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Assessment of green roof thermal behavior: A coupled heat and mass transfer model

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ABSTRACT

Green roofs have a positive effect on the energy performance of buildings, providing a cooling effect in summer, along with a more efficient harnessing of the solar radiation due to the reflective properties found inside the foliage. For assessing these effects, the thermodynamic model was developed as well as the thermo-physical properties of the green roof components were characterized. Its typologies and vegetation styles should also be studied. The proposed model is based on energy balance equations expressed for foliage and soil media. In this study, the influence of the mass transfer in the thermal properties and evapotranspiration were taken into account. We then added the water balance equation into our model and performed a numerical simulation. By assuming the outdoor conditions, the roof support temperature and the drainage water as inputs, the model evaluates the temperatures evolution at foliage and soil ground levels. A parametric study was performed using the proposed model to classify green roofs depending on the considered climate condition. Comparisons were undertaken with a roof slab concrete model; a significant difference (of up to 30 °C) in temperature between the outer surfaces of the two roofs was noticed in summer. The model was experimentally validated according to green roof platform, which was elaborated. The mass transfer effect in the subtract was very effective in reducing the model errors. Simulation results show that the use of vegetation in the roof building improves not only thermal comfort conditions, but the energy performance of a building.

1. Introduction

The building has, by the multiplicity of involved actors, a complex financial questions and growing environmental issues. In Europe, it represents 40% of the overall final energy consumption and 36% of the overall CO_2 emission. This high impact puts the energy savings in buildings at the heart of the strategy against economical problems and global warming.

To overcome these problems, various innovative construction solutions can be implemented. The use of vegetated land roofing is an appealing solution to improve a building energy performance, esthetic purposes, sustainability and environment in urban areas, especially regarding air quality and mitigation of urban heat islands.

In fact, with an insulation role [1–3] associated with an evaporative cooling [4] and better capturing of the solar radiation by the phenomena of inter-reflections within the foliage [5], green roofs have a very positive impact on the energy performance of buildings [4–8]. It also improves the longevity of roofing membranes [9–13].

The principle of a green roof is to cover a flat or a low sloped roof with a vegetated substrate. A green roof consists mainly of five components from the bottom to the top: a roof support, a roofing membrane (membrane protection and roof barrier), isolation, a drainage layer, a growing media and vegetation. Two types of green roofs are generally distinguished: extensive (low soil thickness, less than 10–15 cm) and intensive (high soil thickness, more than 15–20 cm) [12,14,15]. The integration of a green roof in a building is more successful during the initial stages of the building design process, but it is, nevertheless, feasible on existing buildings [16].

Motivated by the recent importance given to green roofs, several studies were done to model or measure the thermal impact of green roofs on building energy performance. The heat transfer in a green roof was analyzed by several studies [7,9,17–19].

The green roof, as an energy efficient solution compared to a conventional roof, was studied by many authors [4–8]. In this context, Wong [6] concluded experimentally that vegetation has the ability to stop up to 60% of external energy contributions in a tropical climate in Singapore. According to [5], about 40% of a building cooling load was saved with green roof in Athens. In the climate of Chicago, a high value of a green roof foliage density reduces the cooling energy consumption during the summer due to

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