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Use of rubber crumbs as drainage layer in green roofs as potential energy improvement material

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ABSTRACT

Today, green roofs are a building system which provides interesting benefits over traditional roof solutions. The most important advantages are the reduction of surface runoff in cities, improvement of the urban climate, biodiversity support, improvement of the durability of roofing materials, and, especially, energy savings. This paper has the aim of studying the performance of green roofs as a passive system for energy savings, within a wider objective of seeking constructive solutions suitable for sustainable and environmentally friendly architecture. This idea is tested at an experimental installation available at the University of Lleida, with several cubicles testing the energy performance of different construction solutions. This work raises the possibility of using recycled rubber from tires as a drainage layer in green roofs, substituting the porous stone materials currently used (such as expanded clay, expanded shale, pumice, and natural puzolana). This solution would reduce the consumption of these natural materials, which also require large amounts of energy in its transformation process to obtain their properties. Moreover it would provide a solution to the problem of waste rubber from the tires, known as rubber crumbs. Since the purpose of the drainage layer is the optimum balance between air and water in the green roof system, first the ability for draining of recycled rubber granules was studied and was compared with the offered by stone materials. The new solution using rubber crumbs is also studied to test if it would keep the same insulating properties that the green roof with stone materials presented in previous studies. Early results show that this extensive green roof system can be a good passive energy savings tool in Continental Mediterranean climate in summer, and that rubber crumbs can be an interesting substitute for stone materials used as drainage layer in this type of green roofs.

1. Introduction

Green roofs have been consolidated in recent years as a construction system that offers interesting advantages over traditional solutions. Some of these are the reduction of surface runoff in large cities, the improvement of the urban environment, the support to biodiversity, the improvement of the durability of waterproofing materials, and especially energy savings [1–21].

The green roofs are usually formed by the following layers [22,23]:

- Vegetation layer.
- Substrate layer: Usually topsoil or garden soil. It is the physical support for the plants. Moreover, it provides nutrients and should have capacity to retain water.
- Filter layer: Usually polypropylene or polyester geotextiles membranes. It allows the water to cross but not of the substrate small particulates that could clog the cavities in the drainage layer.
- Drainage layer: Its objective is to obtain an optimal balance between air and water in the green roof system. Drainage layer must be able to retain water when it rains, while it should also ensure good drainage and aeration of the substrate and roots. Currently being used mainly two types of drainage layer:
  - Polyethylene or polystyrene nodular panels, in which water accumulates, while allow evacuating the water excess, ensuring good ventilation.
  - Layer made of porous stone materials with some water retention capacity, such as expanded clay, expanded shale, pumice, and natural puzolana.
- Protection layer: Usually geotextiles polypropylene or polyester membranes. It provides mechanical protection of lower layers, especially for the waterproofing layer.
- Root barrier and waterproofing layer: It protects the building from the roots and water. Usually bitumen or PVC membranes, reinforced with polyester, fiberglass, plastics, and mineral granules. There are also some made with synthetic rubber or polyethylene.

They can either be extensive green roofs (thin substrate layer, light weight, without irrigation, and resistant species) and

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intensive green roofs (larger substrate thickness, larger weight of the system, with irrigation, and species typical of traditional gardening) (Fig. 1) [23,24].

Green roofs are a constructive solution designed with the goal of building more sustainable and environmentally friendly buildings. However the design is still based on conventional materials such as polypropylene or polyester geotextiles membranes, polyethylene or polystyrene panels, expanded clay, natural puzolana, and bitumen or PVC membranes.

Thus, besides studying their functional benefits, also study the goodness of the construction system itself should be considered. This work follows this idea, focusing on the materials used in the drainage layer.

The work raises the possibility of using rubber crumbs from tires as drainage layer in green roofs, substituting the porous stone materials currently used (such as expanded clay, expanded shale, pumice, and natural puzolana). Several actions were carried out:

(a) Since the purpose of the drainage layer is the optimum balance between air and water in the green roof system, first the ability for draining of recycled rubber granules was studied and compared with the offered by puzolana (comparison of hydraulic conductivity in lab and experimental green roofs in trays).
(b) Second, the new solution using rubber crumbs is also studied to test if it would keep the same insulating properties that the green roof with stone materials presented in previous studies in Continental Mediterranean climate (experimental green roofs in cubicles).

The study took place in Lleida, near Barcelona, in Spain. Lleida has a climate classified as Dry Mediterranean Continental, characterized by its great seasonal variations. It has low rainfall divided in two seasons, spring and autumn, and it has a thermometric regime with large differences between a long winter (between the spring and the last frost may take more than 160 days) and a very hot summer. The average annual rainfall of between 350 and 550 mm, and the mean annual temperatures oscillates between 12 and 14 °C, with thermal amplitudes of 17–20 °C. A special mention must be made to the fog, typical of the region in the months of November, December and January that can be given a period of up to 55 days in the absence of sunlight. This is a very similar climate to that of the area of Madrid, while taking this more annual rainfall and fewer days of fog per year.

The system used corresponds to an extensive green roof with a drainage layer of 4 cm of natural puzolana directly below to the layer of substrate (5 cm thickness) [25]. According to the recommendations given by the company commercializing the reference system used here between these two layers no filter layer was placed. In this type of climate and for extensive green roofs, irrigation during the summer months is also recommended.

2. Materials and methods

2.1. Drainage ability of the materials

In order to compare the drainage ability of the recycled rubber with the natural puzolana, hydraulic conductivity of these materials was studied with a constant load permeameter in lab [26].

The materials used as drainage layer in this first work were puzolana, a volcanic porous gravel (P) with a particles sizes of 4–12 mm, and recycled rubber of tires (R) with three different particles sizes, between 2 and 7 mm (R-Big), between 2 and 3.5 mm (R-Half), and between 0.8 and 2.5 mm (R-Small) (Fig. 2). For the substrate layer a commercial substrate was used [25].

The experiments were done individually for each of the four drainage materials (drainage layer), and later with those materials with a layer of substrate on top of them (drainage layer + substrate layer).

On the other hand, in order to further study the behavior of the analyzed green roof system, and observe what happens when the puzolana is replaced by rubber crumbs as drainage layer, several experimental trays were installed and studied during summer and autumn of 2009 (Fig. 3) [26].

In these trays the same system of green roof was installed, that is, 4 cm for the drainage layer and 5 cm for the substrate layer. The materials used as drainage layer were the same as in the laboratory study of hydraulic conductivity, puzolana (P) and rubber crumbs (R-Big, R-Half, R-Small).

The plants studied were Mesem Pendulina (*Lampranthus* spectabilis (Haw.) N.E.Br. = *Mesembryanthemum* spectabile Haw.), and Rosemary (*Rosmarinus* officinalis L. var. *postratus*).

The analyzed parameters were the water retention capacity of the system, and the plants development.

2.2. Experimental green roofs in cubicles

The aim of this experiment was to study the insulation effect of extensive green roofs in Continental Mediterranean climate.

The first steep was the installation of one provisional extensive green roof on an existing experimental cubicle in a large installation that the research group GREA has in Puigverd de Lleida (Lleida,

Fig. 1. Left: Intensive green roof, Singapore 2007. Right: Extensive green roof, Lleida 2010.