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Green roof energy and water related performance in the Mediterranean climate

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ABSTRACT

Performance of vegetated roofs are investigated in terms of their expected benefits for the building and the urban environment, due to their recognised energy and water management potential scores. A review of related worldwide experiences is reported for comparison purposes. The investigation is here performed within the specific climatic context of the Mediterranean region. Full-scale experimental results are provided from two case studies, located in north-west and central Italy, consisting in two fully monitored green roofs on top of public buildings. The attenuation of solar radiation through the vegetation layer is evaluated as well as the thermal insulation performance of the green roof structure. The daily heat flow through the roof surface is quantified showing that the green roof outperforms the reference roof, therefore reducing the daily energy demand. As for water management, it is confirmed that green roofs significantly mitigate storm water runoff generation – even in a Mediterranean climate – in terms of runoff volume reduction, peak attenuation and increase of concentration time, although reduced performance could be observed during high precipitation periods.

1. Introduction

Integrated water and energy management in the urban context is one major route towards environmental sustainability and the reduction of carbon dioxide emissions into the atmosphere. The understanding of mass (water) and energy fluxes between the building envelope and the surrounding environment is indeed a topical issue whenever sustainability and comfortable living conditions are addressed for urban areas [1]. Sustainable construction in the cities is among the recommendations of e.g., the European Union Thematic Strategy on the Urban Environment [2]. It is recognised that sustainable construction can indeed improve energy efficiency and reduce the impact of day to day use of resources such as energy and water, their intrinsic interaction being a subject of increasing awareness among planners, researchers and practitioners [3–9].

Alternative rooftop coverage solutions play a significant role in this picture and specific greening technologies, largely known as green roofs, vegetated roofs, eco-roofs or nature roofs, are becoming popular instruments to achieve these goals and a still scarcely explored field of research for various disciplines [10–15]. Indeed, although the environmental benefits of green roofs are well-known under a general qualitative perspective, the comprehensive assessment of their potential in scientifically sound quantitative terms is still a challenge in all such disciplines.

The practice of green roofs has been mainly developed for cold regions where the climatic conditions, and especially the rainfall regime along the course of the year, are favourable to the growth of vegetation. International research efforts were consequently addressed with reference to experimental installations in continental or sub-artic climates [16–19] while as far as the Mediterranean countries are concerned, and especially in Italy, scientific studies are scarce and so are the experimental projects aimed to evaluate the effectiveness of green roofs as a tool for sustainable urban development.

Also, the available studies are yet not sufficient to support the development of systematic relationships between the various components of a green roof cover, or the specific sequence of superimposed layers, and the expected performance in terms of e.g., thermal, acoustic or hydrologic variables. This would be especially useful for industrial purposes, as well as for design, town planning and research applications at green roof sites where detailed monitoring of the energy and water related performance is not possible.

Even the common classification of green roof technologies in intensive and extensive solutions (see below) just refers to very qualitative aspects instead of providing a link to performance and benefits. Rather, technology and materials employed, the local climate and the precipitation regime, the orientation and

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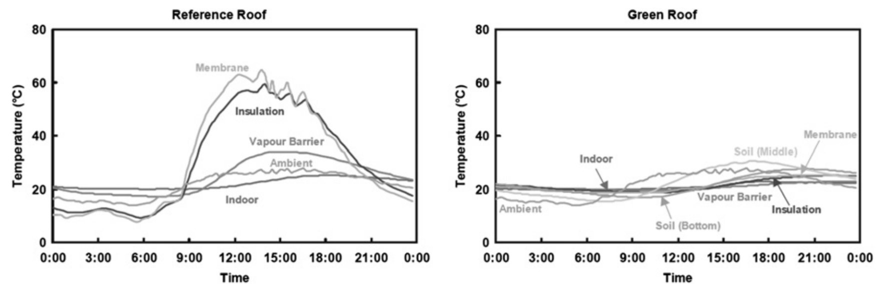

Fig. 1. Temperature profiles within the roofing systems on a summer day (July 16, 2001) indicating that the green roof reduces the temperature fluctuations within the roofing system, according to Liu [21].

Table 1
Energy related benefits of a green roof.

Benefits on the roof	Benefits on the building	Benefits at a larger scale
Thermal transmittance	Heat load	Heat island
Thermal inertia	Thermal comfort	Filtration of airborne particulates
Reduction solar absorbance	Acoustic comfort	Carbon dioxide–oxygen exchange
Reduction of noise	Energetic consumption	Reduce storm water
	Microclimate outdoor	

maintenance of the rooftop are among the most influencing parameters that may affect the expected performance of a green roof.

Accurate monitoring and observation of full-size field experiments support these emerging needs and a bridging effort is attempted in the following between the qualitative and quantitative approaches to the assessment of water and energy related performance of green roofs in the urban environment. In Section 2 the basic green roof technology is recalled and a review of experimental evidences of the related water and energy performance based on literature results is presented. Section 3 is devoted to the description of two test sites available in north-west and central Italy to investigate green roofs performance in the Mediterranean climate. The observed energy related performance are described and discussed in Section 4, while the storm water management performance are addressed in Section 5 before conclusions are drawn.

2. Green roof technology

Green roofs are a complex layered structure. A waterproofing membrane sits immediately on top of the structural roof deck to prevent moisture from entering the building. Typically, above this membrane is a root barrier layer that is designed to prevent roots from penetrating the waterproofing membrane and the structural roof. A drainage layer is next. The drainage layer (realized with either some engineered coarse grained porous media or plastic profiled elements) is typically designed to carry excess runoff to roof drains, and to store water for the plants in dry periods. Next, a filter fabric is installed to prevent soil from washing away and compromising the drainage layer as water drains from the roof. Finally, the growing plants and associated substrate or growing medium (a blend of mineral material enriched with organic material) complete the green roof. The substrate is often a lightweight synthetic soil that is porous and inherently inert, with nutrients added for plant growth.

The available technical solutions for green roof construction are usually categorised in three classes: intensive, semi-intensive and extensive. The differences are essentially based on the thickness of the stratigraphy, the expected use of the rooftop (practicable or not), and the costs required for maintenance. Intensive green roofs are thick and therefore heavy systems used to obtain a generally practicable rooftop with significant maintenance efforts required. Extensive green roofs are lightweight, thin systems that generally do not require maintenance and can not be walked on for any use. Semi-intensive solutions are middle way systems.

Although very common for green roof technologies, many criticisms apply to the above classification, this being not related to precise and objective characteristics of the stratigraphy but rather on weakly defined elements such as maintenance, which might even change from one region to another according to the climate. In this case a specific green roof product could belong to one class at the production site and to a different one at the installation location. The lack of a more precise and technically sound classification also derives, among other reasons, from the still limited quantitative knowledge about the technical performance of these sustainable building systems.

2.1. Energetic performance of green roofs

Green roofs are a solution to increase the energy performance and the sustainability of the building, producing benefits under several aspects. Depending on the climatic and urban context, it is possible to identify direct advantages either on the building itself or on a wider scale.

The green roof technology is able to reduce the energy consumption and to improve the internal comfort during the spring and summer seasons, in sites where the climatology is characterized

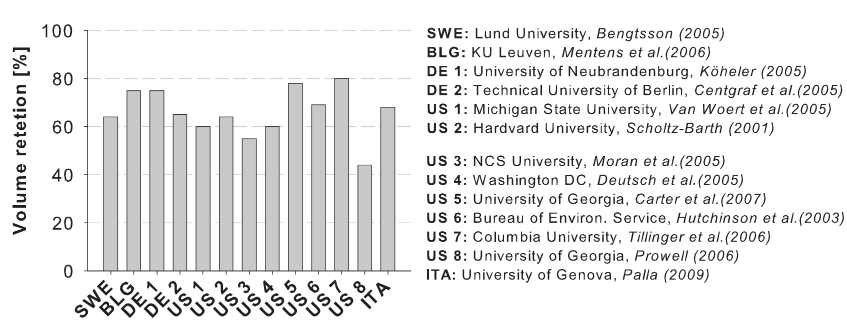

Fig. 2. Annual volume retention observed at experimental sites from a literature review.