COMPARISON OF GREEN FAÇADE SYSTEMS BASED ON EXPERIMENTAL BASIS WEIGHT MEASUREMENTS

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Abstract
Green facade systems are gaining attention due to their potential for the urban environment, building aesthetics, and energy efficiency. This study compares different green facade systems and their surface weight, which is one of the critical parameters for performance and longevity. The research evaluates construction, installation, water consumption, and sustainable operation. Experimental measurements of surface weight examine changes depending on water consumption and performance.

Keywords
Green façade, basis weight, sustainability, urban environment, experimental measurements

1 INTRODUCTION

Green facades are becoming increasingly important in modern urban planning and architecture due to their potential to improve the urban environment, building aesthetics and energy efficiency. This article focuses on the analysis of green facade systems with an emphasis on one key parameter – the areal weight, which is affected by the amount of water in the structure. This changes over time depending on the evapotranspiration of the plants, thus affecting the performance of the green facade in terms of cooling the space in front of the facade. Construction, installation, water consumption and sustainable operation are investigated to determine the behavior and then compare selected green facade systems. As part of this comparison, an indicative determination of the costs for the normal operation and maintenance of these systems was also carried out. From the point of view of sustainable operation, this indicator can be a decisive factor for assessing performance as a natural element for cooling outdoor spaces on hot summer days.

This article presents the results of experimental measurements of the areal weight of green facades and evaluates the weight change over time depending on water consumption. Depending on the measured data, it also lists the price for the normal operation of selected green facade systems. This parameter can be decisive for the sustainable development of these systems in cities. In this way, we can better understand how to effectively design and operate different configurations of green facades with respect to their performance, installation complexity and sustainability.

2 LITERARY OVERVIEW/DESCRIPTION OF THE PRESENT STATE

A comprehensive overview of vertical greenery and its classification is provided by [1], [2]. Within the terminology, terms such as climbing vegetation, green facades, or living walls are encountered. This study focuses on examining prefabricated living wall systems.

These systems offer several potential benefits, ranging from aesthetic appeal to improving air quality, reducing the impact of urban heat islands [3], and positively affecting the energy demand of buildings [4]. The impact of vegetative facades on urban comfort, particularly in terms of reducing ambient air temperature and noise absorption, is addressed by Oquendo-Di Consola in [5], while Tseliou discusses the situation in a specific urban residential area in [6]. A study conducted in Barcelona [7] provides a clear example of the positive impact of a green facade in reducing ambient temperature by 2.7 °C during the summer season. The influence of facades on the energy demand of buildings is addressed in Raji's overview [8].

The implementation issues of vegetative facades are explained by Knifka in [9], where the lack of information and knowledge gaps are emphasized, leading to motivational and practical barriers in the design and implementation of vegetative facades.

Current research primarily focuses on the classification of vegetative walls in terms of species, aesthetics, and botany. However, for an engineering approach to the design of green walls, it is crucial to examine the properties and characteristics of these systems. This analysis is important to meet the requirements arising from legislation, particularly in the Czech Republic, such as Decree No. 268/2009 Coll., which sets technical requirements for buildings [10].

3 METHODOLOGY

The study was conducted based on a methodology developed at the Faculty of Civil Engineering, Brno University of Technology. The methodology focuses on measuring the maximum value of surface weight and its dynamic changes over time. This dynamic change is caused by vegetation growth, irrigation, and evapotranspiration [11]. For the purpose of this methodology, a test stand was created and used for the measurements in this study. The stand is designed as a standalone device that provides a horizontal surface for hanging the test samples of vegetative facades. Within the device, vertical displacement of the samples is allowed based on weight changes, and the measured values are continuously recorded using a load cell and a transducer.

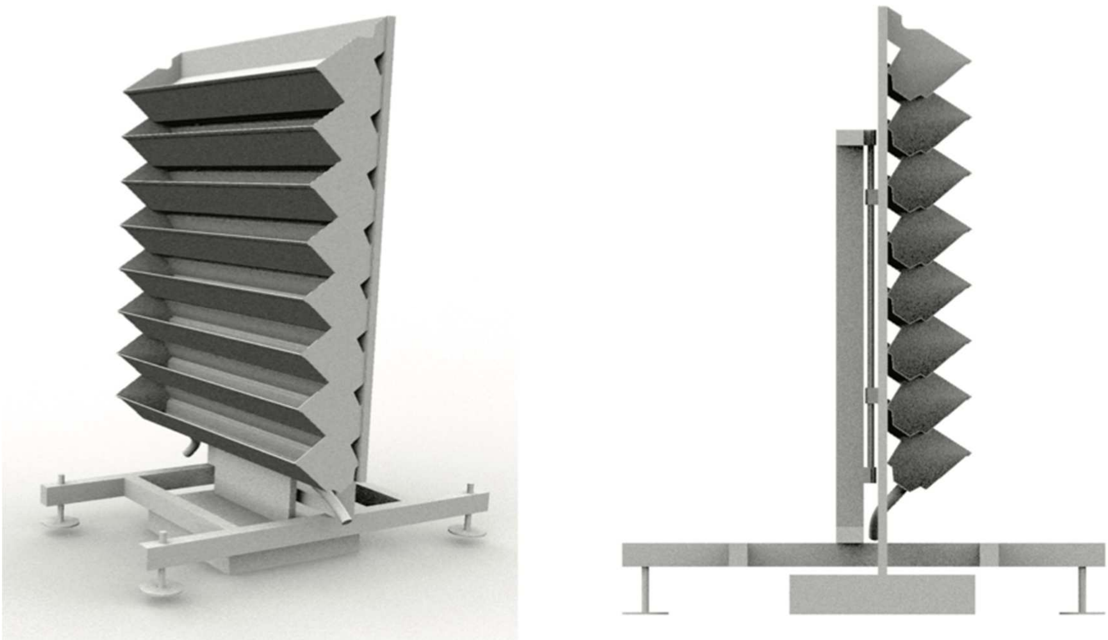

Fig. 1 The test stand is used for testing sectional models of vegetative facades, with the ability to monitor the supplied amount of irrigation water and its subsequent decrease due to evapotranspiration [11].

The experimental measurements took place outdoors in Brno, Czech Republic. During the measurement period, temperatures ranged from 15.4 °C to 36.5 °C, and air humidity varied between 36.9% and 98.6%. No atmospheric precipitation was recorded during the analyzed period.

Test samples

Within the study, two samples of modular living wall systems were analyzed. The first test sample of the façade consists of modules with dimensions of 400 × 600 mm, as depicted in Fig. 2a). For irrigation purposes, both the upper and lower parts of the module are perforated to allow water penetration. The second sample, illustrated in Fig. 2b), is composed of vegetation boxes measuring 850 mm in length and 190 mm in depth. For watering, a level overflow is created at the bottom of the box to enable water penetration through the façade.

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a) b)

Fig. 2 Samples of analyzed green facades.

During the experimental measurement, watering for sample a) was manually provided, while sample b) was irrigated using drip irrigation. At the time of installation and the start of measurements, both samples were fully saturated.

4 RESULTS

The measurements took place over 8 days, with weights recorded at 15-minute intervals. For sample a), the lowest weight recorded was 44.9 kg, and the highest was 67.1 kg. Irrigation was performed 178 hours after sample installation, with the sample's weight increasing by 21.9 kg/m^2 at the time of watering. For sample b), the lowest weight recorded was 45.1 kg, and the highest was 64.9 kg. The sample's weight increased by 18.4 kg/m^2 at the time of irrigation, but watering had to be repeated after 96 hours.

Despite observing similar values of weight per square meter, a significant time interval between individual irrigations is noteworthy. The first sample required watering after 178 hours, with the irrigation volume corresponding to 22 liters per square meter of irrigation water. In the second case, irrigation was necessary after 96 hours, representing almost half the time compared to the first sample. Meanwhile, the irrigation water volume for the second sample was 18 liters per square meter, differing minimally from the first sample. The change in basis weight over time, depending on the volume of water in the samples, can be seen in Fig. 3 and Fig. 4.

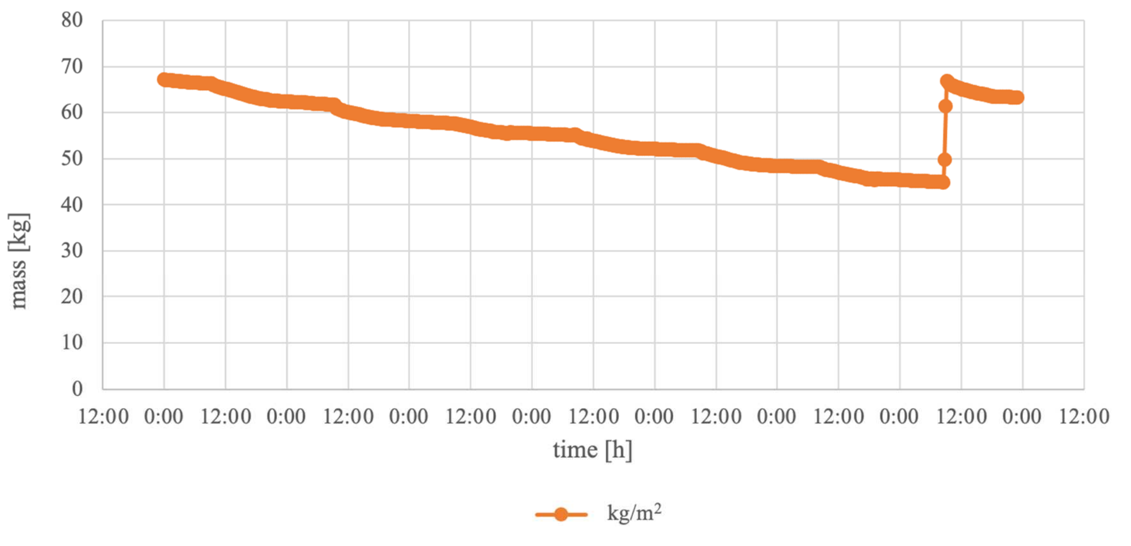

Fig. 3 The course of change in the basis weight of a sample of a green façade a) due to evapotranspiration and irrigation.

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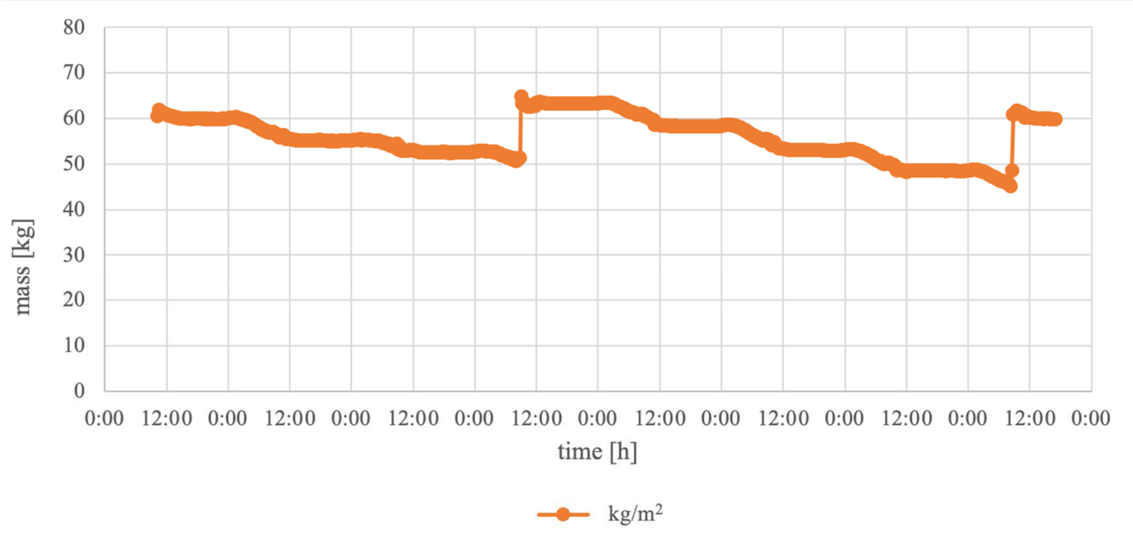

Fig. 4 The course of change in the basis weight of a sample of a green facade b) due to evapotranspiration and irrigation.

The above information quantifies the water consumption for irrigation, specifically 3 l/m^2/day for sample a) and 4.6 l/m^2/day for sample b). At the current water prices in Brno (50.88 Kč/m^3 including VAT, data from 2023 [12]), the total cost of watering 1 m^2 of green facade is 9.2 Kč for the first sample and 14.3 Kč for the second sample. These costs are accounted for over a two-month period of typical summer days with a maximum air temperature of 36.5 °C. It's important to note that irrigation costs should be included in the overall expenses associated with the installation and maintenance of the green facade. This is crucial for cost planning and provides a more comprehensive view of the financial requirements associated with this type of green systems.

5 DISCUSSION

It can be concluded that the identified time difference between the irrigations of the first and second samples indicates potential variability in response to irrigation conditions. The longer time between irrigations for the first sample may be interpreted as higher resistance to drought or more efficient utilization of available moisture. Conversely, the second sample required irrigation in a shorter time interval, suggesting a faster response to irrigation events. Despite these time discrepancies, a relative similarity in weight per square meter and irrigation water volume was observed, indicating that both samples exhibit similar water retention capabilities. This discussion on the temporal aspects of irrigation may contribute to a better understanding of the dynamics of water processes within the investigated vegetative systems.

6 CONCLUSION

Analyzing the areal weight allows for a better understanding of how to design green facades to serve as long and efficiently as possible. In conclusion, it is evident that the study of areal weight analysis of vegetative facades brings new insights into these innovative elements. Their ability to enhance the environment, the aesthetics of buildings, and energy efficiency is undeniable, and the analysis of areal weight provides us with a tool to optimize their design and operation. Overall, it can be stated that green facades are key to the future of sustainable urban planning and architecture, and the study on their areal weight equips us with important tools to achieve this goal.

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