Energy and Buildings 63 (2013) 1–14

Contents lists available at SciVerse ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Experimental measurements and numerical model for the summer performance assessment of extensive green roofs in a Mediterranean coastal climate

F. Olivieri [a,*], C. Di Perna [b], M. D'Orazio [c], L. Olivieri [d], J. Neila [a]

[a] Department of Construction and Technology in Architecture, Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Madrid, Av. de Juan de Herrera 4, 28040 Madrid, Spain
[b] Industrial Engineering and Mathematical Sciences Department, Faculty of Engineering, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, Italy
[c] Construction, Civil Engineering and Architecture Department, Faculty of Engineering, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, Italy
[d] Instituto de Energía Solar, Universidad Politécnica de Madrid, Av. Complutense 30, 28040 Madrid, Spain

ARTICLE INFO

Article history:
Received 3 December 2012
Received in revised form 23 February 2013
Accepted 30 March 2013

Keywords:
Experimental measurements
Mediterranean coastal climate
Summer conditions
Numerical model
Thermal resistance
High insulated roof

ABSTRACT

This paper presents the results of an experimental study carried out on an extensive green roof situated in a Mediterranean coastal climate zone. The aim of the study is to analyze the thermal energy behavior of a green roof during the summer so as to evaluate the effect of vegetation density on the energy performance of the roof and to identify the characteristics of the plants and substrate that have the greatest impact. The paper describes the results of monitoring carried out during the summer in 2010, 2011 and 2012, the development of a numerical model for calculating the thermal resistance of the substrate and the vegetation and the procedure for validating the model using the experimental data. The results show that a green roof which has high vegetation density acts as a passive cooling system when the roof is highly insulated (U value = 0.24 W/(m^2 K)) and that in these conditions the incoming thermal gain is about 60% lower than when the roof has no vegetation.

1. Introduction

Although green roofs have been used for a very long time it is only during the last twenty years that there has been an increasing interest in their energy and environmental benefits, both for the urban area [1–7] as a whole and for the building itself [8–14]. In fact in recent years many studies have dealt with these aspects from both the qualitative and the quantitative point of view, even if the complexity of the phenomena associated with the thermophysical behavior of green roofs has meant that no model for analysis which can easily be integrated in the building design process has yet been developed. For this reason, although green roof technology is well-established [15,16] and the cost of many extensive green roof solutions is competitive if compared with other types of roofing [17,18], in many countries green roofs have still not seen widespread use. Above all green surfaces integrated into architectural designs have not yet been regulated by legislation, and no incentives are available for these solutions [19–22]. Many studies concerning the energy effectiveness of green roofs are based on the development of complex mathematical models [23–26] which involve an understanding of the characteristics of the vegetation and the substrate [27–30]. Generally this goes beyond the know-how of most architects. Moreover, these studies analyze the instantaneous performance of the solution without focusing on its overall seasonal heat balance, although this factor is of great use when a green roof is proposed as an energy efficient solution. On the contrary, research which is based on the observation of monitoring data often refers to short periods of analysis and the results obtained, although of great interest for understanding the behavior of the type of roof analyzed, are difficult to extrapolate for other contexts and for other solutions. Furthermore, in most studies the green roof is considered as a single unit made up of plants and substrate and is always studied when there is the greatest density of vegetation, without bearing in mind that, unless it is a pre-vegetated green roof system, the vegetation takes time to develop after being installed and that the plants may die and the roof may have no vegetation for a certain period of time.

Therefore, the aims of this work are (a) to analyze the impact of vegetation density on the energy performance of a green roof

* Corresponding author. Tel.: +34 913364239; fax: +34 913366560.
E-mail addresses: francesca.olivieri@upm.es, francesca.olivieri.arch@gmail.com (F. Olivieri).

0378-7788/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.enbuild.2013.03.054

heat flux into the urban environment, Building and Environment 46 (2011) 2542–2551.
[33] M. D'Orazio, C. Di Perna, E. Di Giuseppe, Green roof yearly performance: a case study in a highly insulated building under temperate climate, Energy and Buildings 55 (2012) 439–451.
[34] http://www.hukseflux.com/product/hfp01?referrer=/product_group/heat-flux-sensors, retrieved 10th February 2013, HFP01/HFP03 manual version 0612, edited by Hukseflux Thermal Sensors.
[35] T.H. Hong, J.M. Kim, C.W. Koo, LCC and $LCCO_2$ analysis of green roofs in elementary schools with energy saving measures, Energy and Buildings 45 (2012) 229–239.
[36] T. Blanusa, M.M. Vaz Monteiro, F. Fantozzi, E. Vysini, Y. Li, R.W.F. Cameron, Alternatives to Sedum on green roofs: can broad leaf perennial plants offer better 'cooling service'? Building and Environment 59 (2013) 99–106.