laboratory experiment was carried out by simulating a GSHP device operating at different temperatures.

2. Methodology

Three wet swale models were built in the laboratory using polyethylene containers (HDPE) (1 in Figure 1) in order to replicate its standard structure at a 1:2 scale:

- Bottom platform made out of plastic cells 50 mm thick (2 in Figure 1) covered by non-woven polypropylene based geotextile (3 in Figure 1).
- Sub-base layer 200 mm thick (4 in Figure 1): Limestone aggregates 18 and 35 mm particle size.
- GSHP simulated looping (5 in Figure 1): polypropylene flexible pipe 20 mm diameter and 5 m length was placed 50 mm above the bottom line of the sub-base layer.
- Base layer 100 mm thick supporting grass growth in the surface layer (6 in Figure 1).
- Surface layer made out of grass (7 in Figure 1).

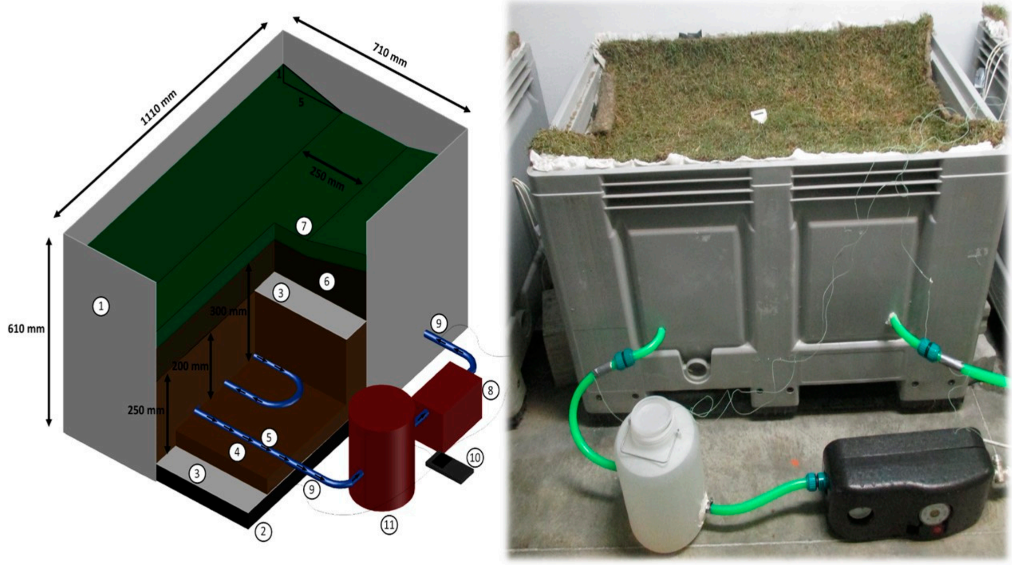

Figure 1. Experimental setup.

Four temperature sensors were located at 100, 200, 300 and 400 mm (RTD 1, 2, 3 and 4 in Figure 2), respectively, from the bottom line of the sub-base layer, measuring the temperature variation between the different layers when circulating water through the flexible pipes at several performing temperatures (20, 30, 40 and 50 °C), simulating a GSHP device. Furthermore, the temperature was measured in the inlet and outlet points of the model (9 in Figure 1) (PCE1, PCE2, respectively, in Figure 2). All temperatures were measured at 1 min intervals and each experiment lasted for 8 h. A 15 L insulated tank was used as a water reservoir (11 in Figure 1), being connected to a hydraulic pump (8 in Figure 1) in order to generate enough water flow inside the flexible pipe. Finally, the temperature within the simulated GSHP device was reached by using an electrical resistance controlled by a temperature device (10 in Figure 1).

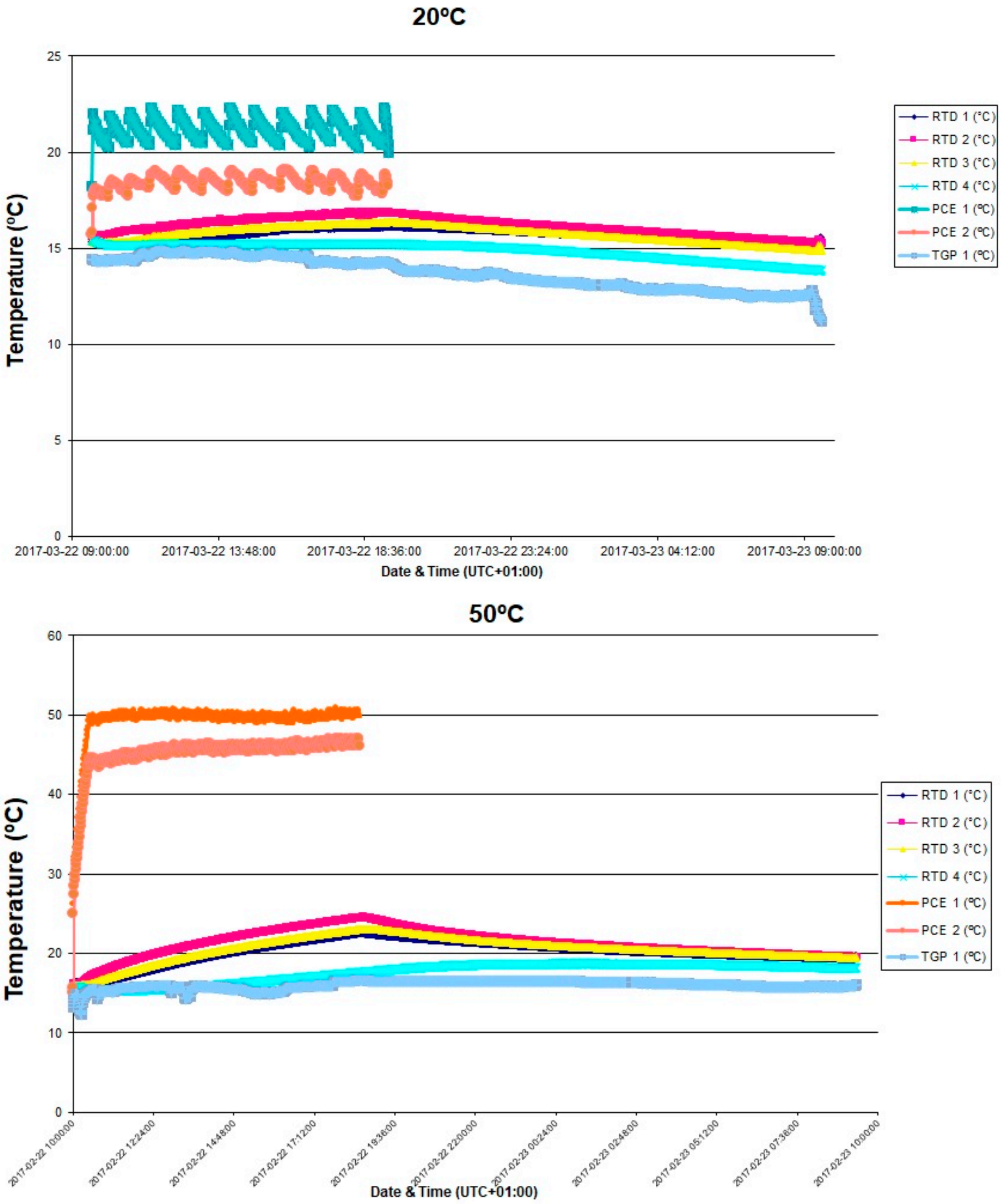

Figure 2. Temperature performance of all wet swale layers: (upper chart) under 20 °C GSHP operation performance (lower chart) under 50 °C GSHP operation performance.

3. Results and Discussions

It was observed that temperature increased constantly within the swale profile (Figure 2). Nevertheless, the systems presented a good isolation performance despite the constant presence of water in the system which could improve the heat transfer between the simulated GSHP element and the surface layer. Temperature in the room is presented in Figure 2 as TGP 1.

The results obtained from this pilot study show that a combined approach to water management and energy saving is possible by using greener SUDS such as wet swales, opening a new research line, although further research is needed at a higher scale and field conditions to finally validate the technology.

4. Conclusions and Future Research Lines

A future research line on the combination of SUDS and GSHP will be taking off over the next years as interest is growing constantly.

Swale structure showed good isolation properties and thermal regulation for the potential use alongside GSHP techniques.

Initial results in the field and in the laboratory have shown a promising path towards the application of renewable energy in Green Infrastructure.

Author Contributions: L.A.S.-F. and S.J.C. conceived the initial research project; V.C.A.-V. and L.A.S.-F. designed the experiments; V.C.A.-V. performed the experiments; All authors analyzed the data and contributed to write the paper.

Funding: Coventry University through the project entitled "*Investigation of Green Infrastructure as a combined technique for Bioretention, Flood Resilience and Renewable Energy*", the University of Oviedofor the funding to develop the UOStormwater through the project with reference PAPI-17-PEMERG-22, and the IUTA through the project with reference SV-18-GIJÓN-1-23.

Acknowledgments: The authors thank Coventry University and the University of Oviedo for the support to develop the research project and the University of Cantabria for providing the space to carry some of the experiments.

Conflicts of Interest: "The authors declare no conflict of interest."

References

1. Sañudo-Fontaneda, L.A.; Anderson, A.; Hunt, W.F. Green Streets: The opportunity to design resilient stormwater management in the cities of the future. In *Stormwater: Sources, Monitoring and Management*; Nova Science: New York, NY, USA, 2018, accepted.
2. Woods Ballard, B.; Wilson, S.; Udale-Clark, H.; Illman, S.; Ashley, R.; Kellagher, R. *The SuDS Manual*; CIRIA 753; CIRIA: London, UK, 2015; p. 968.
3. Charlesworth, S.M.; Faraj-Lloyd, A.S.; Coupe, S.J. Renewable energy combined with sustainable drainage: Ground source heat and pervious paving. *Renew. Sustain. Energy Rev.* **2017**, *68*, 912–919. doi:10.1016/j.rser.2016.02.019.
4. Tota-Maharaj, K.; Scholz, M.; Coupe, S.J. Modelling temperature and energy balances within geothermal paving systems. *Road Mater. Pavement Des.* **2011**, *12*, 315–344. doi:10.1080/14680629.2011.9695248.
5. del Castillo-García, G.; Borinaga-Treviño, R.; Sañudo-Fontaneda, L.A.; Pascual-Muñoz, P. Influence of pervious pavement systems on heat dissipation from a horizontal geothermal system. *Eur. J. Environ. Civ. Eng.* **2013**, *17*, 956–967. doi:10.1080/19648189.2013.837842.
6. Abrahams, J.C.; Coupe, S.J.; Sañudo-Fontaneda, L.A.; Schmutz, U. The Brookside Farm Wetland Ecosystem Treatment (WET) System: A Low-Energy Methodology for Sewage Purification, Biomass Production (Yield), Flood Resilience and Biodiversity Enhancement. *Sustainability* **2017**, *9*, 147. doi:10.3390/su9010147.

© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).