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An investigation of sensible heat fluxes at a green roof in a laboratory setup

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During the last few years, several models have been proposed for the calculation of green roof thermal behavior, but the validation studies of such models are lacking a comprehensive set of highly accurate data. In this study, an experimental laboratory setup was used to create different environmental conditions and to measure sensible heat fluxes to/from a vegetated roof assembly. This experimental setup has been successfully used for different wind velocities (0–3 m/s) to create free and forced convection conditions around green roof tested samples. Furthermore, our study proposed a “basic model” for calculations of the convective heat transfer at green roof assemblies, which is a modified version of the Newton’s cooling law, calibrated and then validated with different sets of data. For forced convection flow regimes, the proposed “basic model” resulted in RMSE (Root Mean Square Error) of 11 W/m^2 and R^2 value of 0.81. Similarly, the model provided RMSE of 6.6 W/m^2 and R^2 of 0.90 for sensible heat fluxes with free convection conditions. In the future, this model will be used in on-site experimental studies to understand its performance under wind conditions that exhibit a much wider range than the studied velocity range near the leaf canopy.

1. Introduction

Vegetation has been used on building roofs and walls since ancient times, with the most famous example of the Babylonian gardens in Mesopotamia. A widespread use of roof vegetation has significantly increased in recent years. Fig. 1 shows an example of contemporary use of vegetation for a traditionally-designed house in Norway. Some European countries have explored opportunities for use of extensive green roofs since the 1970s [1]. The specific purposes of green roof installations vary, but generally hinge upon stormwater reduction or improved building energy efficiency and often both. As stormwater concerns in urban settings have become ubiquitous, green roofs have been introduced as a viable and effective method for reducing urban stormwater runoff from roof surfaces [2].

The types of growing media and roof assemblies vary, but most green roofs consist of a drainage layer, a root barrier, and a waterproof membrane as shown in Fig. 2. A green roof growing media depth is typically between 0.05 and 0.3 m [3], while the vegetation layer can incorporate different plants depending on the local climate [4]. A green roof has numerous benefits that include improved air quality, reduction of the “heat-island effect,” sound attenuation, building envelope protection, esthetic value, and stormwater detention, in addition to the reduction of energy absorbed by the roof assembly [2,5–7]. One of the ecological functions a green roof provides is its stormwater management capacity. Nevertheless, to take full advantage of green roofs, building designers need quantitative assessments of green roof benefits.

Horizontal building surfaces, such as roofs, experience high thermal loads during summer conditions in climates such as the Mediterranean or some U.S. climate regions. Green roofs may offer an adequate solution to this problem [8]. Theoretical and experimental analyses of different roof assemblies to promote cooling mostly focuses on evaporative and radiative heat transfer mechanisms. The green roof vegetation shades this type of roof assemblies from direct solar radiation, and it also cools the roof by means of evapotranspiration from the vegetation layer [9]. The vegetation layer also absorbs large quantities of solar energy during the diurnal biological functions. An incoming amount of solar radiation can affect the internal temperature of a building. Out of the total incoming solar radiation, approximately 27% is reflected, 60% is absorbed by the plants and the soil through evaporation, and 13% is transmitted into the soil [10,11]. As a result, green roofs can control the temperature of the roof assembly and protect the roof membrane from temperature extremes. During summer weather

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