LUMEN ET VIRTUS

Bioclimatic design to reduce temperature in each room and reduce energy consumption, using the shading technique

https://doi.org/10.56238/levv15n39-160

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ABSTRACT

Proper shading on home ceilings plays a key role in the thermal regulation of the interior of living spaces. This article proposes a shading technique with recycled pallets applicable to residential roofs, with the aim of improving thermal comfort and reducing energy consumption in air conditioning. Its effectiveness in the climatic context and architectural conditions of the port of Veracruz, Mexico, is shown. In addition, the benefits associated with implementing these techniques are discussed, including reduced heat load, energy savings, and improved occupant well-being.

Keywords: Direct Solar Radiation, Shading Techniques, Wooden Pallets, Pallets.

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INTRODUCTION

The municipality of Veracruz de Ignacio de la Llave is located in the central area of the state of the same name, in the region known as Sotavento (as shown in figure 1), at coordinates 19° 12´ 02" N, longitude 096° 08´ 15" W, at an altitude of 10 m above sea level. It is bordered to the north by the municipality of La Antigua and the Gulf of Mexico; to the south by the municipalities of Medellín and Boca del Río; to the east by the Gulf of Mexico and to the west by the municipalities of Manlio Fabio Altamirano and Paso de Ovejas.

Figure 1. Location of the municipality of Veracruz, see. [7]

The municipality has a warm tropical climate, so the summer is very hot and humid [1], which directly affects the thermal comfort inside the buildings.

The diagram of the maximum temperature in Veracruz (represented in Figure 2), is a graphical representation that shows how many days per month reach temperatures above 32° C.

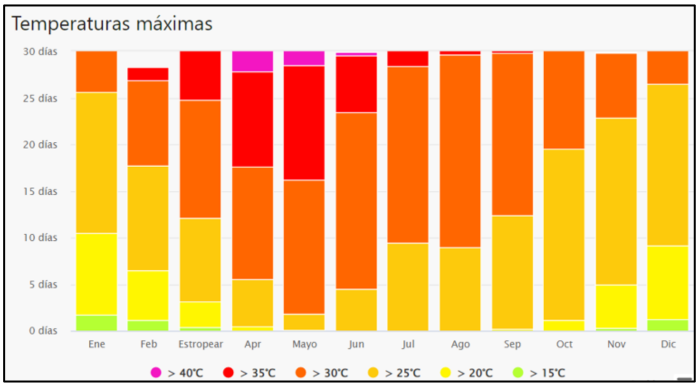
The key details of the graph are described below:

Horizontal axis: (temperature rise): At the bottom of the graph, you will see the temperature values. These are labeled in degrees Celsius.

Colored bars: Each bar represents a month of the year. The bars are colored to indicate different temperature ranges. Here is the interpretation of the colors:

- Magenta: Represents temperatures above 40°C.
- Red: Indicates temperatures between 35°C and 40°C.
- Orange: Corresponds to temperatures between 30°C and 35°C.
- Light yellow: Refers to temperatures between 25°C and 30°C.
- Dark yellow: Represents temperatures between 20°C and 25°C.
- Green: Indicates temperatures below 15°C.

Figure 2. The maximum temperature diagram for Veracruz shows how many days per month certain temperatures reach. . [4]



The warmest months, with the most days above 35°C, seem to be May and June.

The coldest months, with fewer days reaching temperatures above 25°C, are January and February [5].

To reduce the temperatures of thermal sensation inside buildings, it is necessary to consider when constructing a building in this area factors such as orientation, ceiling height, window placement, application of shading technique and thermal envelope [6].

In the construction of buildings in the port of Veracruz, different techniques have been used than the traditional ones, such as the use of brick or concrete block and reinforced concrete slab roofs, which has resulted in hotter buildings and a high consumption of electrical energy required to reduce the temperature through air conditioning. This negatively impacts the economy of families by having to pay higher electricity consumption bills.

Modern bioclimatic architecture considers local climatic conditions to take advantage of natural characteristics and achieve thermal comfort that contribute to lower energy consumption [3]. For example, the direction of the prevailing winds in the hot months can be taken into account to orient the building and place windows that allow natural ventilation (Figure 3 shows the wind speed throughout the year).

The graph in Figure 3 shows the wind speed in Veracruz during each month of the year. The key details are as follows:

Vertical axis (days per month): On the left side of the graph, you'll see a scale that shows the number of days per month. This scale represents how many days in a specific month reach certain wind speeds.

Horizontal axis (months): At the bottom of the graph, you will find the names of the months, from January (Jan) to December (Dec).

Colored bars: Each month has a vertical bar divided into colored segments. These segments represent the number of days with certain wind speeds. Colors indicate different speed ranges:

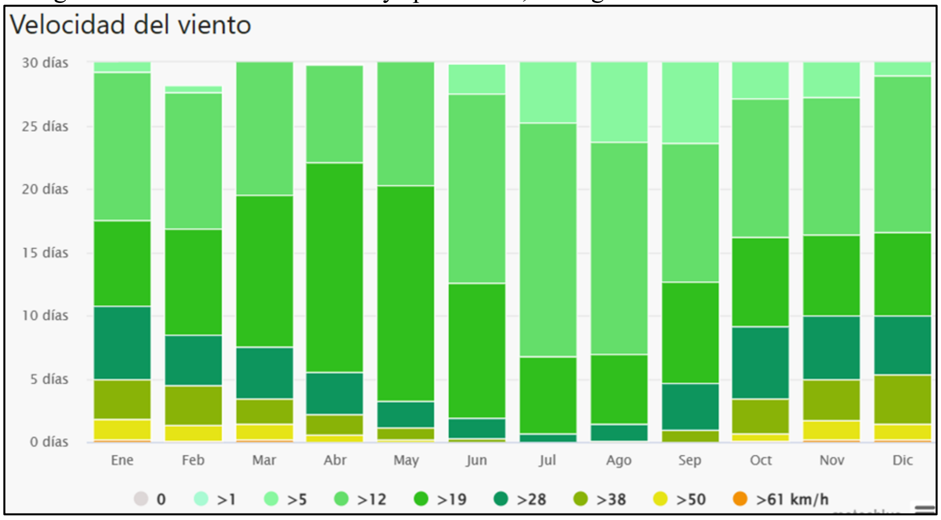
- Yellow: Represents wind speeds greater than 1 km/h.

- Light green: Indicates wind speeds above 5 km/h.
- Dark green: Corresponds to wind speeds above 12 km/h.
- Light blue: Shows wind speeds above 19 km/h.
- Dark blue: Represents wind speeds above 28 km/h.
- Purple: Indicates wind speeds above 38 km/h.
- Red: Corresponds to wind speeds above 50 km/h.
- Magenta: Shows wind speeds above 61 km/h.

In July and August, all the bars are dark green, which means that every day of the month the wind exceeds 61 km/h. In November and December, there are yellow and light green segments on the bars, indicating variety in wind speeds during those months.

This graph provides valuable information about wind patterns in Veracruz throughout the year.

Figure 3. The diagram of Veracruz shows the days per month, during which the wind reaches a certain speed. [4]



If these considerations are not taken into account, buildings can be very hot and consume a lot of electrical energy for air conditioning.

Another way to maintain comfortable indoor temperatures and reduce electricity consumption can be obtained by implementing a thermal envelope in the design of buildings to reduce heat transfer by direct solar radiation [2]. The thermal envelope must be adapted to the climatic characteristics of the area to be effective.

Taking into account the above, this work proposes the design of a thermal envelope for a house-room located in the port of Veracruz, with the aim of reducing the temperature inside the rooms and with a lower energy consumption to achieve thermal comfort. By taking into account the climatic conditions of the area, the energy efficiency obtained by applying this bioclimatic design in a new building in the city of Veracruz, Mexico, and that can be used in other similar buildings, is determined.

MATERIALS AND METHODS

STUDIO DESIGN

In this study, an experimental design is presented that aims to demonstrate the effectiveness of pallets as a thermal envelope material in reducing heat transfer in a controlled environment. A rigorous experimental design was used to compare the thermal performance of pallets with other conventional enclosure materials.

A test module was built with wrapping material, using only wooden pallets. Heat transfer through the envelope was measured using a thermal camera taking readings at different points strategically located inside and outside the envelope.

In this experimental study, the effectiveness of pallets as a thermal envelope material in a controlled environment was evaluated. A rigorous experimental design was used to manipulate the independent variable (the type of envelope material) and measure the dependent variable (heat transfer through the envelope).

The main objective of the study is to determine what is the thermal performance of pallets as an envelope material, and how this can contribute to the energy efficiency of buildings. In addition, it is expected that the results obtained will be useful for informed decision-making in the design of sustainable and efficient buildings.

In summary, this experimental study seeks to provide new evidence on the effectiveness of pallets as a thermal envelope material, using a rigorous and systematic approach. The results obtained can have a significant impact on the energy efficiency and sustainability of buildings and therefore be relevant to the construction industry and society in general.

LOCATION OF THE HOUSE

The house that is considered in this article is located at coordinates 19.208802, -96.176033, more specifically, it is located on Av. Playa Casitas corner with Playa Caletilla, in the Playa Linda neighborhood of the city of Veracruz. It is a spacious and bright house, built on a plot of 190 m2 with green spaces and a few minutes away there is a large lagoon.

MATERIALS USED

Envelope proposed with pallets.

A wooden pallet (shown in Figure 4) is a type of flat, rectangular platform that is used to transport and store products. It is composed of a wooden base and two or more transverse slats that act as supports. Wooden pallets are widely used in industry for the transport of heavy loads and large volumes of goods.

Figure 4. Envelope proposed to be used.

The proposed shading technique is based on wooden pallets that are discarded in the port of Veracruz, which are reconfigured in two layers of 10 cm wide by 1 meter long slabs, separated by wooden poles of 5 cm x 2.5 cm of wood. The upper layer is made up of an alfajilla pattern and a space of 5 cm and another alfajilla, until it reaches a length of one meter. The lower layer complements the upper layer in such a way that the alfajillas are placed in the existing spaces in the first layer, generating a module capable of offering permanent shade at its base of one square meter, additionally rubber heels of 4 cm in diameter by 2.5 centimeters high are placed to allow the drainage of water from the slab in rainy seasons.

MEASURING INSTRUMENTS

FLIR TG165-X MSX® thermal camera.

The FLIR TG165-X thermal imaging camera is a handheld thermal imaging camera designed to measure temperatures non-contact using infrared technology. This thermal imaging camera is capable of measuring surface temperature in the range of -25°C to 380°C and displaying the results on a color LCD screen. It is very useful for detecting overheating problems in machinery, electrical installations, HVAC systems and in many other applications. The camera also has a microSD card slot that allows thermal images to be stored for future analysis or reporting.

PROCEDURES FOLLOWED

The bioclimatic design of a building not only focuses on energy efficiency and sustainability, but also on innovation and the practical application of recyclable materials such as wooden pallets. In the current project, this raw material was used in the roof envelope to absorb and mitigate direct heat, thus creating a more comfortable microclimate within the proposed building. The effectiveness of this technique was measured with the help of a thermal camera, model FLIR TG165-X, which provided accurate data on temperatures before and after the installation of the pallets.

The design began with a detailed characterization of the building to understand its specifications and needs. The building is built on a rectangular plot of 10m x 19m oriented east to west in its greatest length, the built area is 110m^2 which is distributed in a living room, dining room, kitchen, two bedrooms and two full bathrooms, the construction technique used is the traditional type of the area such as:

- Red brick on plastered walls with a mixture of sand, cement and lime.
- Floor-to-ceiling building height of 2.6 meters.
- 0.12 meter thick reinforced concrete slab with an area of 11om2
- Orientation of the main façade to the west

Figure 5 shows the construction of the case study.

Figure 5. Construction of the case study in Veracruz port.

To keep track of the effectiveness of the shading technique, it was decided to cover, using pallets, a bedroom of the building equal to 20% of the area. This offers a suitable scenario to test how the use of wooden pallets contributes to the reduction of the temperature inside the building, having two temperature measurement zones. Figure 6 shows the pallets placed.

Figure 6. Experimental area with the envelope of installed pallets

RESULTS

The data presented in Table 1 provide clear quantitative evidence of the effectiveness of using wooden pallets in the roof envelope for heat mitigation. During the evaluation period, which was from March 21 to April 7, a significant decrease in temperature was observed within the area covered by the pallets compared to the area without envelope. The measurements were carried out daily at a fixed time of 2:00 p.m. It shows that the ambient temperature remained relatively constant, indicating that the variations in the temperature of the enclosure are indeed due to the installation of the pallets.

The temperature difference **Δt** indicates the difference between the ceiling temperature measured inside the building inside the envelope and without the envelope that varied between 7.5°C and 10.4°C, demonstrating that wooden pallets provide a considerable reduction in heat. This result is consistent with the objectives of bioclimatic design, which seeks not only energy efficiency and sustainability, but also innovation in the application of recyclable materials.

Board 1. Evaluation of the effectiveness of bioclimatic design.

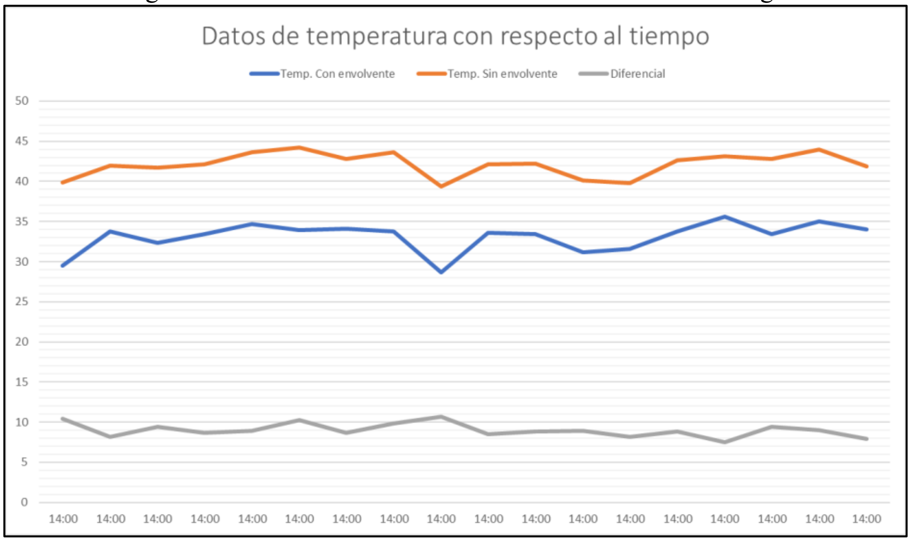
Fecha	Hora	Temperatura ambiente en ºC	Temperatura en ºC en envolvente	Temperatura en ºC del techo sin envolvente	Δt= Trd-Tenv
21 marzo	14:00	30	29.5	39.9	10.4
22 marzo	14:00	31	33.8	42	8.2
23 marzo	14:00	31	32.3	41.7	9.4
24 marzo	14:00	33	33.4	42.1	8.7
25 marzo	14:00	34	34.7	43.6	8.9
26 marzo	14:00	33	33.9	44.2	10.3
27 marzo	14:00	33	34.1	42.8	8.7
28 marzo	14:00	33	33.8	43.6	9.8
29 marzo	14:00	29	28.7	39.4	10.7
30 marzo	14:00	32	33.6	42.1	8.5
31 marzo	14:00	31	33.4	42.2	8.8
01 abril	14:00	30	31.2	40.1	8.9
02 abril	14:00	32	31.6	39.8	8.2
03 abril	14:00	34	33.8	42.6	8.8
04 abril	14:00	35	35.6	43.1	7.5
05 abril	14:00	34	33.4	42.8	9.4
06 abril	14:00	32	35	44	9
07 abril	14:00	31	34	41.9	7.9

These results support the experimental methodology used, mentioning the tangible benefits of incorporating non-conventional materials in bioclimatic design. The implementation of this technique not only contributes to the creation of a more comfortable microclimate within the building, but also highlights the project's commitment to technical innovation and environmental responsibility, while maintaining the economic viability of the design.

The graph in Figure 7 illustrates the comparison of temperatures over time, with and without the wooden pallet envelope, as well as the resulting temperature difference. Based on the data in Table 1, the graph shows how the envelope has a significant impact on the reduction of surface temperature.

The line representing the temperature with envelope consistently shows lower values compared to the line of the ceiling temperature without the envelope, indicating an effective decrease in heat due to the installation of the pallets. The temperature differential, represented by the distance between these two lines, varies between 7.5°C and 10.4°C, confirming the effectiveness of the envelope in creating a more comfortable microclimate.

Figure 7. Evaluation of the effectiveness of bioclimatic design



These results are a graphical representation of the quantitative data obtained from table 1, and reinforce the conclusion that the bioclimatic design implemented in the experimentation can contribute significantly to the sustainability and energy efficiency of the proposed building. The graphic not only validates the experimental methodology, but also highlights the importance of innovation and the use of recyclable materials in sustainable architecture.

DISCUSSION AND CONCLUSIONS

The research presented demonstrates the feasibility of using wooden pallets in bioclimatic design to reduce heat in buildings. The results obtained indicate a significant reduction in the ceiling temperature, which translates into a more comfortable indoor environment in the building and a decrease in the demand for energy for air conditioning.

The decrease in temperature between 7.5°C and 10.4°C, observed in the envelope compared to the roof without the envelope, not only supports the initial hypothesis that recyclable materials can contribute significantly to the sustainability of buildings, but also opens avenues for future research on alternative materials and sustainable construction techniques.

To close, this study highlights the importance of integrating bioclimatic design practices into contemporary architecture. In addition, it highlights the need to continue exploring recyclable materials and innovative techniques that not only improve the energy efficiency of buildings, but also promote environmental responsibility and economic viability in the field of construction.

Finally, the economic impact on electricity billing and its cost-benefit ratio is being evaluated, which will be published in the following months.

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