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A combined experimental and simulation method for appraising the energy performance of green roofs in Ningbo's Chinese climate

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Abstract

A passive means of lowering the energy demand of buildings is the application of green roofs. The complexity between heat and moisture exchanges in green roof layers and the large variations of green roof types make the need for experimental or simulation assessments necessary for quantifying the energy benefits from green roofs. The current treatment of green roofs in simulation programs is either over-simplistic, for example by ignoring heat and moisture exchanges such as evapotranspiration, or the more advanced models have limitations and require inputs that are rarely available in practice. In this paper a combination of experimental and modelling techniques are used to assess the potential heating and cooling load reductions from the application of green roofs in the subtropical climate of Ningbo in China. The method provides a generalised energy performance assessment of green roofs in Ningbo by overcoming the limitations of existing green roof simulation models.

Keywords

green roofs,
energy and carbon savings,
integrated building energy simulation,
measuring boundary conditions

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1 Introduction

Building energy regulations are continuously evolving across the world with the aim of introducing additional measures that could further reduce the energy consumption of buildings. A potential technique for lowering energy consumption in buildings is the application of green roofs. The benefits from green roofs have been extensively discussed in various literature and are not limited to only lowering the energy demand. Green roofs are linked with other socio-economic issues such as storm water management (Mentens et al. 2006; Teemusk and Mander 2007), mitigation of urban heat island (Alexandri and Jones 2008; Susca et al. 2011), enhancement of biodiversity (Brenneisen 2003), improvements on air quality (Yang et al. 2008), etc. The overall advantages of green roofs have been discussed by many researchers (e.g. Banting et al. 2005). A thorough review of previous studies in which the energy savings that could be offered from green roofs were investigated is given by Castleton et al. (2010). Most of these previous studies that have been reviewed by Castleton et al. (2010) were focused on extensive green roofs and the authors concluded that green roofs could mainly offer energy savings to buildings with poor insulation levels. The conclusion by Castleton et al. (2010) was obtained from previous studies that were done for green roofs located in Mediterranean, North American and hot Asian (i.e. Singapore) climates. The paper presented here is concerned with the potential energy savings that green roofs could offer in buildings located at Ningbo in China, under a climate that has hot rainy summers and cold dry winters and belongs to the sub-tropical "hot summer and cold winter" climate zone of China. The assessments for the potential energy savings of green roofs in this climate will be done by introducing in this paper a method that combines experimental and simulation techniques together to overcome potential practical limitations of these techniques. Such limitations will be discussed in this section while the proposed method will be described in Section 2 of this paper.

A classic method in the literature for assessing the energy benefits from green roofs is by using on-site experimental set-ups. Measurements are taken of the heat flux and the

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