Preliminary results of experiments for the evaluation of on-site detention of modular blue roofs

Résultats préliminaires des expériences d'évaluation de la détention de toits bleus modulaires

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RÉSUMÉ

Cet article décrit les caractéristiques expérimental d'un système modulaire de toit bleu (BR) basé sur des plateaux installé pour contrôler le ruissellement depuis la terrasse d'un bâtiment du campus de l'Université de Catania (Italie). Le BR a été installé dans un quadrant de la terrasse tandis qu'un autre quadrant n'a pas été modifié pour permettre la comparaison. Le document décrit également les résultats préliminaires de la surveillance du BR lors du premier événement de tempête qui a été capturé. L'analyse des résultats montre que l'installation fournit une réduction du débit d'environ 55% pour l'événement de plieu analysé. La surveillance à long terme du système permettra d'évaluer les performances du système en matière de détention et de rétention, ainsi que de définir des normes pour la conception des réservoirs d'origine dans les zones urbaines.

ABSTRACT

The characteristics of the full-scale pilot of a modular tray-based blue roof (BR) system installed to control runoff from the roof terrace of a building of the Catania University campus (Italy) are described in this paper. The BR was installed in one quadrant of the terrace while another quadrant was left unmodified to allow comparison. The paper also describes preliminary results of the monitoring of the BR during the first storm event which was captured. The analysis of the results shows the installation to provide a flow peak reduction of about 55% for the analysed event. The monitoring of the system on the long term will allow evaluating the system detention and retention performance, as well as the definition of standards for BR design in urban areas.

KEYWORDS

Blue roofs, rooftop systems, runoff detention, runoff peak attenuation, SUDs

1 INTRODUCTION

Roofs represent a significant portion of the impervious surface of the cities and provide an important contribution to urban runoff generation. As a consequence, including sustainable urban drainage concepts into design of the building rooftops may increase the city resilience to floods (Fletcher et al., 2015).

Blue-roof (BR) systems are starting to appear in various countries as a novel technology for the control of runoff from the roof of the buildings (e.g., Roy et al., 2014). Such systems are designed to allow on-site detention and gradual release of rainwater through the building's drains. Although the concept of detaining rainwater on the building roof is far from the conventional design approach aimed at draining roofs as fast as possible, the benefits of BRs installation as sustainable urban drainage (SUDs) technologies are being increasingly demonstrated in different parts of the world. BR solutions range from pure detention-based systems to hybrid blue-green roof systems that include both storage facilities and vegetative layers for infiltration (Skjeldrum and Kvande, 2017). In any case, the detention action normally depends on the use of flow restrictions that can be customized case by case.

In the scientific literature, the availability of standards concerning BR systems design and construction is rather scarce. Results obtained from early field tests conducted in USA (NYC DEP, 2012) have pointed out the potential of BR systems as storm-water source control measures. However, the results are site-specific and further experiments are necessary to investigate the system behaviour under different climate conditions.

This work summarizes information concerning the installation of a full-scale pilot of a modular BR system. The system has been installed on the roof terrace of one of the buildings of the Campus of the University of Catania, Italy. Based on our knowledge, this is the first installation of this type in the Mediterranean area. Preliminary results of the experiments concerning the detention performance of the BR are included to explore its potential for runoff control.

2 METHODOLOGY

2.1 The pilot installation

The BR has been set up on a portion of the roof terrace of a building situated inside the University Campus in the city of Catania, Italy.

Two adjacent catchment quadrants of the terrace were identified, each characterized by a total surface area of about 26.3 m^2 (4.60 m x 5.72 m). The two quadrants are characterized by a mean slope of about 1.5% and separate roof drain systems (including separate inlet and downspout). One of the two quadrants (Q1) was equipped with a modular BR while the second quadrant (Q2) was left unmodified and used as reference. The BR in Q1 (see Figure 1) was made of 64 tray-modules, disposed in 4 macro-groups of 16 trays each, spaced with corridors of about 0.4 m in width used for system installation and maintenance.

Figure 1: The BR pilot installation

Used modules are made of rectangular open trays in polypropylene. Such material allows long-term system resistance to UV rays and high temperature that are typical of conditions developing on the roof terraces of the buildings of Mediterranean cities. Each tray has a 59.5 x 39.7 cm^2 internal surface area and height of about 11.5 cm, thus enabling a maximum storage capacity of about 27 litres. A circular orifice with the function of outlet was created on the bottom of the tray (Campisano et al., in press). A geotextile layer was placed within the tray to reduce risks of obstruction of the outlet orifice. The type of geotextile and the dimension of the outlet orifice were selected based on preliminary laboratory tests (Campisano et al., in press). In particular, the selected geotextile (of polyester fabrics) is characterized by a mass per unit area of 800 g/m^2, and a cross plane permeability of 11 l/s/m^2, while the diameter of the outlet orifice is about 7 mm. Ballast made of gravel was used to avoid the tray displacement potentially due to wind. The gravel was laid within the tray to build a uniform layer of about 3 cm. Small plastic feet were glued on the external bottom of the trays (external side) to step them up, thus allowing free outflow conditions from the modules on the roof surface during rain events.

2.1.1 Monitoring system

A meteorological station (model Davis Vantage Pro 2) was installed on the terrace to allow for the continuous measurement of the precipitation, as well as of other climate parameters (temperature, solar radiation, etc.). Records (accuracy 0.2 mm) were collected with time step of 5 secs. Moreover, two tanks (1000 litres each) were installed at the base of the building in order to receive runoff collected by the downspouts of the two quadrants, respectively. One piezo-resistive silicon probe (model Jumo Maera S25, measurement range 0-0.250 bar) was installed within each tank to obtain flow discharge through differential water level measurements. Probe accuracy (0.3% MSP = 7.5 mm = 3.75 litres) resulted smaller than the rainfall gauge precision. Same accuracy of water level measurements is provided for water volumes and flow discharges. A PLC device was used to collect, synchronize and store information coming from all the sensor devices in the long-term.

3 RESULTS

The preliminary results of the monitoring of the BR for one storm event that was recently captured (18th - 20th October 2018) are presented in Figure 2. The event consists of 3 successive rain showers for a total rainfall height *h* of 19.8 mm. The three showers (*h*=7.1 mm, 10.7 mm, and 2.0 mm) have durations of about 3.3, 1.1, and 1.4 hours, respectively. While the system was completely dry before the beginning of the event, antecedent dry weather periods (ADWP) before second and third showers are about 4 and 5 hours, respectively. Figure 2a shows the curves of the cumulated precipitation as provided by the rainfall gauge, as well as the cumulated runoff (in mm) from Q1 and Q2 for the considered storm event. The total runoff from Q1 was 14.5 mm, thus pointing out a significant retention performance (about 5.3 mm, about 27%) of the BR system as compared to the total precipitation event. Remarkably, such a retention effect is shown to be larger (about 1 mm more) than non-equipped Q2. The analysis of the results also shows that the ADWP may have had a role on the retention effect of Q1 and Q2, with larger retention effects for larger ADWPs (about 60% of the total retention can be attributed to the beginning of the storm event).

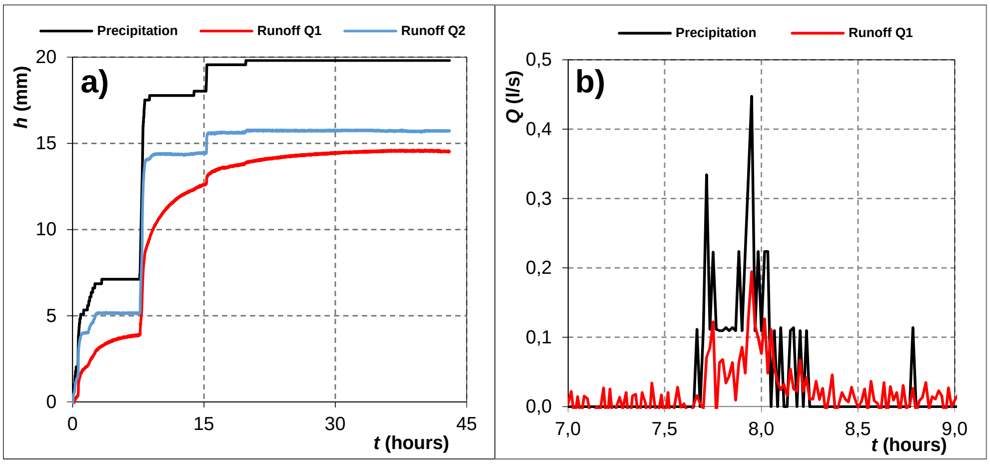

Figure 2: Detention and retention performance of the BR for the event of 18th-20th October 2018.

Side to retention effects, detention provided by the BR system is the most relevant aspect shown in

Figure 2a. The figure points out that the derivative of the curve of Q1 after each rain shower is much smaller than Q2, thus revealing a significant delay of the formation of the runoff in the quadrant with the BR installation. A detail of the detention effect for the second shower is shown in Figure 2b. In particular, the figure highlights a reduction of the runoff peak of about 55% as provided by the BR installed in Q1.

4 CONCLUSIONS

The work described the installation characteristics of a full-scale pilot of modular blue roof system on the roof terrace of a building of the University Campus of Catania, Italy. Two quadrants of the terrace (one equipped with the BR and the other one which was left unmodified for comparison) were considered for the pilot installation. The system will allow to investigate, for the first time, the behaviour of modular tray-based BR installations under climate conditions typical of the Mediterranean area. Preliminary results of the monitoring of the BR during one storm event were also presented. The results show the installation to provide benefits in terms of both detention and retention effects during the analysed rain event. Remarkably, a flow peak reduction of about 55% was obtained for the event. In addition, runoff retention effects were observed to be slightly larger for the quadrant with the BR as compared to the reference quadrant. The analysis of the results of the future monitoring of the system will allow the evaluation of the BR performance on the long-term.

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