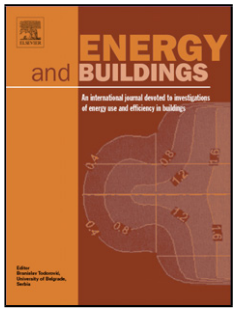

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Real-time temperature monitoring for traditional gravel ballasted and extensive green roofs: A Lebanese case study

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Abstract

The aim of this paper is to study and compare the temperature profile and energy performance of traditional and Vegetative Roofs (VRs) during winter season in Lebanon, a country in the Middle East. Three roof mockups were installed on the rooftop of the Chemical Engineering Department at the University of Balamand: a Traditional Gravel Ballasted Roof (TGBR) and two Extensive Green Roofs (EGRs) with different substrate depth and composition. Each minute, the temperature of air, on TGBR surface, and at different depths of EGR was recorded. The daily cooling and heating demands were also calculated. Results confirmed that VRs protect the roof membrane from high temperature fluctuations and decrease air temperature by a factor of one and a half during sunny winter days ($T_{air\ max} = 32^oC$). Findings of this study also showed that the total cooling demand of EGR decreased by 90% compared to TGBR.

Keywords: Extensive green roof, thermal comfort, economic study, Lebanon

1 Introduction

Vegetative Roofs (VRs) are gaining popularity due to many benefits compared to Traditional Gravel Ballasted Roofs (TGBRs). In particular, VRs have positive impacts on the quality of ambient air through the removal of air pollutants by plants **[1-3]**. From an energetic perspective, the use of such types of roofs can be very efficient. This is especially the case in summertime when VRs could reduce temperature fluctuations through the direct shading of plant canopy and cool the ambient air by consuming solar heat gain for transpiration and photosynthesis processes **[4]**. Moreover, VRs emit less long wave radiation due to their lower surface temperature. As a result, the Urban Heat Island (UHI) magnitude is reduced **[5-9]** and the energy consumption in urban areas is decreased **[10-12]**. In addition, the different layers of VRs block the solar radiation from reaching the concrete membrane, thus lowering its temperature and also reducing temperature fluctuations **[13, 14]**. However, TGBRs absorb solar radiation and the concrete membrane is heated up by the sun during the day and cooled down at night. These daily temperature fluctuations could crack the roof membrane and reduce its durability if occurring frequently **[15-17]**. Furthermore, VRs have an aesthetic appeal **[18, 19]**, can mitigate noise pollution **[14]**, and provide food as well as a safe habitat for many kinds of animals and invertebrates **[20]**. Some of the indirect VRs advantages are reducing the cost of house insurance **[21]** and increasing the building's value **[22]**.

There are two main types of VRs: intensive and extensive. The Intensive Green Roof (IGR) has a thick growing medium (>20 cm) whereas the Extensive Green Roof (EGR) has a thin substrate (<20 cm) **[23, 24]** and is more suitable for existent buildings since no additional roof support material is required **[25]**.

Several researches have been conducted on the temperature regime of VRs compared to TGBRs to prove that VRs protect the roof membrane from extreme temperature fluctuations **[7, 26]**. Studies were also done to assess and analyze VR's heat transfer capacity and its impact on the temperature fluctuations reduction and on the buildings' energy consumption **[12, 15, 27-32]**.

Jaffal *et al*. (2012) studied the energy performance of VRs compared to TGBRs in a temperate oceanic climate concluding that average indoor air temperature under TGBRs and VRs differed only by 1.5°C in a sunny winter day, and was the same (19.0°C) in a typical winter day **[26]**. Another aspect investigated by Wong *et al*. (2003) was the thermal benefits of VRs in a tropical climate acting as a cooling system in warmer days where maximum temperature on hard surface was 57.0°C compared to 36.0°C under planted soil **[7]**. Alternatively, the results of a simulation study done by Gagliano *et al*. (2015) established that an insulated EGR significantly decreases the cooling energy needs of a residential building and mitigates the UHI effect in mild Mediterranean areas **[28]**. To