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Analysis of hygrothermal comfort in a bioclimatic design with Bambusoidae *Guadua aculeata* for a community library in Cacahuananche municipality of Arcelia, Guerrero, Mexico

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Abstract

In the community of Cacahuananche Municipality of Arcelia Guerreo there is a warm humid climate. In the months of April and May the temperature is in a range of 45° C and 50° C. and an average relative humidity of 72%. Currently the houses in this community use sheets on the roofs; the heat is outside the comfort range.The Postgraduate Bioclimatic Design with the title *"Analysis of hygrothermal comfort in a bioclimatic design with Bambusoidae Guadua Aculeata for a community library in Cachuananche municipality of Arcelia, Guerrero. Mexico"* scientifically demonstrates; that it is possible to reach the range of hydrothermal comfort: 20°C-28°C, with the thermal properties of bamboo in the "Xóchitl Tlamatini" community library (Wisdom in a flower. Nahuatl). In this research, a descriptive, analytical methodological combination has been used. Following the descriptive methodology, the geographic-climatic context of the community of Cacachuananche municipality of Arcelia Guerrero was characterized, for this first stage the climate of the place where the library will be built was characterized, this was carried out by specialized software: Meteornom, Climate Consultant, andrewmarsch.For the analytical part, thermal conductivity tests were carried out on the construction system, which includes bamboo, for which a temperature greater than 45 ° C was considered, thermal conductivity data of the construction system with bamboo were collected and processed and analyzed in a model. of the building in the Software Designbuilder-EnergyPlus, it was demonstrated that the Bambusoidae Guadua Aculeata maintains the required temperature to achieve hygrothermal comfort inside the building. Therefore, this research will contribute to the development of Bioclimatic and sustainable Design, integrating the use of natural resources in buildings built with bamboo.

Keywords Bamboo; Aculeata; Hydrothermal comfort; Thermal conductivity; Bioclimatic Design

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1. Introduction

After 15 years, the number of native bamboos in Mexico has increased to 56 species; of which 34 are endemic to Mexico. Otates (Otatea acuminata) is a species of bamboo native to Mexico according (Ruiz, 2018). An example is the zongón that when cut grows faster and disperses better through its rhizomes in the tropical areas of Veracruz, in the municipality of Arcelia in the state of Guerrero, there is bamboo endemic to Mexico: Bambusoidae Aculeata, Bambusoidae Otatea. , Bambusoidae Acuminata, two bamboo species not identical, others that have adapted are. Bambusoidae Olhami, Bambusoidae Phyllostahquis.

Hygrothermal comfort in a building collects both humidity and optimal temperatures for human comfort. According to Givoni (1969), the recommended parameters for summer indoor hygrothermal comfort are 20 to 27 °C; and for Olgyay (1963), up to 28ºC; furthermore, these authors agree on determining appropriate limits of indoor relative humidity, values between 20 and 80%. "Analysis of hygrothermal comfort in a bioclimatic design with Bambusoidae Guadua Aculeata for a community library in Cacahuananche municipality of Arcelia, Guerrero , Mexico" It is an investigation of the Postgraduate in bioclimatic design, Sciences and Arts for Design (CyAD) of the Universidad Autónoma Metropolitana Unidad Azcapozalco (Flores, 2020) with which qualitative results will be obtained, in an analysis of hygrothermal comfort of a building built with bamboo and other natural materials; It will increase the use of bamboo and contribute to the development of Bioclimatic and sustainable Design, integrating the use of natural resources in buildings built with bamboo. In the community of Cacahuananche there is a warm subhumid climate. In the months of April and May the temperature is in the range of 37° C - 45° C. and a relative humidity of 27° C. Currently the homes in this community use sheets on the roofs; the heat is outside the comfort range, with the development of this research we seek to scientifically verify that with the thermal properties of bamboo, thermal hygrothermal comfort can be achieved in architectural spaces in an area with a warm humid climate. In this research, a descriptive and analytical methodological combination has been used. Following the descriptive methodology, the geographic-climatic context of the community of Cacachuananche, municipality of Arcelia Guerrero, was characterized. For this first stage, the climate of the place where the library will be built was characterized. This was carried out by specialized software Meteornom, Climate Consultant, andrewmarsch. For the analytical part, thermal conductivity tests were carried out on the construction system which includes bamboo, for which a temperature greater than 45° C was demonstrated, thermal conductivity data of the construction system with bamboo in the thermofluids laboratory of the Department of Energy, Basic Sciences and Engineering Division (CBI) of the same Academic unit, were collected and will be processed and analyzed in a model. of the building in Designbuilder-EnergyPlus Softwar. (Martínez, 2020)

2. Materials and methods

2.1. General objective

Achieve thermal comfort in an architectural space of a community library, Cacahuananche municipality of Arcelia Guerrero; demonstrate that in an area with a warm subhumid climate it is possible to have temperatures below 23°C.

2.2. Specific goal

Scientifically demonstrate that thermal conductivity can be isolated in a composite material: lime, clay, bambusoidae Guadua aculeata, proposed cover for the Xóchitl Tlamatini community library (Wisdom in a flower, in Mexica), temperatures greater than 40° centigrade are not conducted to the interior space of the project.

2.3. Methodology

In this research, a descriptive and analytical methodological combination has been used. Following the descriptive methodology, the geographic-climatic context of the community of Cacachuananche, municipality of Arcelia Guerrero, was characterized. For this first stage, the climate of the place where the library will be built was characterized. This was carried out by specialized software Meteornom, Climate Consultan. For this article, the first stage of the total investigation of the thesis is presented. For the analytical part, only the thermal conductivity analysis of the composite material was carried out, the thermal balance analysis of the building processing the thermal data of the composite material is missing.

The methodology has the following development:

i. Description of the Xochitl Tlamatini library.

The library is called “Axochitl Tlamatini”, a Nahuatl name that means “Wisdom in a flower”. This concept is originated by the community's indigenous identity, by the use of space, which is to promote knowledge while being aware of the time and violence that is being experienced in the area. The covers are shaped like hyperbolic paraboloids, alluding to flowers with their petals open, and beneath this flower the education of young people is being strengthened and “wisdom in a flower” is being formed. Education and research is the essence of the project, hence its name.

Sustainability and bioclimatic design will be integrated into the architecture of the project, in addition to promoting the use of bamboo in construction, natural materials from the area will be used, such as bamboo, earth, sand, water, lime, clay or mud. In the bioclimatic design, correct ventilation and rainwater collection will be considered. For the bathroom core, dry bathroom eco-technics will be implemented to avoid wasting water. With this system, waste will be used as fertilizer for plants and to achieve comfort. hygrothermal, a cross ventilation system will be designed to reduce the thermal load of 24 computer equipment.

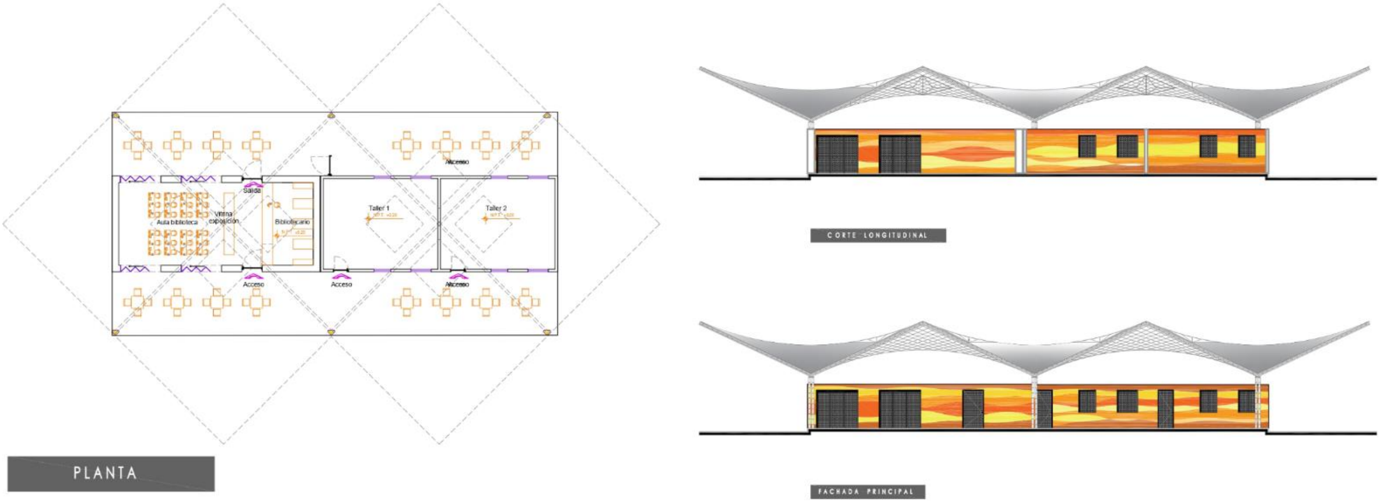

Figure 1 Plans of the Xochitl Tlamatinini library *(Ulises, 2021)*

ii. Justification of the Xochitl Tlamatini project

In the area where the Cacahuananche Community is located, there is endemic bamboo: Bambusoidae Aculeata, Bambusoidae Otatea. Others that have been adapted are: Bambusoidae Olhami, Bambusoidae Phyllostahquis. Bamboo, in architecture and engineering, is known as vegetable steel, it behaves better than steel and concrete in the event of an earthquake. (INBAR.11th Bamboo World Congress 2018). Internationally it is known as sustainable wood, its growth and production is the fastest in natural form that exists. One hectare of bamboo releases 60 tons of Oxygen and absorbs 40 tons of Carbon Dioxide, and captures carbon for 60 years. (Luna O. 2014). Increase the use of bamboo and contribute to the Development of Bioclimatic and sustainable Design, integrating the use of natural resources in buildings built with bamboo. The cost of a building is lower (INBAR.11th Bamboo World Congress 2018).

The building will be sustainable by integrating a rainwater collection system, a dry bathroom and a backyard garden. With its bamboo construction, new sources of employment will be generated and bamboo architecture will be promoted in the community. This project will meet two of the UN sustainable goals: Sustainable cities and communities, climate action.

iii. Climate Classification

The climate of Cacahuananche was classified as warm submedo Koppen, Garcia (Amaro, 2004)The climate was determined according to the Koppen-García climate classification Garcia(1973). The climate of the Cacahuananhe community, municipality of Arcelia Guerrero, is A W0 (W)(i) g: Warm humid with little annual thermal oscillation, ganges type, there is no heat wave; This classification is defined as follows:Climate group A: Warm climate; hot summer with an average annual temperature of 27.8°C, the temperature of the coldest month is 25.4°C, May has the highest average temperature of 32.4°C.W0 (W) Defines the sub humid climate with a coefficient P /T (Precipitation/Temperature) less than 43.2, a rainfall regime in summer and a percentage of winter precipitation less than 5%. An epw document was generated with climatological data from Cacahuananche Guerrero, the place where the library will be built. This was done by specialized software Meteornom, and processed Climate Consultant, andrewmarsch. The Cacahuananche community is located at the GPS coordinates: longitude (dec): -100.126944, latitude (dec): 18.287222.

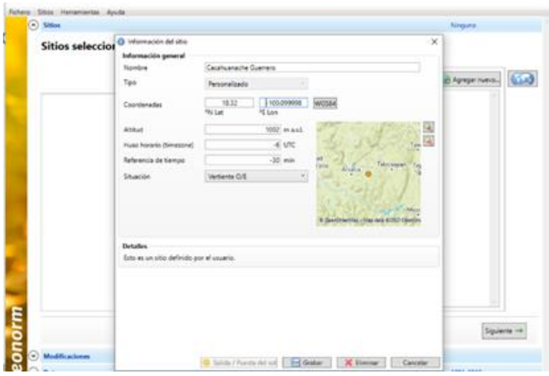

Figure 2 Location Cacahuananche

Figure 3 Document epw Cacahuananche

Figure, 2 The Meteonorm software tells us that the community of Cacahuanache is located at an altitude of 1,002 m a.s.l, a time zone of minus six hours, a time reference of minus thirty minutes and an O/E slope which indicates a middle mountain area. The location of the community of Cacahuananche is defined by the orange dot between the mountainous area of the municipalities of Arcelia and Teloloapan, introducing the geographical coordinates. In this image, the Meteonorm software tells us that the community of Cacahuanache is located at an altitude of 1,002 m a.s.l., a time zone of minus six hours, a time reference of minus thirty minutes and an O/E slope which indicates a middle mountain area. Figure 3 shows data from the Climatological Normals, meteorological station of the municipality of Arcelia Gro, Meteorological Station: 00012008, Height 414.0 MSNM. Processed data from the community of Cacahuananche municipality of Arcelia, Guerrero, the program considers the information entered to obtain the following result data, Uncertainty of annual values: GH=6%; Bn=11%;2.4°C, Tendenciadegh/year 4.9%.. Interpolated radiation sites, Ciudad Altamirano (59 km), Instituto Mexicano del Techo (11 interpolations temperature locations).

iv. Temperature

Figure 4 Climate Consultant Software shows the annual temperature graph of the community of Cacahuananche, the average annual temperature is 27.8° C, the Comfort Zone has an upper limit of 24.95° C and 19.95° C. Months with average comfort temperature are the months March, April and May with a maximum possible temperature above 43.8° C, the month with the extreme maximum temperature is May with 43.8° C, the month with the extreme minimum temperature is the month December with a temperature of 14.5 C. Months with a temperature at the upper comfort limit (28.95 C) are March and June. The highest average temperature is in May with a temperature of 32.4 C, the climate in summer is hot, the record for the highest temperature in the year is 44 C fig 3, the month of May has this record, and the temperature record lowest is 14.5 in December (Meteornom, 2020).

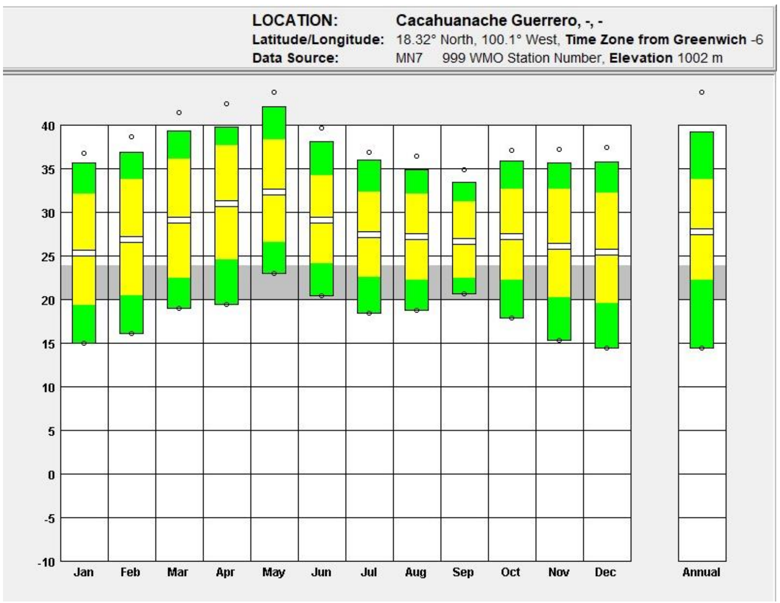

Figure 4 Temperature Cacahuananche

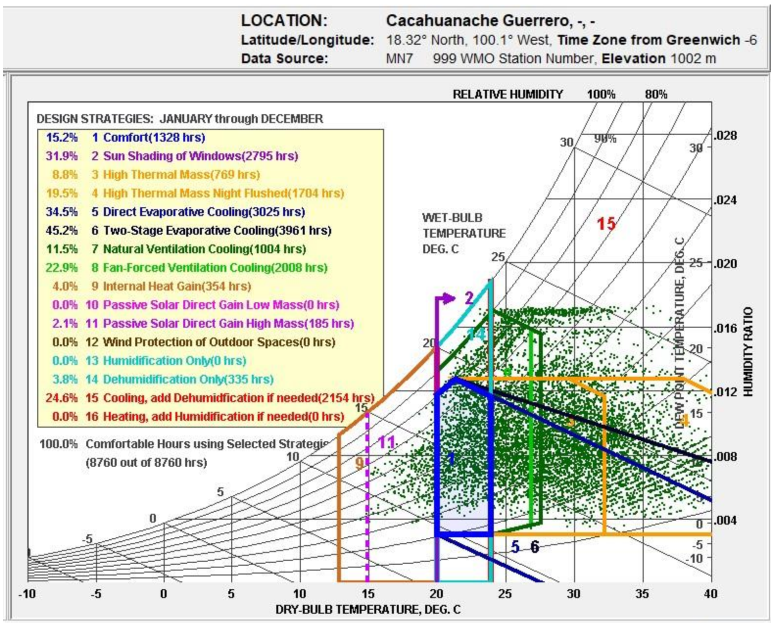

Figure 5 Phsicometric diagram

The psychometric chart in figure 5 of Software, the comfort zone is between 23.95°C and 28.95°C in the dry bulb (horizontal), as can be seen in the chart, most of the year the temperature is low in the mornings from July to October in the afternoon, but not November, December and January, which are the months with low temperatures at night and in the morning. Strategy 06: Two-point evaporative cooling (3063 Hrs) 35.0%. More cooling is needed in the afternoons from 1:00 p.m. Throughout the year the temperature is high, the graph shows that the dry bulb temperature ranges from 33°C onwards. Ventilation is required in the months of, March, April and May, Design cross ventilation (SOCIEDAD DE EDUCADORES EN CIENCIAS DE LA CONSTRUCCIÓN, 2021). The graph shows that in the hours from 8 to 12 hours in most of the year it is in comfort.

Strategies hidden by the Psychometric Chart:

2. Solar protection of windows, 31.9% (2,795 hours)
5. Direct evaporative cooling, 34.5% (3,025 hours)
6.Two-stage evaporative cooling, 45.2% (3,961 hours)
7.Natural Ventilation Cooling, 11.5% (1,004 hours)
8.Cooling by forced ventilation, 22.9% (2,008 hours)
16.Cooling, add dehumidification, if necessary, 24.6% (2,154 hours)

In figure 6, the sunlight and shading in the project model, in October 2022 at 11:00 a.m., it is observed that the leftovers of the stylet have the same shading angle of the roof in the model,

Figure 6 Structure Roof Model. *(Ulises, 2021)*

the climate is extremely warm subhumid, for which reason the design of a double-height 6-meter bamboo roof was chosen for shading. Skylights were designed in the upper part of the roof. In this model, the excess cardboard represents natural lighting. The shaded areas represent solar penetration for natural lighting fig.6 the path of the sun on May 21, the roof in this model was left transparent, therefore, the projection of the skylights on the upper part of the bamboo roofs project shadows from the East side, in reality it is the penetration of the sun through the skylights. Without even analyzing certain hours during the year, it can be deduced that from 12:00 pm to 3:00 pm, there will be solar penetration. Solar penetration analyzes are carried out on May 21 at 3:00 p.m. because it is the month with the highest temperatures, and December 21 because it has the lowest temperature. May 21 is considered for analysis, 15:00 pm is the time with the highest temperature simulated with a schematic model of the building in Autodesk Revit software, since the large windows will be folding with a personalized design with native bamboo from the Cacahuananche community.

v. Desolation analysis

The natural lighting inside the building with the skylights affects the users inside the building, mainly in the months of April and May, which are the ones with the highest temperatures, bamboo devices are proposed, a design that allows lighting indirectly or diffuse lighting. It will be a ceiling light placed at the bottom of the roofs. Because it is a warm subhumid climate, a layer of lime is proposed as a reflective material, to reflect the sun's rays and also to provide waterproofing in the rainy months. You can take advantage of the radiation from the environment in the upper part of the roof with skylights, and a ceiling design with bamboo for the penetration of indirect natural light. On the south and west façade there are trees that prevent direct sunlight. The best orientation in yellow will be towards the north, the length of the building in the community of Cacahuananche should be oriented towards the north with an angle of 2.5° towards the east from the north, the worst orientation is towards the south, for Being a climate grouped as hot, humid, extreme, you should have more to spare. For this reason, a large roof and trees must be considered in the project to gain shade for most of the year. Some of the strategies recommended here are: a distribution with a north-south orientation and a long east-west axis, constant ventilation In premises with a gallery, a massive roof above 8 hours of thermal retardation is recommended. The openings should be small. Considering the strategies above, it is recommended to use materials of natural origin From the Cacahuananche community area, these materials work best with a good bioclimatic design. By design Roof system formed by four hyperbolic paraboloids with three layers of materials: Bamboo, Guadua Aculeata, Clay, Lime.

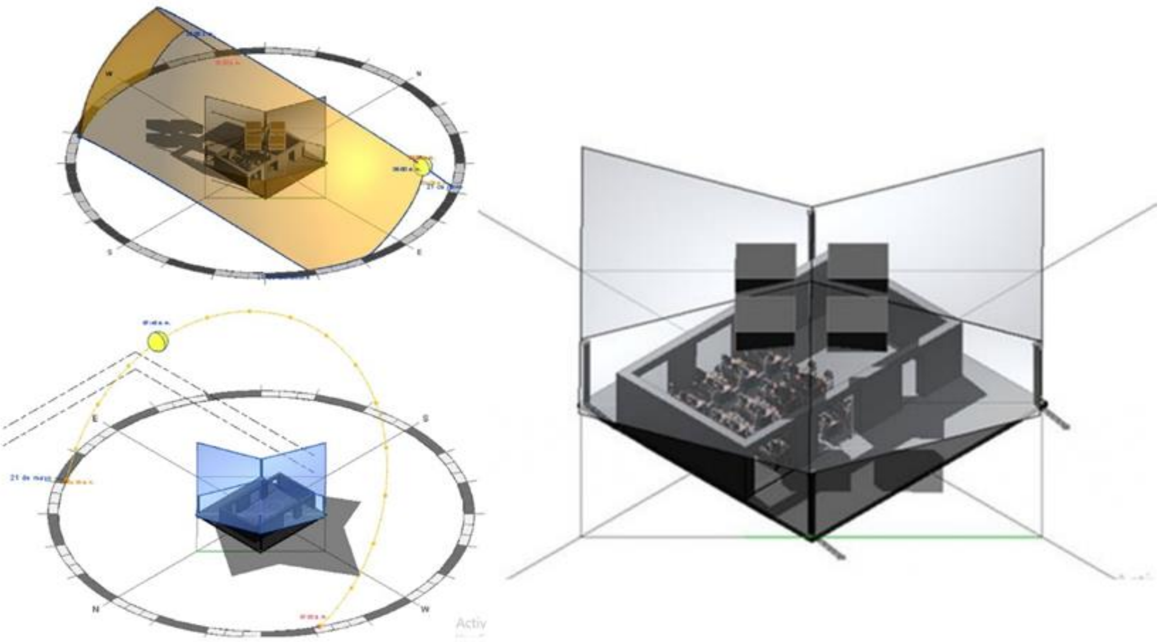

Figure 7 Sunlight library in Autodesk Revit software

Strategies numbers 2, 5, 6, 7, 8 and 16 of the Psychometric Charter were considered for the bioclimatic design of the Xochitl Tlamatini library, taking into account the recommended strategies, skylights were designed to avoid direct sunlight inside the library space, as well It is considered a passive strategy for naturally cross ventilation.

In May the highest maximum temperatures occur, it was decided to analyze the natural lighting at 12:00 p.m., this time is when there is more overhead lighting inside the building (See previous infographic) The figure shows that already There is no natural lighting inside the building, in the four skylights on the roofs. The section shows the device (ceiling lamp under the bamboo roof), which blocks natural lighting in the building. The angle of 40.13° is considered for the shadow conveyor calculation. Only the skylights on the upper part of the roofs are analyzed, since There is no incidence of solar rays in the windows of the walls. To proceed with the ventilation analysis, the dimensions of the space, its volume and area of window openings are considered.

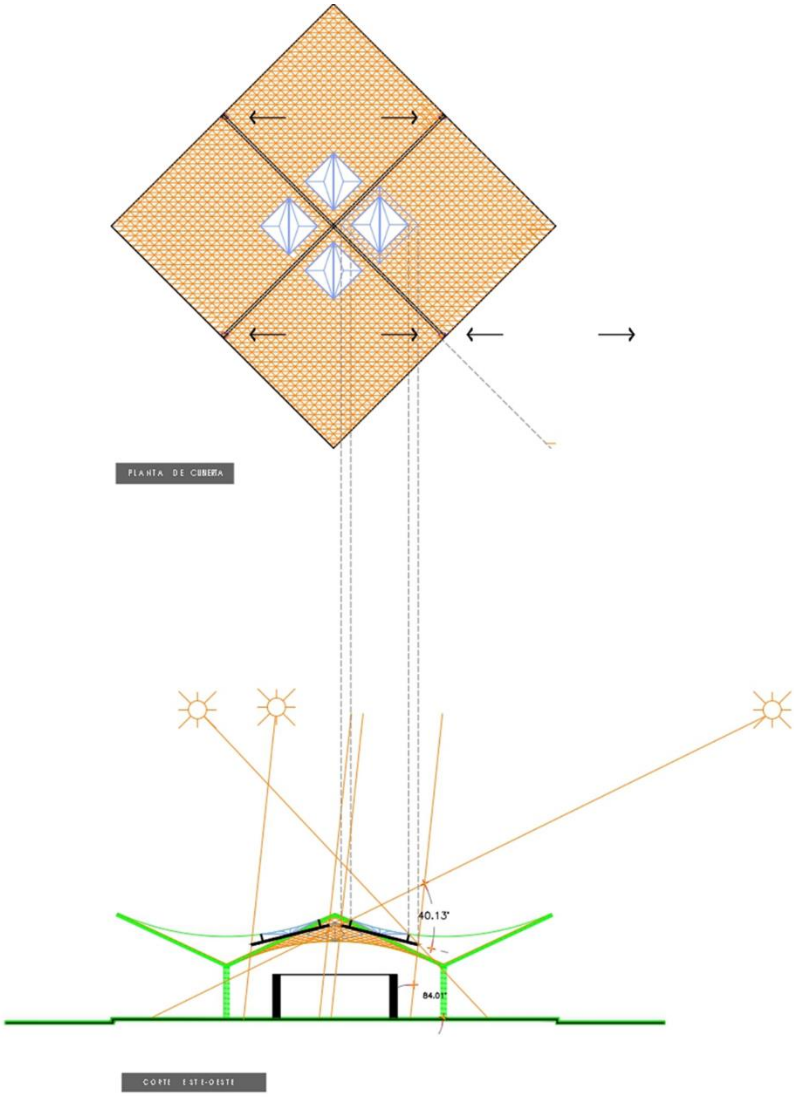

Figure 8 Sunlight library, Schematic section of the project avoiding solar penetration

vi. Natural ventilation

The wind graph from the Climate Consultan software shows the prevailing annual winds from east to west. The wind increases clockwise, the wind speed is 0.9 m/s SE. Figure 9.

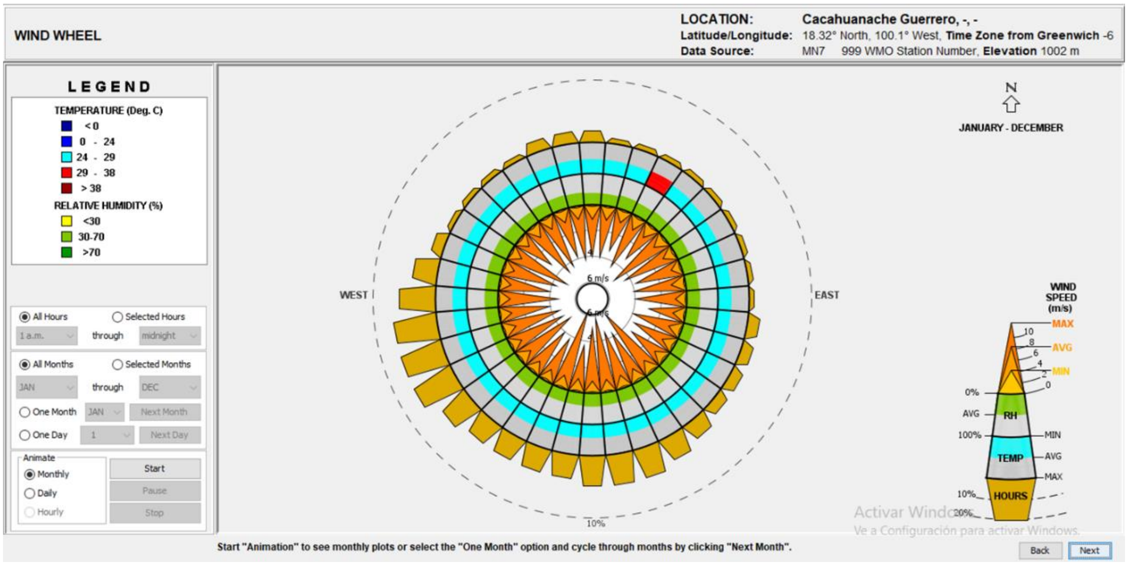

Figure 9 Wind rose graph Climate Consult, wind speed.

Dimensions of the library computing space
Length: 11.54 m
Width: 4.96m
Height: 3.00 m
Area: 57.23 m2
Volume: 11.54 m*4.96 m*3.00 m = 171.69 m3

Window Dimensions
Width: 2.40 m
Height: 3.00 m
Opening area: 2.40 m*3.00 m = 7.20 m2

Air renewal in the computing space

Determine the ventilation rate and air changes necessary so that the air in a computing space of 171,69 m3, located in the community of Cacahuananche Guerrero Mexico, occupied by 24 people doing light seated work, does not exceed the 0.1% threshold. (0.001) of CO2. ASHRAE. (ASHRAE, 2013)

$$Q_a = \frac{S}{C_i - C_o} \qquad CAH = \frac{Q_a}{V}$$

Qa= 0.019/ 0.001-0.0007= 63.33 m3/h
Qa=63.33 m3/h*24 people = 1,519.92 m3/h
CAH =(1,519.92 m3/h)/171.69 m3
***CAH* =8.85 Air changes per hour**
CAH = 6.00 minimum air changes per hour according to Mexican construction regulations. It is fulfilled, the Calculation asks us for 8.85 Air Changes per hour.

Cross Ventilation Olgay Air Flow in the computing space
Determine the ventilation rate; a wind speed V =0.9 m/s perpendicular to the windows; an area of ventilation openings of 7.20 m2* 2 Windows = 14.40 m2 (windward) and an exit area of 7.20 m2* 2 Windows = 14.40 m2 (leeward). All windows have an opening of 7.20 m2 so: 7.20 m2*2 = 14.40 m2

$$C_v = 0.6\ fr \qquad R_v = \frac{A_s}{A_e}$$

Cv=0.6 fr Rv=As/Ae

The window openings are the same; so window ratio

Rv = 17.40.36 m2/ 14.40 m2 = 1

The Ratio Factor fr = 1,000

CV = 0.6*1=0.6

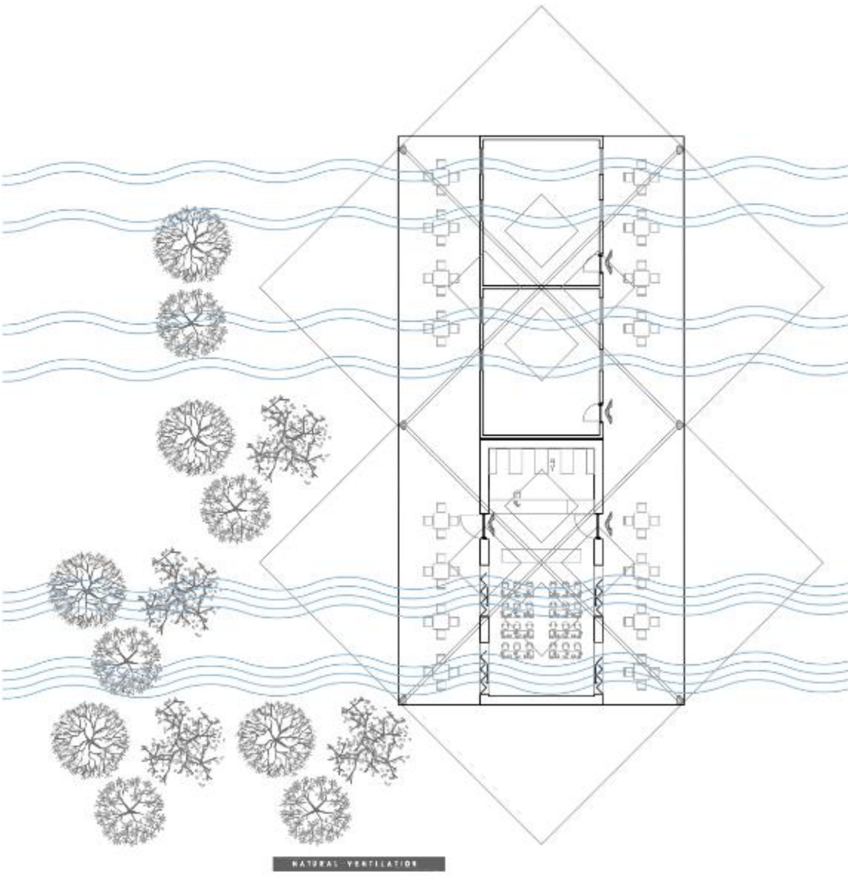

Figure 10 Graphic scheme of natural ventilation of the Xochitl Tlamatini library on the ground floor (Ulises, 2021)

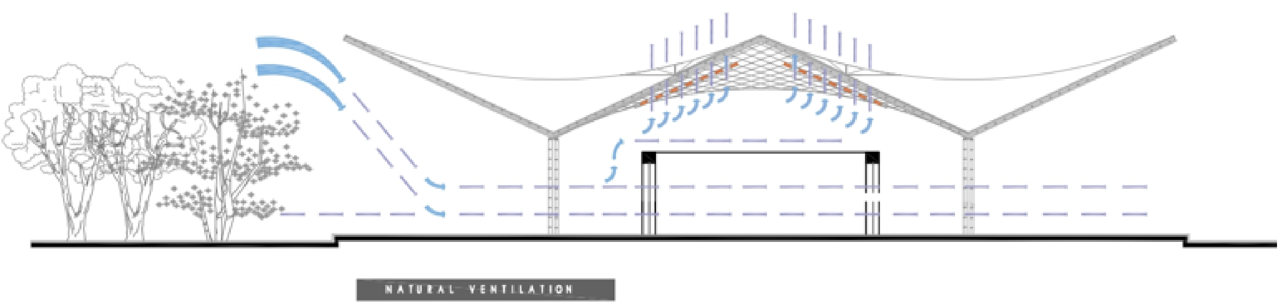

Figure 11 Graphic scheme of natural ventilation of the Xochitl Tlamatini library on the in elevation (Ulises, 2021).

$$Q = C_v\ A_e\ v \quad (seno\ \theta)$$

Q = Ventilation rate (m3 /s)

Cv = Coefficient of effectiveness of openings

A = Area of entrance opening (m2)

v = Wind speed (m/s)

fr = ratio factor between openings

Q = 0.6*14.40 m2* 0.9 m/s* (sin 90°)

Q = 0.6*14.40 m2* 0.9 m/s* 1 = 7.776m/s

ACH = (3600 s) (Q)/V

ACH = (3600 s) (7.776 m/s) / 159.25 m3 = 27,993.6s/171.69m3

ACH = 163.04 changes/hour.

The National Institute of Physical and Educational Infrastructure (INIFED) is the regulatory institute for educational buildings in Mexico, in its Regulatory document Volume 5 volume 3 of Air Conditioning on page 23 establishes 10 air changes per hour for classrooms The bioclimatic design of Olgay Air Flow Cross Ventilation in the computing space of the Xochitl Tlamitini Project complies with the provisions of the standard; ACH = 163.04 changes/hour is the ventilation obtained 15 times more than what is established by the INIFED.

Combined Ventilation: STACK effect and cross ventilation.

Determine the ventilation rate due to the stack effect in a space 15.00 m high, with ventilation openings: 4 openings on the floor equal to 28.80.42 m2, with a height difference between the window axes of 3.00 m. The outside temperature is 44°C (May Temperature Graph from Climate Consultant software) and the inside temperature in the highest part is 24°C.

$$Q_s = C_D\ A \sqrt{\frac{2\ g\ \Delta H_{NPL}\ (T_i - T_e)}{T_i}}$$

To determine the pressure difference between both openings, it is necessary to estimate the density of the air according to the temperatures at each point of the windows:

Outside temperature

Te=44+ 273.15 = 317.15 K

Indoor temperature

Ti = 24+ 273.15 = 297.15 K

Qs = Ventilation rate (m3/s)

CD = Aperture discharge coefficient (CD = 0.65 for unidirectional flow)

A = Effective ventilation area (m2)

HNPL = distance from the midpoint of the lower opening to the NPL (m)

Ti = Indoor temperature (K)

Te = Outside temperature (K)

g = gravitational acceleration = 9.81 m/s2

Q=0.65(7.20) 〖((2*9.81)〗^ 〖(0.062)(317.15-297.15)/317.15)〗^0.5

Q=4.68 〖((19.62)〗^ 〖(0.062)(20)/317.15)〗^0.5

Q=4.68 〖(24.32/317.15)〗^0.5=4.68(0.2769168828) =**1.29 m/s**

Upper part ventilation calculation, window openings are equal; so window ratio:

Rv = 8 m2/ 8 m2 = 1

The Ratio Factor fr = 1,000

CV = 0.6*1=0.6

Q = Ventilation rate (m3 /s)

Cv = Coefficient of effectiveness of openings

A = Area of entrance opening (m2)

v = Wind speed (m/s)

fr = ratio factor between openings

Q = 0.6*8 m2* 0.9 m/s* (sin 90°)

Q = 0.6*8 m2* 0.9 m/s* 1 = **4.8 m3/s (Stack Effect)**

For the Combined ventilation calculation, the ASHRAE formula will be used. (ASHRAE, 2013)

Total Ventilation Calculation

$$Q_t = \sqrt{Q_v{}^2 + Q_s{}^2}$$

Qt = Total ventilation rate (m3/s); Qv = Cross ventilation rate (m3/s)

Qs = Ventilation rate due to Stack effect (m3/s); Qv = 1.28 m/s; Qs = 4.8 m3/s

Therefore

Qt= (〖1.28〗^2+ 〖4.8〗^2) 〖^0.5〗 = (1.6384+23.04) 〖^0.5〗 = 4.966890375 m/s

Qt= (24.67) 〖^0.5〗 = 4.966890375 m/s

vii. Bambú *Guadua aculeata*

The five species of *Guadua* existing in Mexico are the ones that reach the largest dimensions of all the bamboos that grow in this country. Of the five species, *Guadua aculeate* figure 11 located in Cacahuananche reaches 20 m in height and 5 inches in diameter. at the base. It is a species that develops spines on all branches, has hollow internodes 20 cm to 30 cm long and 2 cm thick Ruiz (E.2022). In research, the lengths of the fibers obtained for G. aculeata varied between 1.66 mm and 2.66 mm, values higher than those found by Omobowale and Ogedengbe (2008). Bamboo fibers have a polylaminar structure; At maturity the greatest number of blades is present, a characteristic observed in G. aculeata. The fibers are the support structures; the thicker they are, the mechanical resistance increases; The thick walls of G. aculeata together with the polylaminar structure make its culms suitable for use in construction Liese, (1998). According to the classifications that exist, the values obtained for the coefficients of rigidity and flexibility, the slenderness index and the Runkel ratio indicate that the fibers of G. aculeata are long but with thick walls, therefore, it is a poor-quality material for making paper, Porres and Valladares, (1979), Tortorelli, (1956). (Flores, 2021)

Figure 12 Bambú *Guadua aculeata* in Cacahuanche Arcelia Guerrero, México

2.4. Thermal Conductivity test

The ASTM C518 standard covers the measurement of steady-state thermal conduction through flat plate samples using a heat flow measuring apparatus (ASTM, 2020). This test method involves measuring steady-state thermal conduction through flat plate specimens using a heat flow measuring apparatus. This test method provides a rapid means of determining the steady-state thermal transmission properties of insulations. thermal and other materials with a high level of precision when the device has been properly calibrated. For the test, a 14x12cm specimen was used, with 1.5 cm walls of the bamboo species Guadua aculeata, 4.5 cm wide bamboo slats were used, these were taken from the middle part of the total culm of the bamboo, it should be noted that the hardest part , the outer layer will be placed at the bottom of the library cover, this part is the hardest in the cross section, as can be seen in figure 12, this material was dried in the sun's rays and shade for a period of three months, he was treated and immunized by immersion. Figure 13A shows the specimen with its three layers of natural materials, from top to bottom it is composed of: Guadua Aculeata bamboo, Clay, lime extracted and cooked in an artisanal way in the community of Cacahuananche, this is the cover on the structure of hyperbolic parabolide from the library.

Figure 12 *Guadua aculeata* bamboo slats

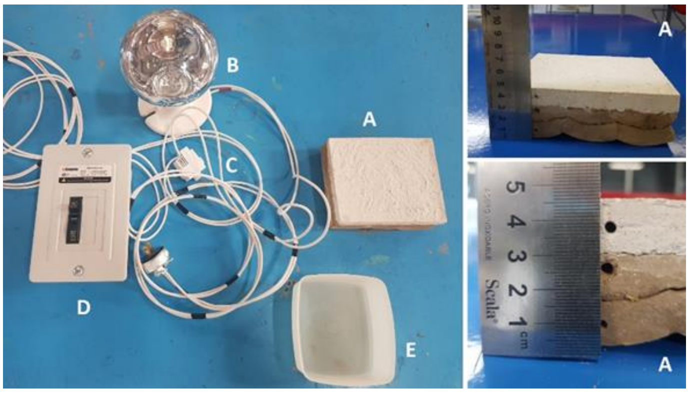

Figure 13 Specimen and electrical equipment for testing

Figure 13B is a reflector-type incandescent light bulb to preserve hot food, model BR40/CL, Power: 250W, voltage: 127V operating frequency of 60Hz, base: E27 material mirrored glass, color temperature: Warm white opening angle: 180 ° Luminous flux: 15,000 lm Power factor: 1, lifespan: 5,000 hours environmental protection: IP50; With this focus there are temperatures above 40°C on the specimen. Figure 9C is a 127 Volt voltage regulator, model 7120 from the CORSA brand. Figure 9D is a thermomagnetic switch to prevent any short circuit. Figure 9E is a 12x12x5 cm plastic stopper, on which the specimen will be placed. For To determine the thermal coductivity, five szzijia brand thermocouples were used - 1m K-type thermocouple temperature sensor (50 ~ 700 °C) and a thin rod, three each going inside the layers respectively (Figure 14), and Figure 15 shows two EXTECH instruments model SDL200 thermometers with 4 thermocouple channels.

Figure 14 Specimen with termocouples

Figure 15 Thermal conductivity test

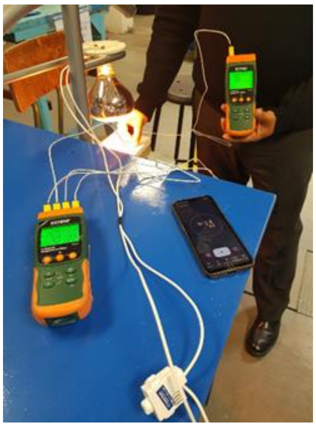

Figure 16

For the thermal conductivity test procedure we considered two climatic data from the community of Cacahuananche Guerrero: the warm submedo climate Koppen, Garcia (2004) was determined according to the climatic classification Koppen-García (1973). In figure 3 the The record for the highest temperature in the year is 44° C. This test was carried out in the thermofluids laboratory of the Department of Energy, Division of Basic Sciences and Engineering (CBI) of the Universidad Autonoma Metroplinana Unidad Azcapotzalco.

Figure 15 shows two thermometers with the temperatures, one of these records the temperature 0, it is the incandescent light bulb with 44°C in the month of May, this being the warmest, the thermocouple TP-1 equal to a temperature of 44°C is on the top. of the capadecal (upper level of the cover), thermocouple TP-2 equals 42.7°C records the internal temperature in the lime, thermocouple TP-3 equals to 28.7°C records the internal temperature in the clay, thermocouple TP- 4 equals 22.7°C records the internal temperature in the bamboo Guadua aculeata, TP- 5 equals 22.4°C records the temperature lower level in the bamboo Guadua aculeata (Lower level of the bamboo cover), temperature 6 is the space between the building and the roof is six meters high from floor to roof. Figure 12 shows two thermometers with the temperatures, one of these records the temperature 0, it is the incandescent light bulb with 48.2°C in the month of May, this being the warmest, the thermocouple TP-1 equal to a temperature of 48°C is stable. higher than the temperature of the warm month to test the thermal conductivity of the cover, it was arranged on the top of the capadecal (top level of the cover), thermocouple TP-2 equals 42.0°C and records the internal temperature in the lime, the thermocouple TP-3 equals 29.2°C records the internal temperature in the clay, thermocouple TP- 4 equals 22.6°C records the internal temperature in the Guadua aculeata bamboo, TP- 5 equals 22.1°C records the lower level temperature in the

Guadua bamboo aculeata(Lower level of the bamboo roof), temperature 6 is the space between the building and the roof, six meters high from floor to roof. These are preliminary tests, more were carried out with similar results as can be seen in table 1

3. Result and Discussion

3.1. Thermal conductivity

Table 1 shows temperatures regulated at a temperature range higher than that of the warmest month, which is May, the incandescent bulb 0 (Height 65mm) was regulated until reaching a temperature of 48.6° in the five tests with temperatures T, T1, T2, T3, T4, the thermocouple TP-5 is the Lower level Guadua aculeata bamboo shows a regular temperature with little variation, as can be seen for this research case the Guadua Aculeata bamboo presents a Temperature T=21.9° C, T1= 22.1°C, T2=21.5°C, T3=22.9°C, T1=21.10°C, temperature of the bamboo cover at the bottom is very regular with the difference of 1°C. There will be no thermal conductivity into the library.

Table 1. Thermal conductivity test with temperatures 48°C

Material	No.	T (°C)	Y (mm)	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)
Incandescent spotlight	0	48.6	65.0	48.6	48.6	48.6	48.6
Higher level Cal	TP-1	48.6	55.0	48.6	48.6	48.6	48.6
Cal-Internal	TP-2	42.1	47.5	42.0	42.0	42.3	42.1
Clay-Internal	TP-3	29.8	32.5	29.6	29.7	30.3	29.5
Bamboo *Guadu aculeata* Internal	TP-4	23.3	17.5	23.0	23.2	23.3	23.5
Lower level bamboo *Guadua aculeata*	TP-5	21.9	10.0	22.1	21.5	22.9	21.0
Interior space	6	21.9	0.0	21.9	21.9	21.9	21.9

Figure 13 shows TP-2 equals 40.0°C records the internal temperature in the lime, thermocouple TP-3 equals 24.7°C records the internal temperature in the clay, thermocouple TP-4 equals 22.3°C records the internal temperature in the bamboo Guadua aculeata, TP- 5 equals 21.6°C records the temperature lower level in the bamboo Guadua aculeata (Lower level of the bamboo canopy), temperature 6 is the space between the building and the canopy, they are six meters high from floor to deck. Figure 14 shows two thermometers with the temperatures, one of these records the temperature 0, it is the incandescent bulb with 50.5 °C in the month of May, this being the warmest, the thermocouple TP-1 equal to a temperature of 50.5 °C is above the upper part of the capadecal (upper level of the cover), thermocouple TP-2 equal to 42.2°C records the internal temperature in the lime, thermocouple TP-3 equals 25.5°C records the internal temperature in the clay, thermocouple TP- 4 equals 22.5°C records the internal temperature in the *Guadua aculeata* bamboo, TP- 5 equals 21.7°C records the lower level temperature in the

Guadua aculeata bamboo. With this, even raising the temperature of the incandescent bulb 50.5°C, the temperature of the bamboo It is maintained at 21.7°C within what will be the interior space of the library close to the lower limit of the hygrothermal comfort according to Givoni (1969). The recommended parameters for summer interior hygrothermal comfort are 20 to 27°C; considering the constant flow of ventilation, the building will remain comfortable even in the warmest months.

Figure 13 Temperatures in Specimen

Figure 14 Temperature 50.5 °C

Conclusion

The use of Guadua Aculeta bamboo slats in the integrated lime and clay roof presents an alternative to reduce the negative environmental impact due to the use of cement in construction. Thermal insulation can be obtained, achieving hirothermal comfort for the user in the library, the temperature of the bamboo is maintained at 21.7°C within what will be the interior space of the library close to the lower limit of comfort. This article presents only some tests, more will be carried out on each layer of material separately to determine the thermal conductivity of the materials. The thermal conductivity of the bamboo cover will be calculated with a formula with clay and lime, once these results are obtained it can be processed. in Software Design Builder-Energy Plus. model, analyze the library with bamboo and visualize its thermal balance. This Research was recognized by the PENUMA-ONU (Flores, 2020).

The bioclimatic design was considered for the natural ventilation of the Xochitl Tlamatini library, which complied with the regulations corresponding to the INIFED and the Construction Regulations of Mexico. The ventilation part was advised by Dr. Victor Armando Fuentes Freixanet, (A., 1995) with the air changes it is possible to be in thermal comfort, this will be confirmed with the thermal simulation that is being carried out. in the Design Builder software. This research is about to be completed by the main author, the thermal simulation analysis and the complete research will be presented at the 12th Bamboo World congress Taiwan 2024.

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Conflict of Interest

The authors declare there is no conflict of interest

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