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Vertical greening systems and the effect on air flow and temperature on the building envelope

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ABSTRACT

The use of horizontal and vertical greening has an important impact on the thermal performance of buildings and on the effect of the urban environment as well, both in summer and winter. Plants are functioning as a solar filter and prevent the adsorption of heat radiation of building materials extensively. Applying green façades is not a new concept; however it has not been approved as an energy saving method for the built environment. Vertical greening can provide a cooling potential on the building surface, which is very important during summer periods in warmer climates. In colder climates evergreen species create an external insulation layer and contribute to energy savings and loss of heat. In this study an analysis of the effect on air flow and (air and surface) temperature of vertical greening systems on the building level is presented. An experimental approach was set up to measure the temperature (air and surface) and the air flow near and on different types of green façades and a living wall system to evaluate the influence of wind velocity and its effect on the thermal resistance. A comparison between measurements on a bare façade and a plant covered façade has taken, in the beginning of autumn, to understand the contribution of vegetation to the thermal behaviour of the building envelope.

1. Introduction

The integration of vegetation on buildings, through green roofs or vertical greening, allows obtaining a significant improvement of the building's efficiency, ecological and environmental benefits. The benefits gained thanks to the use of vegetation are the subject of studies and researches starting from the seventies [3]. During this period the first projects which revolved around nature and the environment emerged such as the work of the American architect James Wines who is associated with the SITE group, Emilio Ambasz, Rudolf Doernach, and Oswald Mathias Ungers.

Green façades and living wall systems (LWS) offer numerous ecological and environmental benefits, can have a positive influence on the comfort and well being in and around the building, besides social and aesthetical value [3]. The ecological and environmental benefits of vertical greening systems, as for green roofs, concern the reduction of the heat island effect in urban areas, the air quality improvement [10] and energy savings. In fact both the growing medium and the plants themselves provide insulation and shade which can reduce, especially in Mediterranean area, energy for cooling [13].

Starting from climbing plants planted at the base of building façades, diffuse in traditional architecture since 2000 years ago, there are now several different ways for vertical greening. The many systems available on the market can be classified into façade greening and living walls systems [7].

Green façades are based on the use of climbers (evergreen or deciduous) attached themselves directly to the building surface (as in traditional architecture), or supported by steel cables or trellis. Living wall systems, which are also known as green walls and vertical gardens, are constructed from modular panels, each of which contains its own soil or other growing medium (soil, felt, perlite, etc) based on hydroponic culture, using balanced nutrient solutions to provide all or part the plant's food and water requirements [4].

Living wall systems and green façades have different characteristics that can have influence on some of the benefits like cooling and insulating properties. This comes, among other things, due to the thickness of the foliage (creating a stagnant air layer and shading the façade), water content, material properties and possible air cavities between the different layers. The role of stagnant air layers is to slow down the rate of heat transfer between the inside and outside of a building.

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By constructing green façades and green roofs great quantities of solar radiation will be absorbed for the growth of plants and their biological functions. Significant amounts of radiation are used for photosynthesis, transpiration, evaporation and respiration [8]. A part of (5–30%) the remaining solar radiation is passing through the leaves and affects the internal climate of buildings when it passes the façade or roof. Especially in dense and paved urban areas, the impact of evapotranspiration and shading of plants can significantly reduce the amount of heat that would be re-radiated by façades and other hard surfaces. At the building level, as a consequence, every decrease in the internal air temperature of 0.5 °C can reduce the electricity use for air conditioning up to 8% [4].

Covering façades with leaves on outside walls, also known as green façades or vertical greening, is discussed in many studies. Field measurements on a plant covered wall and a bare wall by Bartfelder and Köhler [1,2] shows a temperature reduction at the green façade in a range of 2–6 °C compared with the bare wall. Also Rath and Kieβl [12] measured differences in the temperature gradient across a green covered wall. The corresponding factor in both researches is that at 1 m in front of the vegetation layer no temperature differences were measured between the greened and non-greened façades. However the temperature difference found in both investigations (conducted in Germany) at the wall surface between a greened and non-greened façade is approximately 6 °C. Another recent study by Wong et al. [13] on a free standing wall in Hortpark (Singapore) with vertical greening types shows a maximum reduction of 11.6 °C. This means that a greened façade absorbs less heat then a non-greened façade and reveals in less heat radiation in the evening and night.

The thermal transmittance of a construction is among other things dependant on the wind velocity that passes along the surface of a construction. The current Dutch standardisation [9] assumes an average wind speed of 4.0 m/s year round on the exterior surface for calculating the heat transfer coefficient. For interior surfaces the standardisation [9] applies 0.2 m/s along the wall surface. Green façades, however, change the wind velocity on the underlying exterior construction material. According to literature it is claimed that leaves (foliage) of plants create an almost stagnant layer of air or reduce the wind strength proportional [5,6], values however of these effects are missing or hardly known in literature.

In this study three common systems for vertical greening of buildings situated in Delft, Rotterdam and Benthuizen (The Netherlands) are considered and analyzed (Fig. 1):

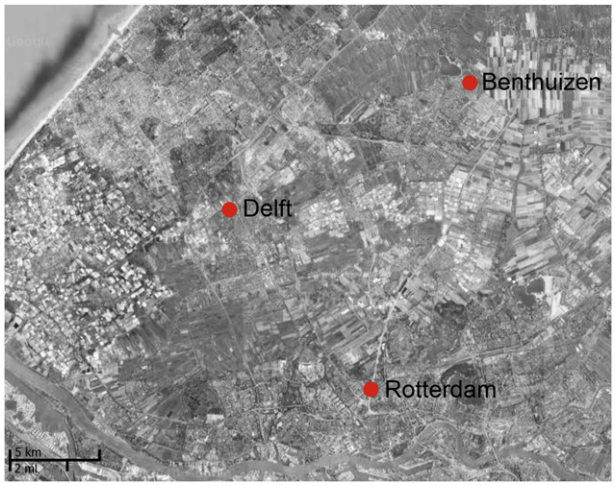

Fig. 1. Locations of the vertical green systems analyzed.

1. a direct façade greening system
2. an indirect façade greening system
3. a living wall system based on planter boxes filled with potting soil

1.1. Aim of the study and research questions

There are claims in literature [8,11] about the insulation properties of greening façades due to a reduction of the wind speed which can cause a possible stagnant air layer or an “extra” air cavity; however these effects are not quantified yet. Therefore the aim of this study is to quantify the above described possible effects. Beside this the objective of the quantification is to evaluate the potential energy savings (energy needed for heating and cooling) with different vertical greening systems due to the increase of the insulation properties of buildings.

Since the aim of this research is to measure the possible reduction of the wind velocity and (air and surface) temperature by different green concepts (direct, indirect and LWS), the following research questions have been formulated:

- Is there a difference in wind speed reduction between different greening systems?
- Is there a difference between air temperature in front of a bare façade compared with a greened one and between the surface temperatures of the bare and greened façades?

2. Materials and methods

The chosen greening systems for this research are based on different characteristics such as materials used, plant type and configuration. Due to the characteristics of each investigated greening system it is hypothesized that there is a difference on the microclimate (air-, surface temperature and wind speed) around and in, behind the green walls. The locations of the three façades investigated are all in the Netherlands (province Zuid-Holland) and are not further away than approximately 20 km from each other (Fig. 1).

The direct façade greening (Fig. 2a), situated in Delft on a 1920 building, consists of a well grown evergreen climber *Hedera helix*, attached directly to the building surface and planted at the base of the greened façade. The second system analyzed in this study is based on an indirect façade greenery (Fig. 2b) situated on the façade of 280 m^2 of a residential building from the seventies in Rotterdam. This system is constituted by aluminium pots, filled with soil, placed at several heights and connected to steel frames, acting as support for evergreen climbing plants (*H. helix*, *Vitis*, *Clematis, Jasmine and Pyracantha*) with a computer-controlled system for water and nutrients. The third investigated greened façade, a living wall system (Fig. 2c), located in Benthuizen, is based on plastic modules (HDPE), filled with potting soil and planted with several evergreen species (no climbers), with a computer-controlled system for water, nutrients and drainage.

All of the air-, surface temperature and wind measurements are done from September till end of October 2010, during days without rain or extreme high wind speeds (above 10 m/s). Measurements have been done between 12:00 and 15:00 h.

The period have been chosen for the experiment due to the main interest in measuring the wind flow and the importance of taking data during a cooler period.

Description of the greening systems analyzed

1. Direct façade greening system (Delft), Fig. 2a
   Orientation: North-West