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The heat transfer of a modular green façade system

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Abstract

The aim of this research is to develop a method, which can simplify the establishment of thermal transmittance of green façades. The examined green façade cladding system consists of different layers, including stainless steel boxes, which contain substrate, and a front plate behind the plant coverage made of painted mineral wool. The water content of the substrate and the plants make the complexity of the structure even higher as they do not have a permanent condition. The calculation of the unit heat loss rate of a green façade with ordinary methods is not possible. Therefore an experimental measurement system was needed to be installed on a green façade in Hungary. Examination of the external surfaces and air temperature was carried out on several points of the façade. Based on the measured data, thermal transmittance can be calculated. This research studies the factors that may affect the accuracy of this method: the temperature difference between the two sides of the structure, the places where sensors are installed, the frequency and length of measurements. This paper represents the effects of these factors and the sensibility of the calculation method on the different factors. Based on these calculations, the measurement of the thermal transmittance of a modular green façade cladding system may be simplified and shortened without decreasing the accuracy.

Keywords - component; Green walls, Green façade cladding system, Thermal transmittance, Sustainable building envelope

1. Introduction

Green façades are not just a novel and decorative cladding for contemporary architecture, but are also the focus of much research in building physics. [1] Besides the role of green façade in the thermal protection of buildings [2], principally in the reduction of cooling energy demands [3], their benefits on the psychical quality of the sustainable urban environment are also significant [4].

In recent research, green façades are modelled with the parameters of green roof. The performance of the two structures are slightly different therefore a detailed examination of the thermal properties of green façade is required. A calculated and proven model of green wall layer would contribute to the energy calculation of a building. The aim of this paper is to represent the method for measuring and calculating the thermal transmittance of an unknown living wall structure. As the system consists of different layers the U-values may be calculated on a rough estimate. Additionally, the inconstant soil humidity makes the standardized calculation more difficult.

2. Typology

Two types of green walls have to be introduced: green façade and living wall. [5] The main difference between the two solutions is in their technical background. Living walls have the technical complexity of a building material while green façades are basically climbers mounted by either a wire system or by the vertical surface of a wall. Living wall system requires to be introduced more detailed as a solution applied in this study.

Research carried out on the market of living wall shows a process of purification in terms of structure of different systems.

The basic idea and concept of green walls with technical background was presented by Stanley Hart White in his patent in 1938. [6]

Felt system was introduced by Patrick Blanc who planted plants without soil between layers of PVC and geotextile [7]. The advantages of this system inhere the adjustability of design on any walls and the flexibility of the materials. Due to the thickness of the system it is particularly sensitive to cold weather and well-developed plants cannot be applied. Under Mediterranean climate this system works well as the differences between the summer and winter temperatures are not so high.

Modular system shows a high variability in point of materials, growing medium and structural background. Modular systems can ensure long lifetime for the plants depending on the structure of the system.

Living walls have integrated irrigation system that provides for the plants the necessary amount of water and nutrients.

3. Methodology

To determine the U-value of the façade wall the physical parameters of all the layers must be known. The U-value of the background wall can be easily calculated according to data given on the specification of the product used. The U-value of the unknown living wall structure can be determined regarding the properties of the different layers. As these properties were not known measuring was needed to be analyzed.

The measurements were carried out in Hungary under typical European continental influenced climate with cold winters and warm summers. The location of the wall is close to the capital of Hungary but still out of the dense city center along the Danube in a small village called Leányfalu. The building functioning as a tank station has a living wall of the size of an approximately 42 square meter.

Sensors were installed in November 2015 therefore more than two months could be examined. Sensors measure the outside temperature, the temperature both on the outside and inside surfaces of the modules and the temperature of the sandwich panel wall on its outer facing. (Fig. 1)

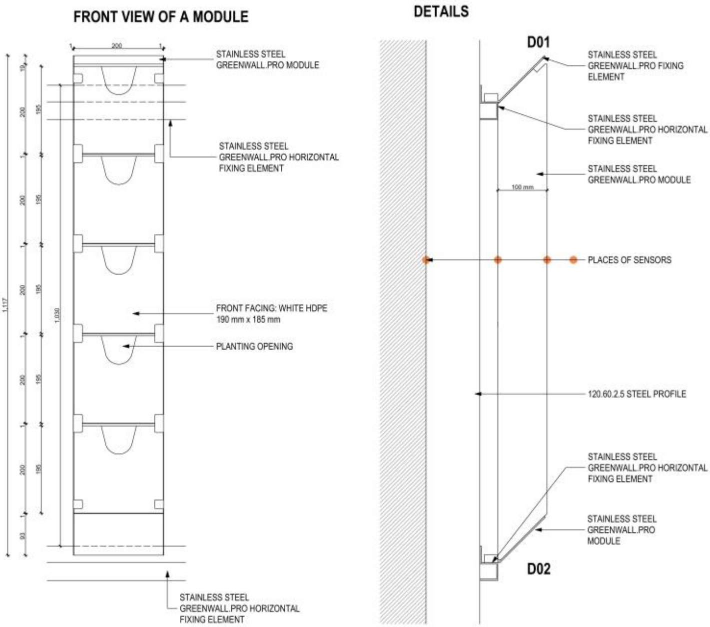

Fig. 1 The construction of the living wall panels and the places of the sensors

According to the standards, sensors should be mounted onto the surface to ensure a result which is representative for the whole structure. Sensors were placed into the middle of the examined vertical surface.

Duration of the test should last at least 72 hours if temperature is stable otherwise it should be extended to up to 7 days. [4]

The methodology of this study is based on standards:

- ISO 9869-1: 2014 Thermal insulation – Building elements – In-situ measurement of thermal resistance and thermal transmittance
- ASTM C1155 – 95 Standard Practice for Determining Thermal Resistance of Building Envelope Components from the In-Situ Data

4. Data and Calculations

The system is built up of stainless steel modules that can be adjusted easily to the desired wall size. The growing medium the modules are filled with is non-organic substrate. The size of each modules is about 20 cm x 100 cm and between the modules and sandwich panels there is an air gap of 160 mm. (Fig. 1)

During the measured period the irrigation system was not in operation due to the risk of frost and the evapotranspiration of the growing medium and plants is not significant.

The parameters of the layers are shown in Table 1.

Table 1. The construction of the wall covered with plants

Depth		Layer
5	cm	thermal insulation
10	cm	insulated wall panel
12	cm	vertical “Z” profile (steel)
4	cm	horizontal profile (stainless steel)
10	cm	stainless steel living wall modules with substrate
varying		plants

The background wall that the vertical garden is mounted onto is insulated wall panel with a beneficial U-value of 0.23 W/m²K.

The U-value of the complete layered structure is 0,214 W/m²K calculated with estimated values. The difference between the bare wall and the plant-covered wall is about 7-8 % that is close to the standard-required accuracy of 5 % therefore the calculation of the living wall layer should be measured independently from the background wall in that case.

Formula [8]:

$$U = \sum q / \sum (T_2 - T_1) \quad (1)$$

U	Thermal transmission coefficient
q	Density of heat flow rate
T_2	Inside temperature
T_1	Outside temperature

Calculation of thermal transmittance is based on the difference of temperature on the outside and inside surface of the undefined structure, the living wall structure in this study.

The inside temperature is the temperature of the air gap behind the modules of living wall while the outside sensor measures the temperature of the air.

Sensors measure instantaneous temperature therefore instantaneous U-values can be calculated. If the temperature outside decreases the structure starts to get cooler but due to its heat capacity mass the decrease of inside temperature is delayed. Therefore an average U-value needs to be calculated.

The heat capacity effects get evened during a cycle of warming and cooling periods thus the average U-values show the real values.

The measurements have to be carried out for 7 days at least to give the exact thermal transmittance value according to the standard [8]. In this research the measurements were carried out for two months to be able to analyze the required time while measuring only a part of the façade wall.

5. Results

In this study one-month period was measured in two months and the U-values are similar in both cases.

Fig. 2 shows the instantaneous and average U-values measured in December 2015.

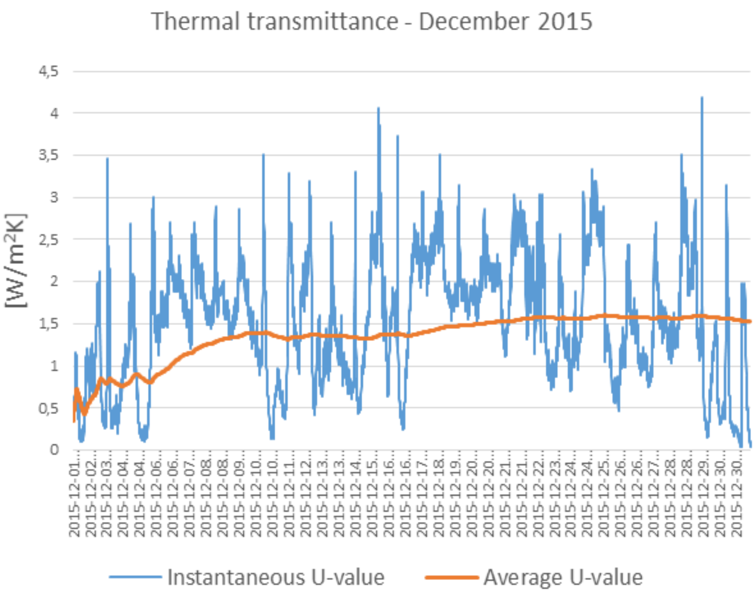

Fig. 2 The construction of the living wall panels and the places of the sensors

Fig. 3 shows the instantaneous and average U-values measured in January 2016.

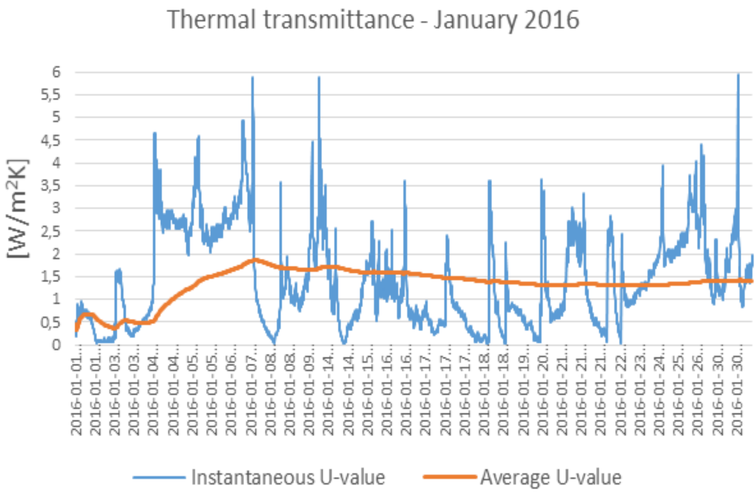

Fig. 3 The construction of the living wall panels and the places of the sensors

Both of the figures show that under the period of 24 hours the instantaneous U-values may vary on a large scale therefore long-term measurements give higher accuracy.

On the one hand the reason for the high differences may be the rate of accuracy to the measured differences in temperature. On the other hand the heat capacity mass may have significant impact on the structure. Therefore measurements have to be carried out for a longer period than 3 or 7 days.

Both Fig 2. and Fig 3. show that an average period of 14 days resulted in the accuracy of 5 %.

Calculating the average value for a longer period than 14 days the graphs did not show significant differences. The results of two measured months show the same thermal transmittance values on average.

The average U-value, in both cases, approaches the value of 1.475 W/m²K for the modular green wall structure.

According to the measurement method mentioned above the U-value of the whole structure can be determined.

$$U_f = 1 / (1 / U_w + 1 / U_g) \quad (2)$$

The U-value of the whole façade is 0,193 W/m^{2}K in accordance with calculation.

6. Conclusions

This paper represents the results of the measurement of thermal transmittance of a modular living wall system. The determination of the U-values of greenwall structure shows a growing demand on the field of building energy. Experiences of the measuring process show that as the differences between the inside and outside temperature are low (1~5 C°) a period of at least 14 days of measurement has to be accomplished in accordance with the principles of the standards. Calculations of U-data on different vertical gardening systems may serve as useful tools for engineers and building designers.

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