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Thermal analysis of a new modular system for green walls

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ABSTRACT

Green walls can protect building envelope from surrounding environment while contributing to improve buildings design and thermal performance. The design concept of a new modular system (Geogreen) for vegetated surfaces has been developed to create more sustainable green roofs and green walls.

This paper aims to present the study of Geogreen system thermal performance in a Mediterranean climate. This work is based on the evaluation of local meteorological conditions in three different periods. The Geogreen system is tested in an exterior test cell, comprising a reference wall and a wall covered with Geogreen modules. The analysis is based in the interior surface temperatures and interior surface heat fluxes of two compartments with the same dimensions and thermal characteristics.

Resuts show that Geogreen system contributes to: reduce maximum interior surface temperatures and increase minimum interior surface temperatures up to 7 °C; mitigate heat transfer, reducing maximum income heat flux by 75% and maximum outgoing heat flux by 60%; enhance thermal insulation of a wall; and increase thermal delay between the exterior and the interior. These aspects can lead to reduce and shift air-conditioning power loads and to improve buildings thermal performance.

1. Introduction

Green wall is the common term to refer to all forms of vegetated wall surfaces. Green walls can be subdivided in two main systems: green facades and living walls. There is an evident distinction between green facades, where usually climbing plants grow along the wall covering it, and the most recent concepts of living walls, which include materials and technology to support a wider variety of plants, creating a uniform growth along the surface. Green facades can be classified as direct or indirect. Direct green facades are the ones in which plants are attached directly to the wall. Indirect green facades include a supporting structure for vegetation. Living wall systems (LWS) can be classified as continuous or modular, according to their application method. Continuous LWS are based on the application of lightweight and permeable screens in which plants are inserted individually. Modular LWS are elements with a specific dimension, which include the growing media where plants can grow. Each element is supported by a complementary structure or fixed directly on the vertical surface [1].

Nowadays green wall systems are becoming popular [2] though they are still evolving and more knowledge on some of their particular impacts is required. The traditional composition of plants and soil substrates have been combined with new technologies in order to improve their performance and enhance the benefits allowed with these systems [3].

The final Report of the Horizon 2020 Expert Group on “Nature-Based Solutions and Re-Naturing Cities” enhances the attractiveness of green walls among other nature-based solutions, as in the long run they can be more cost-effective. As pointed out in this Report there are a number of new approaches for the implementation of nature-based solutions including integrating living systems with built systems through innovative combinations of soft and hard engineering. Heat stress in cities can be addressed by increasing green spaces and using green walls and green roofs. These measures could reduce temperature by up to 10 °C in Mediterranean areas. All of these approaches can also contribute to decrease flood risk and air pollution hazards, reduce energy demand in buildings (by 10–15%) and improve quality of life [4].

Green walls can be a smart approach of urban rehabilitation, contributing to the integration of vegetation in the urban context without land occupation [5], encouraging the fruition of urban areas [6] and improving buildings design and performance.

Green walls can make part of a sustainable strategy for the urban environment [7,8]. In fact the integration of vegetation in urban areas has several environmental benefits [9], contributing to: improve air quality [10], through the absorption of CO_2 [11] and the retention of dust particles and heavy metals [12]; mitigate the urban heat island effect [13], influencing the local climatic

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conditions (temperature and humidity); and biodiversity [14–16].

At the same time, the integration of vegetation in the urban environment makes a positive impact on human health and has economic benefits [17]. The presence of green areas influences aesthetically the surrounding urban area and contributes to increase property value [18].

Green wall systems can also protect building envelope from local climate and surrounding environment. They have the ability to function as a complementary acoustic protection [19,20], contributing to improve comfort of interior spaces. In fact, green walls can be integrated in buildings among several passive design solutions [21] as a strategy of evaporative cooling [22]. Most importantly, they can shadow the envelope [11,23–25], avoid overheating and degradation of coating materials, while contributing as an additional thermal protection [26–30], minimizing buildings energy demand for heating and cooling [13,31,32].

Green wall systems thermal contribution depends of several factors, such as: the type of vegetation and plants characteristics (e.g. leaf shapes, stage of development, colours, forms, solar transmittance, vegetation coverage percentage) [23,22,33,29,34]; type of substrate and its moisture content [23,22]; the system used (green façade or living wall, their composition, materials used, distance from wall), building characteristics (solar orientation, wind exposure) [34] and local climate conditions (e.g. external temperature, humidity, wind, rainfall). So, it is important to understand the context and conditions in which each green wall system is applied and how it can improve buildings energy performance [26].

In Mediterranean regions buildings are exposed to high solar radiation in summer and subjected to high daily and annual temperature variations. Therefore, insulating the envelope can contribute to reduce the impact of solar radiation in summer and protect it from large temperature differences between the interior and the exterior [35]. Some studies have been conducted in Spain and Greece [21,22,34,35] on the thermal performance of green facades in the Mediterranean climate. However, the energy performance of living walls is still a subject relatively new [36].

Thus, the present study aims to analyse the influence of a new modular green wall system on the thermal behaviour of building envelopes and its impact on their indoor environment in a Mediterranean climate. The thermal analysis is performed for a bare wall and the same wall covered with the modular system. The work is developed for 3 different periods in the central region of Portugal, between September and December 2013. A comparison regarding the bare wall and the covered wall is attained via an experimental setup. Results refer to temperature and heat flux values obtained in the interior surface of both walls.

2. System design

The design concept of a modular system (Geogreen) has been developed with the purpose of creating a more sustainable system for green roofs and green walls (see Fig. 1). This solution emerged from the R&D project PTDC/ECM/113922/2009 in which the authors were part of the team. It occurred in University of Beira Interior, Portugal between 2011 and 2014 and was partially funded by the Portuguese Foundation for Science and Technology (FCT). Its development makes part also of a Ph.D. study funded by the scientific research grant SFRH/BD/98422/2013, supported by FCT and POPH/ESF financing program. The presented modular system is patented (PT106022A) and was prized in Portugal and USA for its innovation in design, use of local and recycled materials and integration of climate adapted plant species.

The development of Geogreen system is based on the purposes to minimize its environmental impact and irrigation needs, enabling its suitability to different surfaces in new buildings and retrofitting, allowing the substitution of each module individually and improving buildings thermal performance [37,38].

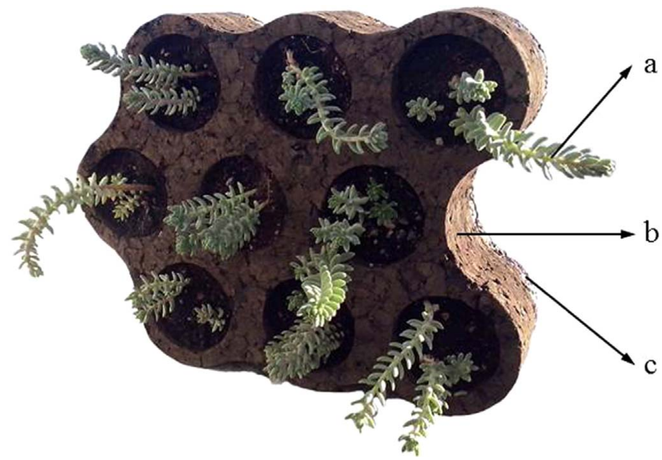

Fig. 1. Geogreen modular system design with plants and substrate. a. Adapted plant species; b.Upper plate in expanded cork board; c. Base plate in geopolymer binder.

The Geogreen system is designed to be more versatile than existing green roofs and green walls, allowing the creation of either green roofs or green walls, or both. The application process allows modules to remain locked together. However, in vertical or sloped surfaces, the system may include a support structure inserted in the voids between modules (Fig. 2), allowing its continuity and a reinforcement of its stability. The modular system materials selection is based on the reutilization of mine waste materials to develop alkaline activated binders (geopolymers), combining natural local materials (like expanded cork) with the insertion of endemic vegetation resistant to dry mesomediterranean conditions [37]. The Geogreen modules comprise a geopolymer base plate and an Expanded Cork Board (ICB) upper plate (see Fig. 1). The base plate is made of geopolymeric binder using a blend of mine waste mud and other recycled alumina silica rich waste materials. By increasing the water absorption capacity of the geopolymer plate, the system is able to absorb water and

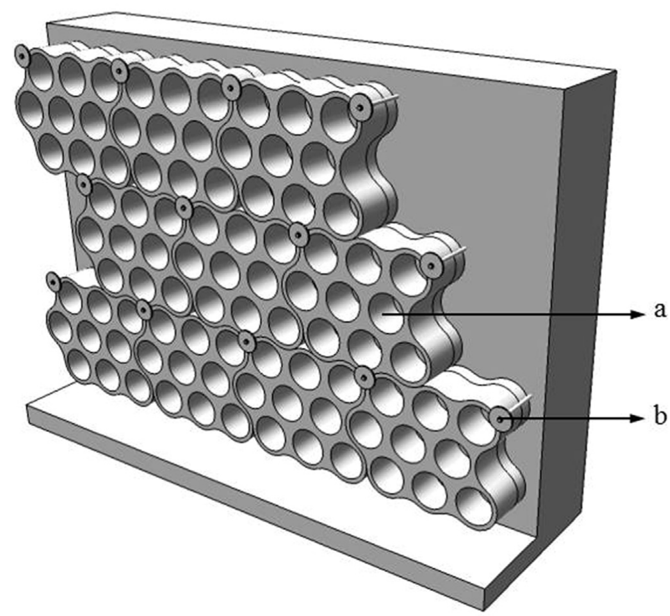

Fig. 2. Geogreen modules in vertical position with interlocking system. a. Geogreen modules (empty of soil and plants); b. Support elements.