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ORIGINAL

Thermal evaluation of a rustic building prototype at 1/5 scale with vegetal envelope during the winter in southern Peru

Evaluación térmica de un prototipo de edificio rústico a escala 1/5 con envolvente vegetal durante el invierno en el sur de Perú

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ABSTRACT

The purpose of the study was to demonstrate the benefits of a model for scientific research in the sense that a construction system with a vegetated enclosure could benefit the internal environment of Juliaca in winter. To do this, we used an experimental procedure to compare the thermal resistance of a fifth-scale adobe high Andean house without vegetation and a house built in the climatic zone with vegetated facades. It simultaneously records the internal surface temperature, the internal air temperature, and the external environmental conditions. The results obtained show that the use of photosystems in buildings is an effective passive technique to reduce energy consumption due to its ability to insulate and protect internal thermal conditions.

Keywords: Bioclimatic; Thermal Performance; Green Facade; Temperature.

RESUMEN

El propósito del estudio fue demostrar los beneficios de una maqueta para la investigación científica en el sentido de que un sistema constructivo con cerramiento vegetal podría beneficiar el ambiente interno de Juliaca en invierno. Para ello, utilizamos un procedimiento experimental para comparar la resistencia térmica de una casa altoandina de adobe en quinta escala sin vegetación y una casa construida en la zona climática con fachadas vegetadas. frío. Registra simultáneamente la temperatura de la superficie interna, la temperatura del aire interno y las condiciones ambientales externas. Los resultados obtenidos muestran que el uso de fitosistemas en edificios es una técnica pasiva efectiva para reducir el consumo de energía debido a su capacidad para aislar y proteger las condiciones térmicas internas.

Palabras Clave: Bioclimática; Comportamiento Térmico; Fachada Verde; Temperatura.

INTRODUCTION

Concern for the environment and climate change has led to an increase in the demand for more sustainable buildings that consume less energy. For this reason, the vegetation cover index in urban areas and buildings has become an important indicator to measure the environmental impact of buildings and to contribute to the reduction of energy consumption in buildings. In addition, it could be mentioned that vegetation cover also helps to reduce urban heat, improves air quality, and increases biodiversity in cities.

The use of vegetated roofs and facades is an increasingly popular technique in sustainable building design. According to studies such as Perez et al.[1] this technique has a positive impact on urban climate, as plants create shaded areas, absorb part of the incident solar radiation, and promote rainwater infiltration, increasing relative humidity. These factors contribute to reducing the "heat island" effect in cities. However, insulation of neighboring buildings is still the most common solution according to Oliveira et al.[2]

Despite this, the implementation of green facades and green roofs aims to provide a wide range of eco-systemic services.[3] In addition, insulation materials and building envelopes have a higher heat capacity than water and vegetation.[4,5]

Vertical gardens are a new opportunity in ornamental gardening, as well as in the landscaping and urban design professions.[6] Green roofs provide several ecological, economic, and social benefits, such as water resource management.[7]

The irruption of new technologies has made it necessary to increase the connection between biomass and architecture, as pointed out by Flores et al.[8] For example, the use of solar panels and rainwater harvesting systems, together with vegetation, can contribute to reducing the energy consumption of buildings and improve their sustainability. In summary, the use of green roofs and facades is an effective strategy to improve the urban climate and the sustainability of buildings.

The proposed study evaluates the thermal performance of a 1/5 scale rustic building prototype with a vegetal envelope during winter. Experimental results of module A without vegetation treatment were compared with those of module B with vegetated façade treatment.

The final results showed the potential of vegetation to reduce internal heat losses, as these heat losses are one of the most important measures to improve indoor environmental conditions. The study area is located in the city of Juliaca in the Puno region of southern Peru, at an altitude of 3820 m.a.s.l. in the Andes mountain range, with a cold and dry climate.[9]

Vegetation is an important factor in this region, as it can help reduce low temperatures and improve air quality in buildings. The results of the study could be useful for the design of sustainable buildings in cold and dry climate zones.

METHODS

This research study is quantitative and its objective is to analyze the effect of vegetation cover on the thermal performance of adobe high Andean housing modules. The experiment was carried out at UTM coordinates X: 380135, Y: 8282513, recording temperature and relative humidity data inside the house both with and without vegetation cover. The measurement period was 30 minutes in each case, with a measurement frequency of 1 minute. The results obtained in this study provided valuable information on the impact of vegetation cover on the thermal performance of high Andean dwellings, especially in high-altitude areas with cold and dry climates. Furthermore, these results could contribute to the design of more sustainable and comfortable housing in these regions.

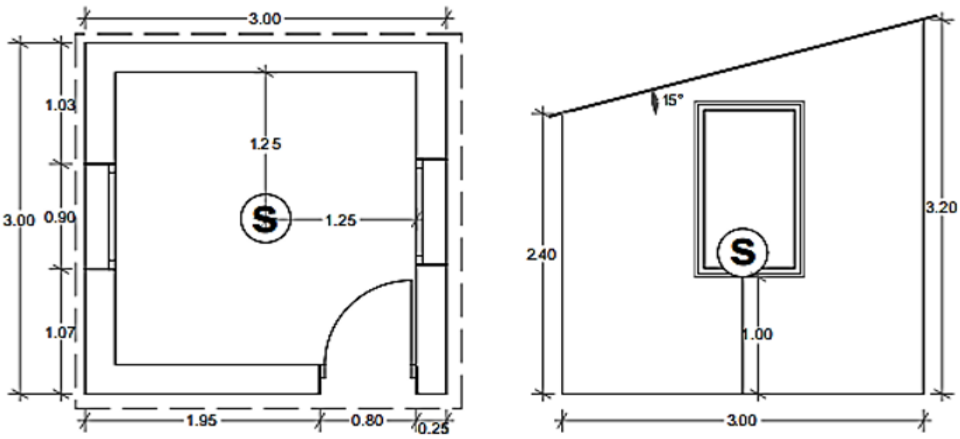

Figure 1. Dimensions of test modules A and B, (S) location of sensor instrumentation

In figure 1, wall A was oriented to the north side, which has no vegetative covering. Wall B has a vegetation treatment from floor to ceiling and is oriented to the west. In this study, the impact of green roofs on the thermal performance of high Andean adobe housing models was evaluated. Two 1/5 scale models were experimented with: the first model (A) was built without any thermal application and was used as a control group to compare the data obtained with the second model (B), in which vegetation coverings were used on two of the walls, located to the east and west.

The study was carried out in the Republic of Peru, in the department of Puno, in the province of San Roman, in the peripheral zone of the district of Juliaca. The location of the study is important because Puno is known for its cold and dry climate, which makes it an unfavorable area for the design of comfortable and sustainable housing.

The results obtained in this study provided valuable information on the impact of green roofs on the thermal performance of high Andean dwellings, especially in high-altitude areas with cold and dry climates. Furthermore, these results could contribute to the design of more sustainable and comfortable dwellings in these regions, allowing greater adaptation to climatic conditions and improving the quality of life of the people living in these dwellings.

Interventions

The instrument used to record data in this study was a digital thermometer (HTC-1) without a data logger, with an error of 1 °C and 1 %. This instrument was selected because of its accuracy and ease of use, which allowed accurate measurements of temperature and relative humidity inside the housing models.

Statistical analysis

SPSS v22 and Excel 2019 software were used to analyze the data collected. The results were tabulated in different formats (TXT, CVS, XLS, XLSX) for further analysis. Descriptive statistical techniques were used to calculate the mean of the measured variables and compare the results between model A (without vegetation cover) and model B (with vegetation cover) using a T-student test for independent samples. In addition, the implementation of multivariate analysis techniques, such as linear regression and principal component analysis, could be considered to explore the relationships between the measured variables and obtain a more complete understanding of the results obtained. The use of sensitivity analysis techniques could also be considered to evaluate how changes in environmental conditions affect the thermal performance of the housing models.

RESULTS

Under the climatic perspective used in this work, the experimental day was defined considering the winter season for the test period. In this sense, meteorological data such as temperature, relative humidity, wind speed, and solar radiation, among others, were taken into account to determine the appropriate day to carry out the experimentation.

In addition, the solar exposure of the housing models during the experimental day was considered, taking into account the orientation of the walls and the presence of elements that may affect the incident solar radiation, such as trees and surrounding buildings.

In this sense, the implementation of an automated monitoring system to collect meteorological data could be considered, to obtain an accurate and reliable database for the analysis of the results.

This would allow obtaining a more detailed understanding of the climatic conditions and their impact on the thermal performance of the housing models, the monitoring period of development in June the coldest of the whole year in the Puno region showing the results in figure 2.

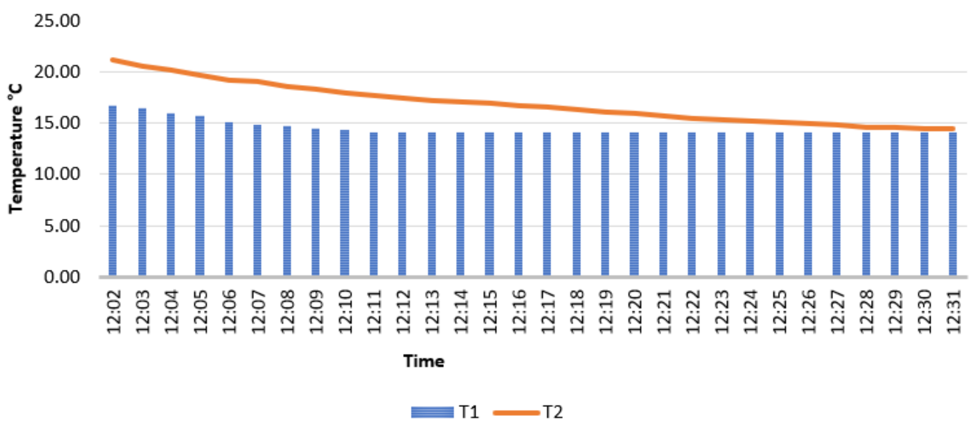

Figure 2. Thermal comparison between blocks A and B

In figure 2, the graph shows the comparison of the internal temperature of module A, without vegetation cover, and module B, with vegetation cover on the east and west walls.

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A thermal difference of 2,44°C is observed between the two housing models. This result suggests that the presence of green roofs on the east and west walls has a significant impact on the reduction of the internal temperature of the house.

This is because plants can provide shade, absorb solar radiation and promote rainwater infiltration, which helps reduce internal heat and increase relative humidity. In addition, the analysis of other thermal comfort indicators, such as the thermal efficiency index (TEI) or the humidity index (HI), could be considered to evaluate the impact of green roofs on the environmental comfort of the dwelling.

This would allow a more complete understanding of the results obtained and their relationship with the comfort of the people living in the dwelling. Also, the application of thermal simulation models, such as EnergyPlus or TRNSYS, could be considered to evaluate the thermal performance of the housing models and compare the results with those obtained in the experimental study.

This would allow a more accurate and detailed evaluation of the impact of green roofs on the thermal performance of the house.

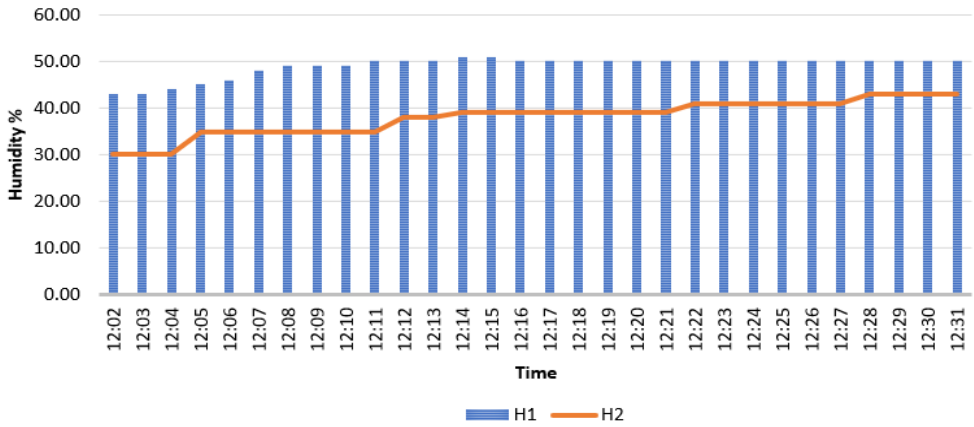

Figure 3. Moisture comparison between blocks A and B

In figure 3, the graph shows the comparison of the internal relative humidity of module A, without vegetation cover, and module B, with vegetation cover on the east and west walls. There is a 10,9 % difference in relative humidity between the two housing models.

This result suggests that the presence of green roofs on the east and west walls has a significant impact on increasing the relative humidity inside the house. This is because plants can transpire, which helps to increase the relative humidity and improve the indoor climate. In addition, the presence of vegetation on the roof helps to reduce the impact of the sun's rays, allowing for better ventilation and increased transpiration, which helps to improve relative humidity.

The results obtained in this study show that the use of green facades in high-Andean buildings has a positive impact on the internal air temperature, reducing the thermal difference by 2,44°C compared to a building without vegetation cover.(10,11)

In addition, it has been observed that vegetated roofs are an effective alternative to thermal insulation, as they help retain rainwater and reduce annual runoff volumes in areas where this can be a problem.(12)

However, it is important to mention that the maintenance of green facades may be an aspect to consider, as plants require constant watering and care.(2) In addition, the installation height of green facades should be taken into account, since it has been observed that the maximum thermal difference is 4°C at a height of 3 meters.(13)

As for the statistical analysis, SPSS v22 and Excel 2019 software were used to tabulate the results and calculate the means. Temperature and relative humidity measurements were compared between module A and module B using a Student's t-test for independent samples. Overall, this study suggests that the use of green facades in high Andean buildings is an effective strategy to improve indoor environmental conditions and reduce energy consumption in buildings. However, it is important to take into account the maintenance and installation height of green facades when implementing this technique.

CONCLUSIONS

The conclusion of the study on the thermal performance of buildings with vegetation envelopes in Juliaca, Peru, is that vegetation can be an effective tool to reduce the variation of internal temperatures during the winter. The results obtained indicate that the use of vegetation envelopes on the facades of a building can act as a thermal insulator, protecting the roof from heat loss. In addition, it was observed that the module with the vegetal envelope presented a more stable internal temperature, with a difference of 2,44°C compared to the module without the vegetal envelope. In general, it can be affirmed that the use of vegetal envelopes in architecture is a viable and beneficial technique to improve thermal comfort in buildings and for the environment.

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PREPRINT

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Data curation: Francisco Curro Pérez
Formal analysis: Vitaliano Enríquez Mamani
Acquisition of funds: Kely Lelia Cotacallapa Ochoa
Research: Grover Marín Mamani
Methodology: Alioska Jessica Martínez García
Project management: Kely Lelia Cotacallapa Ochoa
Resources: Vitaliano Enríquez Mamani
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