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GREEN ROOFS FOR SUSTAINABLE WATER MANAGEMENT IN URBAN AREAS

Extended abstract

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Background

New housing developments and city infrastructures have led to a predominance of impervious areas in the urban environment and rainwater can no longer percolate naturally in the soil, leading to changes in the ground-water balance. Green roofs, green streets, and vegetated walls are increasingly addressed and studied as elements that help cities to adapt and mitigate the effects of climate change, achieve environmental benefits, enrich architecture and life quality. At the same time the principle of green corridors, till nowadays an element of the suburban territory, is reaching the urban environment because of its benefits in improving the microclimate and the urban quality of life.

Although many urban green technologies require availability of land space which is usually not available in densely built downtown urban areas (Berndtsson, 2010; Gambi et al., 2011), in every city, however, there is an abundance of roof area.

Moreover turning the roofs green through covering them with soil and vegetation is widely believed to contribute to achieving numerous hydrological benefits: studies show that, compared to traditional hard roofs, green roofs decrease runoff peak discharge, delay peak runoff and reduce runoff volume. Furthermore, green roofs and vegetated walls are beneficial for buildings, reducing noise levels, energy consumption and providing a better indoor comfort for their inhabitants (Berghage et al., 2010; Carter and Rasmussen, 2006; VanWoert et. al., 2005).

Green roofs are therefore being more and more installed by constructors and designers, but often it is just an aesthetical matter, and their scientific performance is still not known in detail.

In fact their performance is site specific, and taking other project as references is fine, but especially in different climatic areas it could lead to mistakes.

This is why it is very important the monitoring of pilot projects for an effective design and correct building codes for green roofs in a specific climatic area.

Objectives

This paper presents the description of a pilot green roof on the engineering laboratories of University of Bologna, Italy. The first results of the monitoring and simulation phase of the green roofs project that has been carried out by University of Bologna in collaboration with the Columbia University of New York aim at providing more evidence on green roof stormwater performance.

This project is the first green roof in the city of Bologna as no green roofs have been monitored for annual stormwater retention in this area.

Only one green roof in City of Genova, belonging to north Italian climate (the specific climatic context of the Mediterranean region: areas with this climate receive almost all of their precipitation during their winter season, and may go anywhere from 4 to 6 months during the summer without having any significant precipitation.) has been monitored and gave a 70 percent result in retention of the annual runoff (Palla et al., 2009).

The main objective was to compare this result to the Bologna pilot green roof and see how it differs from the other climatic area results.

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Outline of the work

This work is divided in two main parts:
- the first part describes a literature review on green roofs and the characteristics of the green roof built in Bologna;
- the second part presents the experimental data collected on the pilot green roof project

Methods

We have many different design choices in realizing a green roof on flat or tilted roofs, garages, basement parkings. Green roofs are made of different overlapping layers: essentially a waterproofing layer is right above the structural roof part. Then a root protection sheet, a drainage panel and a fabric filter go next, and at the end the growing medium and the plants. The growing medium thickness determines the type of roof, and if it's moderate, we can talk about an extensive green roof. There is still ambiguity in literature about the exact thickness borderline between extensive and intensive green roofs, but usually we can say that extensive ones are 8-15 cm high, above that range we have an intensive green roof. Extensive roof means low build-up height (80-150 mm), low load (from 80 kg/m^2) and low-growing plant, thus we usually have low care and maintenance. On the other hand an intensive roof means higher build-up (250-500 mm), heavier load (300-600 kg/m^2), larger plant selection but also more care and maintenance. The advantage is that it can be utilizable and walkable, so it can constitute a green garden within the city. In both cases the growing medium can host a variety of plants.

For the Engineering School of Bologna University the choice was driven by the structural constraints on site: the existing roofs had a load capacity that was able to host only an extensive roof, without the costly need of being reinforced.

In the extensive roof type the vegetation is usually very drought resistant and plants can adapt to difficult environmental conditions. Therefore sedum was chosen for the pilot green roof in Bologna and the sedum shoots were scattered on the growing medium during the construction that was held in June 2013. As the construction ended in summer good watering was important after the planting, and the substrate was always kept moist during the first few weeks thanks to the sprinkler irrigation system installed. The full scale installation of the sedum extensive green roof in the city of Bologna, Italy provided an experimental green roof area of about 50 m^2.

Moreover as the starting roof had a square shape, it was divided in two equal areas by a steel median divider: in one half the experimental green roof of 50 m^2 (substrate depth 10 cm) was installed while on the other half the conventional roofing assembly with bituminous membrane was left as reference twin roof. The entire surface went under maintenance of the bituminous membrane on both parts (total of 100 m^2) (Fig. 1). Both roof sections (green and black) were instrumented to monitor runoff profiles within the roofing systems using a hydraulic device made in the DICAM-CIRI laboratory. On the perimeters of the roof there is a gravel strip: 30 cm wide – grain size 18/30 mm.

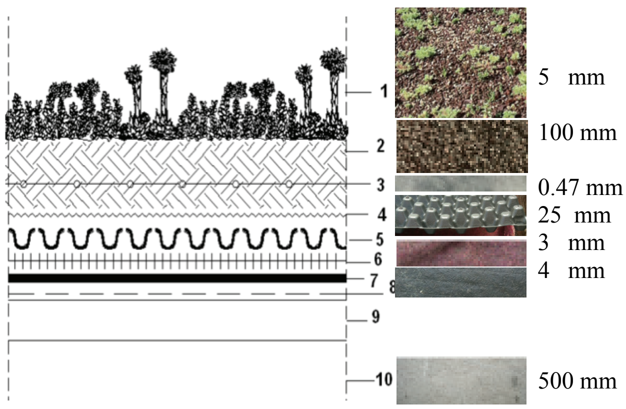

Fig 1. Extensive green roof with sedum plants and twin reference roof; Layers for green roof (* Elements constituting the SEIC green roof system): 1.Extensive vegetation – Sedum; 2.SEIC extensive substrate - growing medium; 3.Optional anchoring system for tilted roofs; 4.MediFilter MF1 - filtering mat; 5.MediDrain MD 25 – drainage element; 6.MediPro MP300 - root protection fabric; 7.Waterproofing root barrier membrane; 8-9-10.Structural elements

The hydraulic device for the water flow monitoring consists of a transparent low-density polyethylene (LDPE) rectangular channel equipped with a 90º V-notch weir and an ultrasonic level measurer placed above the instrument. The dimension of the V - notch orifice has been designed to be able to calculate the flow rates with a conversion formula from the water level.

The equation (Eq. 1) adopted for the conversion from the water level measured and the flow is the following one:

$$Q = 1.42 \cdot h^{2.5} \quad (1)$$

where: Q is the flow in m^3/s, h the water depth in m.

This is measured on both twin roofs: this set-up allows direct comparison of the performance and benefits of the green roof and the impervious reference roof.

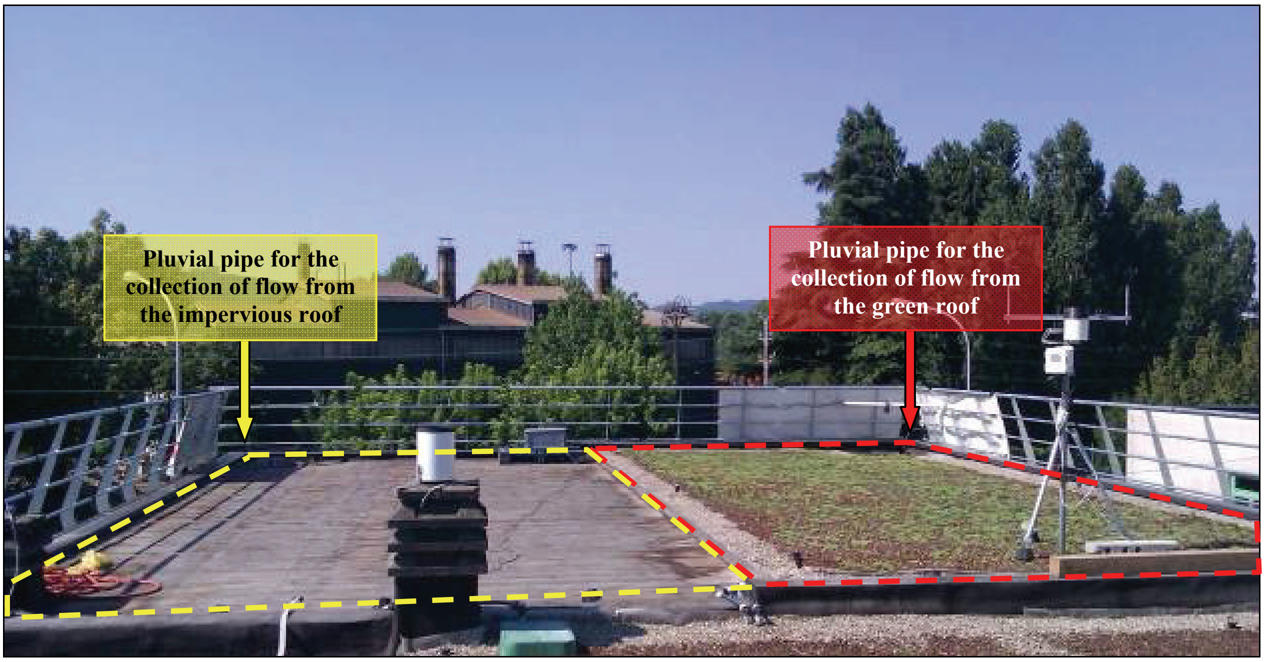

Fig. 2. Representation of the green roof and the impervious roof with the bituminous membrane

Results and discussion

Green roof stormwater performance is affected by regional climatic conditions, storm size, rain intensity, frequency, and duration, antecedent moisture in the soil, transmissivity of drainage layer, vegetation species and diversity, length of flow path, roof size, growing medium composition and depth, and roof age.

In this paper the following factors affecting runoff dynamics from green roofs were considered: type of green roof and its geometrical properties; soil depth and moisture characteristics; season, weather and rainfall characteristics; vegetation.

All these aspects were controlled and monitored thorough the design and construction process and then through specific environmental sensors which were installed on the prototyped extensive green roof located in Bologna, Italy, on the roof of the DICAM Department laboratory.

Given the fact that an irrigation system was installed, it was possible to run rain simulations at specific external conditions. Therefore a compared study of the delay in time between the simulated rain event and the real rain event registered in a period of a month was studied.

For example the time delay for the green roof for the last week of July, after the 2 daily irrigation sessions, at 5:00 am and at 9:00 pm, was recorded with the instrumentation put in place. The duration of one irrigation is 20 minutes and the total flow is about 360 liters. The results showed a different behaviour of the roof for the irrigation at 5:00 am (substrate still wet) and the 9:00 pm one (soil dried during the hot day). For the irrigation at 5 am the flow to the pluvial vertical pipe started after about 18 minutes from the start of the irrigation, while for the irrigation that started at 9:00 pm there is flow to the vertical pluvial pipe after about 34 minutes.

During rainfall events it is possible to study the behaviour of the impervious roof compared to the green roof. For example the rainfall event recorded on August 20th, 2013 (Fig. 3) is characterized by 2 rainfall peaks, the first with a maximum intensity of about 54 mm/hour, and, after one hour, the second peak of a maximum intensity of about 18 mm/hour and the total rainfall is about 9.7 mm. It is interesting to observe that the first peak generates a peak flow of about 0.24 L/s for the impervious roof and about 0.02 L/s for the green roof while the second rainfall peak generates a maximum flow of about 0.14 L/s for the impervious roof and about 0.05 L/s for the green roof, greater than the first peak due to the saturation of the soil. It is possible also to observe that the delay between the rainfall peak and the maximum flow is about 2 minutes for the impervious roof and 13 minutes for the green roof.

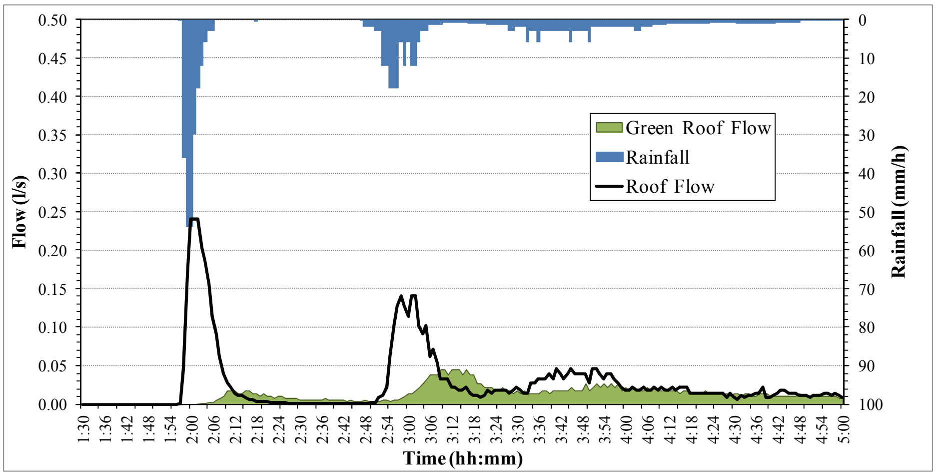

Fig. 3. Monitoring results for the rainfall event collected on 20/08/2013; comparison between impervious roof and green roof flows

Concluding remarks

In this paper the green roof installed in the University of Bologna and the first results of the monitoring activity were described.

The research is still at its first phase, as the roof has been completed at the beginning of July 2013, but the first results show the effectiveness of the green roof in delaying and reducing peak flows compared to a traditional impervious roof.

In the next months the monitoring activity will allow to collect other rainfall events and it will be possible to analyze the behavior of the green roof also through numerical models.

Keywords: green roof, monitoring, rainwater discharge delay, stormwater

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