Bioclimatic Reconditioning in Tepetlixpa Handicrafts Market

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Abstract: This work presents the bioclimatic rehabilitation of a building located in the municipality of Tepetlixpa, State of Mexico. It is currently used as a gymnasium and offices, and presents deterioration and thermal comfort problems. The location of the site has a temperate climate, so several proposals were made, which were then evaluated in the Bioclimatic Architecture Laboratory of the Universidad Autónoma Metropolitana, Unidad Azcapotzalco, as well as specialized software to be used.

The primary issue with the building concerns overheating, resulting from inadequate ventilation and unsuitable roofing material. To resolve the overheating difficulties, the Ener Habitat software was employed to examine the building's construction materials. The analysis revealed that the roof was the most problematic component, and consequently, a change of material was recommended.

A project model was created and analyzed in the heliodon, capturing solar incidence during the equinoxes and solstices. To address this, a shading system using pergolas and sunshades was proposed, which creates a microclimate between the building and esplanade, enabling appropriate solar control on the façades.

A 3D model was generated using new adaptations and solar protection proposals, which were analyzed with the Design Builder 7.0.2.004 software to evaluate the building's thermal behavior. The outcomes revealed that temperature fluctuations within the building were usually within the comfortable ranges corresponding to that specific region's climate type. Therefore, the proposed alterations in materials and the integration of solar control technologies facilitate bioclimatic retrofitting, avoiding the need for mechanical systems to attain optimal thermal comfort for occupants.

Keywords: bioclimatic reconditioning, thermal comfort, solar control devices, heliodon, Ener Habitat, Design Builder.

1. Introduction

This project involves developing a handicraft market in the municipality of Tepetlixpa, State of Mexico, in the municipal esplanade of the town, with an area of 389.75 m2, with a front of 47.30 m, a length of 8.24 m and a height of 8.17 m. The market will be located in the municipality of Tepetlixpa, State of Mexico. The current project is designed with two levels. The first level comprises a double-height gymnasium on the north side and unoccupied spaces on the south side. Meanwhile, the second level houses offices. The building's use will change per the request of the Tepetlixpa municipality, proposing a handicraft market featuring a cafeteria, shops, as well as workshops for wood and pottery.

The building experiences issues with overheating in its interior due to its construction system. It has a galvanized sheet roof and lacks any ventilation. The majority of the façades are glazed, but none of them The cafeteria, premises, and handicraft area experience overheating issues due to direct solar incidence. Employing bioclimatic strategies and analyzing the temperate regional climate, characterized by minimal oscillation according to Köppen-García, will establish a year-round comfort zone within the building, ranging from 66.9ºF to 75.9ºF as per the Szokolay temperature formula. experience overheating issues due to direct solar incidence.

The modification of roofing materials, the implementation of solar control devices, adequate ventilation to ensure proper air renewal for the user, are considered for the thermal analysis of the building that takes into account all aspects of the construction system, proposing new materials, opening and closing openings in walls and roof, the selection of solar control devices and vegetation, are part of the bioclimatic proposals that can be considered using the Design Builder software to generate simulations and propose the most appropriate solutions for the project.

2. Objective

This study presents a thermal analysis of the handicrafts market located in Tepetlixpa, State of Mexico to optimize thermal comfort for users. A bioclimatic design approach is proposed, including measures such as protecting the northwest façade, designing appropriate openings and cross ventilation, replacing the roof, providing sufficient lighting for workshops and craft areas, and installing acoustic coating for workshops.

3. Method and Material

Based on a climatological study of the region, bioclimatic recommendations could be suggested to adapt the building. There is no overheating at any time during the year, and the comfort zones occur between 1:00 PM and 3:00 PM. Outside of these times, the temperatures fall below the comfort zone. Rainfall is high in summer and early fall, often exceeding the indicated limit of 40 mm to 150 mm. With this data, initial bioclimatic recommendations for the building can be made, such as modifying the roof, adding openings, and incorporating vegetation. A study was conducted to measure the amount of solar penetration in the building, with the aim of suggesting efficient solar control mechanisms. Using the obtained data, the building was simulated in 3D within the Design Builder software to determine the feasibility of implementing the proposed adaptations.

This software produces .CSV files of hourly temperature data for each month, allowing for observation of the operating temperature behavior in relation to the outdoor dry bulb temperature. The data generated was analyzed to determine whether the use of new proposals maintains the building's desired comfort zone.

3.1 Sunlight analysis: Determining solar control devices

To conduct the sunlight analysis, we identified areas where solar control devices were necessary for the project, leading to the selection of the appropriate device. This essential step resulted in the creation of a stereographic graph, facilitating the analysis of each facade in the project.

After obtaining the northwest stereographic facade, the solar control device was calculated for the summer solstice, which is when the sun's rays penetrate directly for an extended period. The calculation was performed between 4:00 PM and 6:00 PM to avoid direct solar penetration. The factors of temperature and solar incidence, supported by the stereographic graph, were also taken into account. (See figure 1)

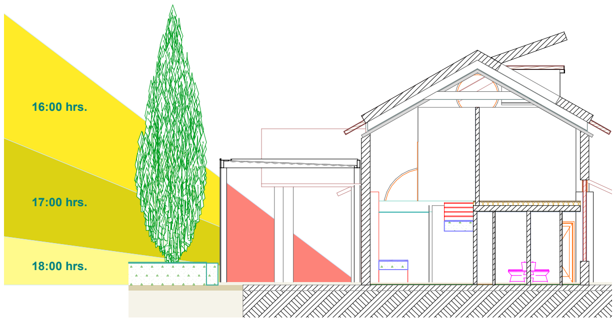


Figure 1. Solar penetration on the northwest facade Self-design, using Archicad software.

3.2 Thermalanalisys

Thermal analysis was conducted using Ener Habitat and Design Builder software to compare the building's behavior with the outside temperature and ensure that comfort criteria are met. The building must remain in the comfort zone for the user during an occupancy schedule from 8:00 to 21:00 hours.Two comparative evaluations were conducted: one in the current state and the other after the implementation of new proposed building systems.

Various building materials were evaluated using Ener Habitat software, and the most thermally efficient materials were selected for the project and loaded as templates into the Design Builder software for use.

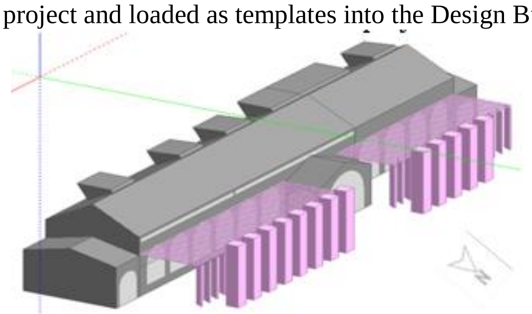
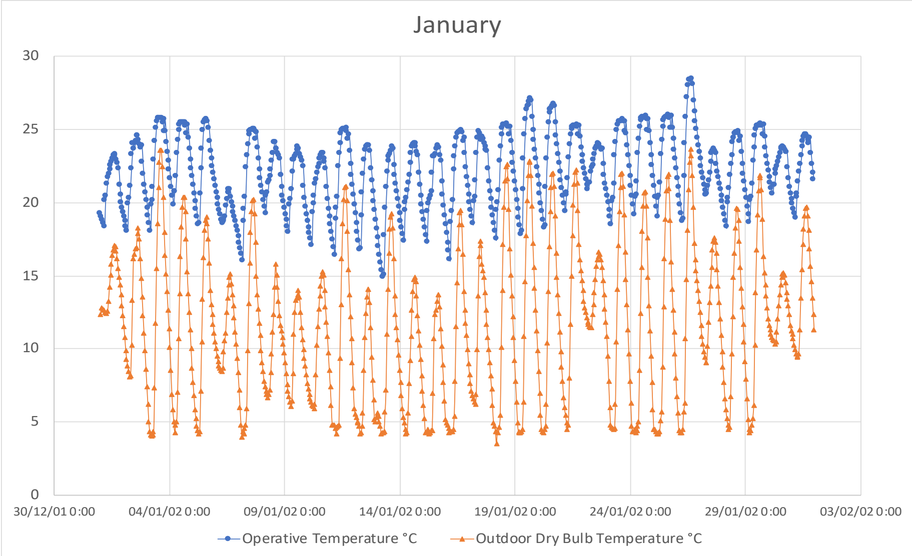


Figure 2 Craft market modeled in 3D. (Source: own work, software used Design Builder)

Using the Design Builder software, we developed a 3D model of the building incorporating new adaptations and materials. This model was used to conduct a thermal analysis, which enabled the input of activity-specific data into the system. To feed the climatological data, we used a weather file format EPW format, which is generated by the Meteonorm software with the information of this file, the Design Builder program can plot the climate either annual, monthly and hourly, all of which were taken into account for the comparison between the outdoor dry bulb temperature and the operating temperature of the building. The Design Builder software aligns with ASHRAE Standard 55 for producing energy-efficient and safe buildings.

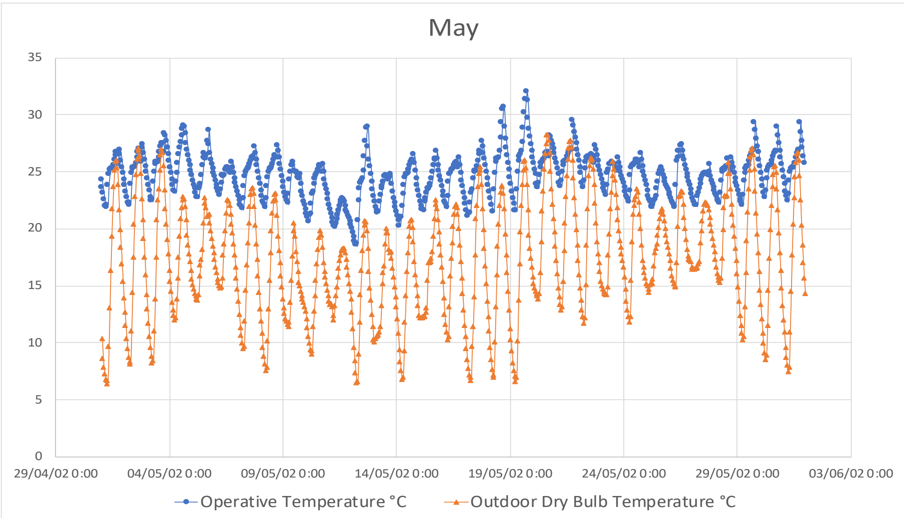
Current state of the building:

The initial graphs depict the relationship between the operative temperature and the external dry bulb temperature of the building in its present state. No adjustments have been made to the building's current condition, and it is constructed with 26-gauge galvanized sheet roofing, block walls, and openings in the 4 facades with 6-mm glass windows that are completely closed, with no openings.



Graph 1. January temperature, current status. Tepetlixpa, State of Mexico. Source: Data source: Self-created using Design Builder.

Neutral temperature for January is 21.01 degrees Celsius. The comfort zone varies from 18.51 to 23.51 degrees Celsius. In graph 1, it can be observed that the outdoor temperature fluctuates between 3.5ºC to 23.5ºC in the month of January. The operational temperature ranges from 15°C to 28°C. The hours of occupation are from 9:00 AM to 9:00 PM. Throughout the month, the building remains outside of the comfort zone except for the time period between 6:00 and 9:00 hours when it enters the comfort zone.

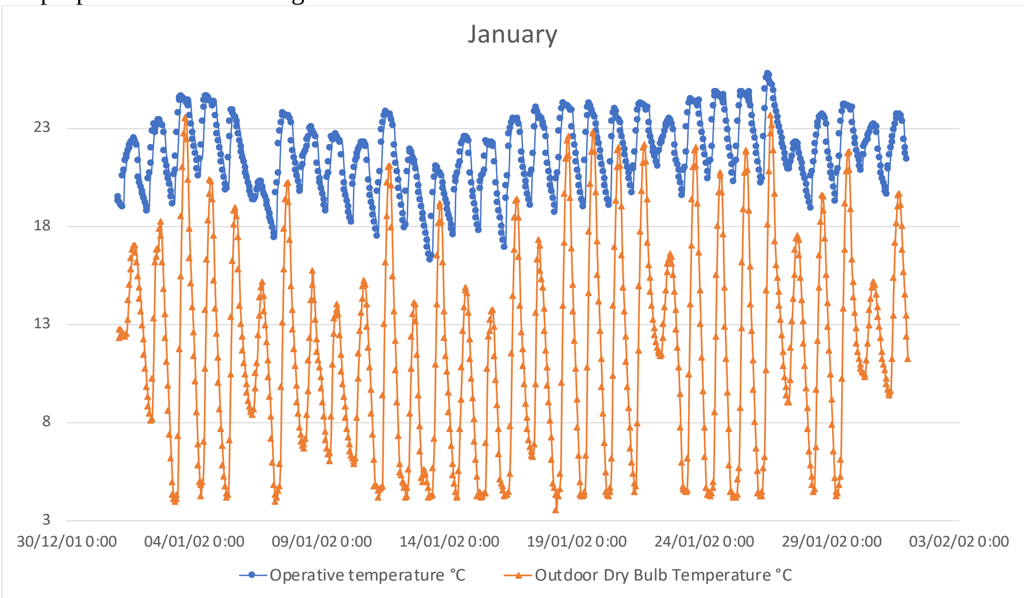


Graph 2. Temperature May, state acts. Tepetlixpa State of Mexico. Data source: Self-created using Design Builder software

Neutral temperature in May was 22.87°C with a comfort zone between 20.37°C and 25.37°C. Graph 2 shows that during the month of January, the temperature outside ranged from 3.5°C to 23.5°C. The operating temperature ranged from 18°C to 32°C. The building's hours of occupancy are from 9:00 to 21:00 hours. The building was outside the comfort zone for the whole month, except between 6:00 and 12:00 hours. It does not meet the necessary adaptations in terms of its current construction materials and bioclimatic systems to ensure user comfort during this particular month of the year.

4. Results and Discussion

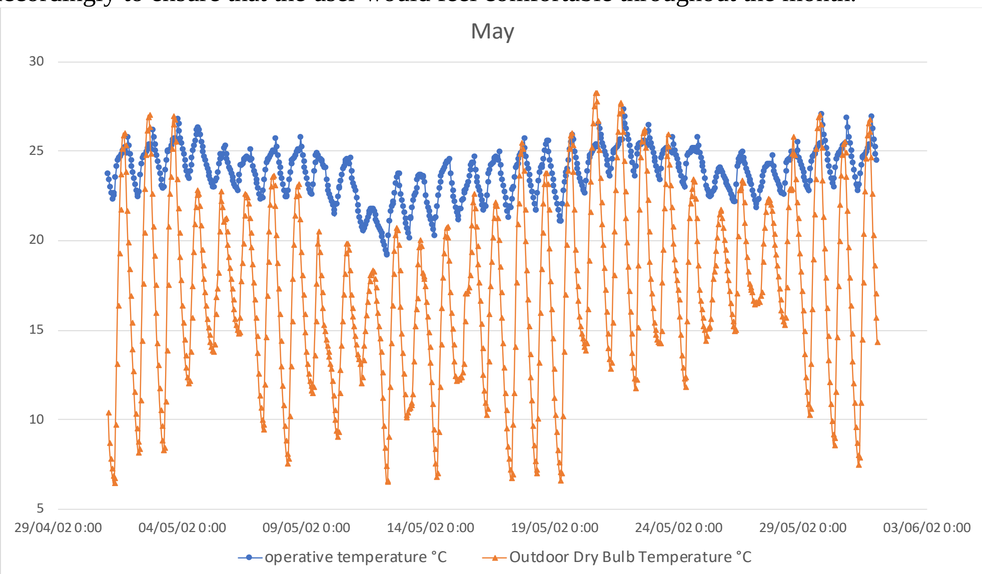
Bioclimatic proposal for the building



Graph 3. January Temperature in Tepetlixpa, State of Mexico. Data source: Self-created using Design Builder software

Neutral temperature for January is 21.01 degrees Celsius. Comfort zone ranges from 18.51°C to 23.51°C. As indicated in Graph 1, the temperature outside fluctuates from 3.5°C to 23.5°C in January. The operating temperature falls between 16.5°C and 26°C. Occupancy hours are from 9:00 AM to 9:00 PM.

The operating temperature is within the comfort zone for 17 days, but exceeds it during the schedule from 2:00 to 3:00 PM. On days 4, 5, 6, 12, 12, 18, 19, 20, 21, 22, 24, 25, 26, 29, and 30, the temperature remains below the level of comfort, despite the user being absent. The materials used and the bioclimatic devices were modified accordingly to ensure that the user would feel comfortable throughout the month.



Graph 4. Temperature May, Tepetlixpa, State of Mexico. Source: own elaboration, Design Builder software.

Neutral temperature May 22.87 Cº. Comfort zone 20.37 Cº to 25.37 Cº.

As shown in Figure 2, during the month of May, the outdoor temperature ranges from 6.5º C to 28.3º C. The operating temperature ranges from 19º C to 27.5º C. The hours of occupancy are from 9:00 to 21:00.

The operating temperature is in the comfort zone for 20 days, the temperature exceeds the comfort zone on days 1, 2, 3, 4, 19, 20, 21, 22, 23. It is worth mentioning that in a schedule from 14:00 to 15:00, it is below the comfort zone for 3 days, days 13, 14 and 15, in a schedule where it is not occupied.

It complies with the necessary adaptations based on its construction materials and bioclimatic devices to keep the user in comfort during this month of the year.

Ventilation

The main problem in this building is overheating, but that's generated inside the building. There are no vents, only the main door and a pair of circular openings about 80 cm in diameter at each end. Most of the building is glazed with 2.30 x 1.20 m doors. We are looking at redesigning all of the openings as well as creating new ones to provide adequate ventilation.

The building's current windows are entirely sealed. To facilitate the analysis, they were modified to become hinged and operable for the user. To achieve this, a standard window was generated that will be adapted to each existing window.

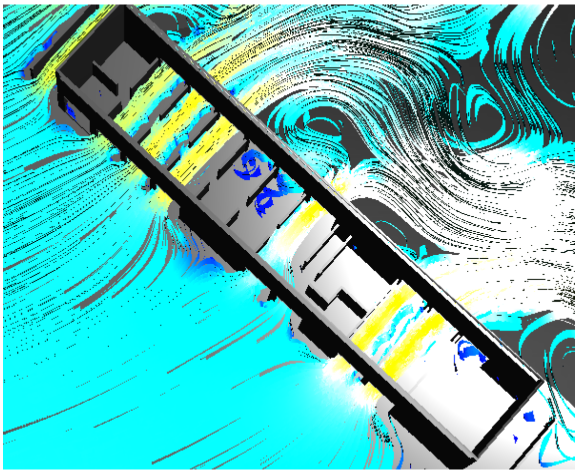


Figure 3. Cross-ventilation, craft market, Tepetlixpa, State of Mexico: Self-design, using Flow Design software.

By means of new window adjustments it was possible to create cross ventilation to achieve the 10 air changes required by NOM-016-STPS-1993.

The prevailing environmental winds come from the north, entering through the northwest façade on the side of the craft sales area, the hot air rises through the intermediate skylight of the building and exits through the louvers proposed on each side of the project, this cycle will repeat throughout the day.

As the hourly temperature increases or decreases, the windows can be operated by the user to close or open them as needed.

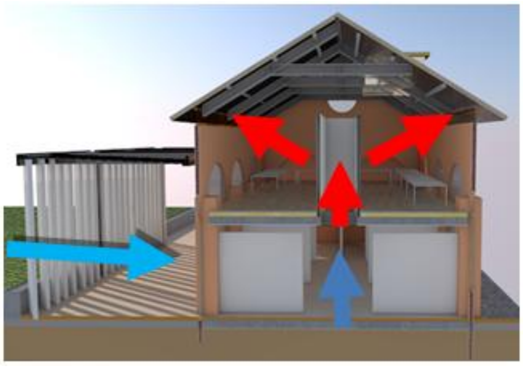


Figure 4. Ventilation, handicrafts market, Tepetlixpa, State of Mexico: Self-design, using Archicad software.

5. Conclusions

In the study presented, January corresponds to the coldest month, while May corresponds to the warmest month. In this period, it is observed that in the month of January, the operating temperature remains within the comfort zone throughout the day, except for 15:00 hours (see graph 3). In the month of May, during 20 days the operating temperature remains in the comfort zone, 10 days exceed the comfort zone between 14:00 and 15:00, the rest of the day remains in the comfort zone (see again graph 4).

The proposed construction system behaves in a favorable way due to the fact that in all months there are more days inside the comfort zone than outside the comfort zone.

In order to enjoy an adequate comfort zone for the user in this project, a broad bioclimatic analysis was carried out in the specialized areas of comfort: thermal, acoustic, lighting and ventilation.

The project employed an extensive bioclimatic analysis in the specialized areas of comfort: thermal, acoustic, lighting and ventilation, in order to obtain results and improvements to create an adequate comfort zone for the user.

The project has a current state that shows overheating problems due to its lack of ventilation and its defective construction system. The architectural project has been subjected to several tests in the aforementioned aspects in order to obtain favorable results and propose improvements to the project.

A site study was conducted to observe the natural physical environment and the artificial environment in which the project is evaluated, observing the environment in which the building is developed, then a climate analysis is made, following appropriate design strategies to begin to propose solutions, the project is located in a cold area with low hourly temperatures most of the year and none with overheating, the maximum humidity exceeds the comfort zone; The average is at the limit and the minimum is within the comfort zone during the month with the highest humidity which is August and on the contrary, the month with the lowest humidity is March when solar radiation is low, cloudiness and annual precipitation is high, with these data collected and contrasted solutions are beginning to be generated.

The study of the solar penetration showed that during the equinoxes the sun's rays penetrate the building both in the morning and in the afternoon, during the summer solstice the sun's rays do not penetrate in the morning but only in the afternoon, during the winter solstice the sun's rays penetrate directly in the morning and after 1 p.m. they no longer penetrate the building, in May and August in the morning the sun's rays penetrate little, while in the afternoon they penetrate too much. In May and August, the sun's rays penetrate little in the morning and too much in the afternoon.

In the winter, the mornings are cold, so no solar protection is needed; for the northwest façade, a solar protection device was designed, consisting of sunshades and a pergola, which creates a microclimate between the building and the promenade, for the summer, which presents direct penetrations into the building, and for May, when the temperatures are the highest. These devices have been mathematically tested by means of an analysis with the stereographic graph, in order to later corroborate it with the Heliodon, and in this way to observe that their operation is appropriate for the building.

Regarding the thermal aspect, the Ener Habitat software was first used to evaluate the northwest façade in order to obtain results. The objective was to know if the materials were appropriate and to make an analytical comparison to know if the solar control systems were functional, giving remarkable stability to this façade.

Furthermore, using the Design Builder software, new material adaptations are applied, which in this case, the proposed result was a change of roofing, which in its current state is galvanized sheet and the new proposal is multi panel, resulting in an improvement in thermal comfort inside the building, on the other hand, in both cases the results were favorable.

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