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Thermal regulation impact of green walls: An experimental and numerical investigation

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HIGHLIGHTS

- Green wall enables 6.1 °C temperature reduction in sunny days compared to bare wall.
- Temperature reduction in cloudy days is still promising by 4.0 °C.
- Greenery and green wall surface temperatures show similar tendency in cloudy days.
- Thermal regulation feature highly depends on plant intensity and orientation.

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ABSTRACT

Green walls can be basically defined as climbing plants grown either directly against, or on support structures integrated to external building walls. Similar to other types of green infrastructure, they are in the centre of interest owing to their remarkable benefits such as reducing internal building temperatures, mitigating building energy consumption and facilitating urban adaptation to a warming climate. In this research, thermal regulation feature of green wall systems is experimentally and numerically investigated through a case study conducted in the Jubilee Campus of University of Nottingham. Internal wall temperatures are measured time-dependently for different cases and the results are compared with those of ordinary walls for a reliable and realistic approach. Different sky conditions are also considered within the scope of this research as an independent variable. Experimental results are verified by numerical models carried out in Ecotect. The results reveal that an average of 2.5 °C reduction in internal wall temperature can be achieved via green walls with about 10 cm thick climbing vegetation of *Hedera helix*, which is very promising.

1. Introduction

Urbanization is one of major problems of today's world. As a consequence of rapidly growing interest to urbanization especially in developed countries, a significant number of natural vegetation is replaced with concrete constructions notably having surfaces with low reflectivity. This causes several severe environmental issues such as urban heat island (UHI). There is a consensus among scientists that decisive measures need to be taken urgently due to growing significance of UHI effects especially in highly populated and urbanized cities like New York. Susca et al. [1] clearly reports in their recent research that average temperature difference between the most and the least vegetated areas of New York is about 2 °C, which unequivocally demonstrates the influence of UHI on environment. Notable temperature rises especially in highly urbanized areas necessitate some urgent, cost-effective and environmentally friendly measures to be taken. In this respect, governments invoke new tendencies such as covering external walls of buildings with vegetation for a low-cost and efficient thermal regulation of built environments as well as minimizing adverse effects of UHI. As it is reported by Alexandri and Jones [2], significant temperature decreases can be achieved through green walls depending on climatic conditions, building type and vegetation considered.

Plants can be considered to be an effective way of improving the function of original walls as stated by Ottelé et al. [3] in their comparative life cycle cost analysis green facades. As a general consensus, any type of facade covered with vegetation is referred to as green wall system. In order to cover external walls with plants, lots of functionally traditional or novel ways can be utilized as clearly stated in literature such as growth in the ground, directly living on the facade, or box and rack systems fixed on the facade [4,5]. The most common configurations utilized in previous works are

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direct facade and double skin facade as illustrated in Fig. 1. Direct green facades feature self-clinging climbers, which adhere to the external walls through adventitious roots or self-adhesive pads like in *Hedera helix* and *Parthenocissus quinquefolia*, respectively. It is reported by Sternberg et al. [6] that the cover provided by self-clinging climbers can play a bio-protective role, resulting notable reductions in wall temperatures. However, it is also noted that self-clinging climbers might damage building wall surfaces notably timber and cladding products. Planting a self-adhesive climber in the soil at the base of an external wall is a low-cost and effective form of green walls as also underlined by Hunter et al. [7]. Double-skin green facades are required some support structures such as stainless steel cables, modular trellises, or stainless steel mesh to assist the upward growth of climbing plants. In addition to the feature of shading impact, double-skin green facades provide a promising thermal insulation owing to the air gap between foliage and the external walls as emphasized by Perez et al. [8,9]. These systems have stem and petiole twining climbers as well as tendril bearers [10]. Double-skin green facades are especially preferred to be utilized on tall buildings.

The impact of existing structure and thermophysical properties of external walls on energy loss from buildings and UHI is unequivocal as reported by Ohashi et al. [11]. Green wall systems are considered to be a key solution to overcome these challenges owing to the feature of enhancing shading and thermal insulation feature of external walls in a cost-effective and environmentally friendly way. Plants on facade can effectively lower the temperature of the wall surfaces by absorbing incoming solar radiation for photosynthesis and providing thermally resistive air gaps between foliage and the external walls [12]. The optimized control of heat and mass transfer across the external walls via plants enable remarkable reductions in cooling demand especially in extreme weather conditions. For this reason, green wall systems are widely utilized in tropical environments [13]. Besides efficient thermal regulation, green wall systems have some additional benefits such as improving air quality, saving energy, reducing noisy sounds and mitigating greenhouse gas emission.

In literature, there are several ways of classifying green walls. However, according to different construction techniques and main characteristics, green wall systems generally can be split into two categories as green facades and living wall systems (LWS) as shown in Fig. 2 [14]. Green facades can be designed as direct or indirect. Direct green facades are based on the use of evergreen or deciduous climbers attached themselves directly to the building surface which can be seen in the traditional architecture. Indirect green facades include a vertical support structure for climbing plants development which is supported by trellis or steel cables. In this way, plants are guided to develop along the support structure. It is noted by several researchers in literature that direct green wall systems are more cost-effective compared to indirect

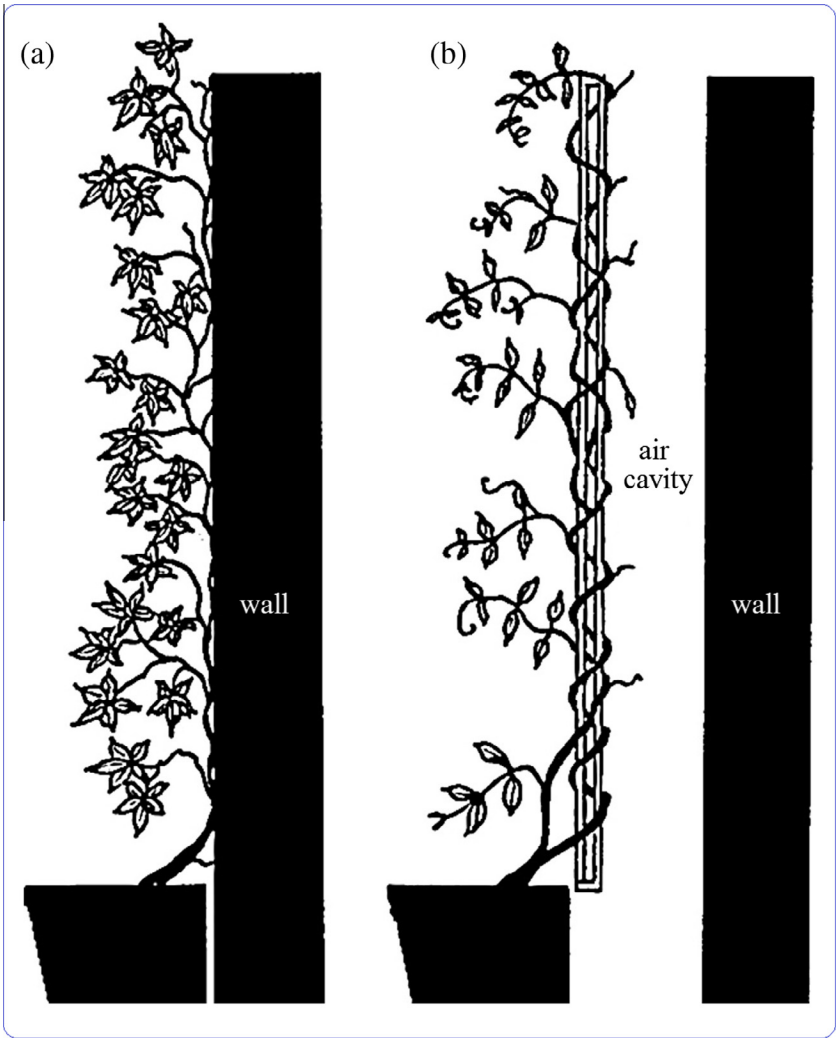

Fig. 1. Green wall systems: (a) direct green facade, (b) double skin green facade [4].

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