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Tesis

Revaluation of Vernacular Architecture in a Hot Humid Climate in Villa Rica-Peru: A Study of Thermal Comfort Compared to Confined Masonry

Nahomi Lynn Castro Barrientos
Vladimir Simon Montoya Torres

Para optar el Título Profesional de
Arquitecto

Huancayo, 2024

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Título:
Revaluation of Vernacular Architecture in a hot humid climate in Villa Rica - Peru: A study of thermal comfort compared to confined masonry

URL / DOI:
https://www.hrpub.org/journals/article_info.php?aid=14523 / 10.13189/cea.2024.120611

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Revaluation of Vernacular Architecture in a hot humid climate in Villa Rica - Peru: A study of thermal comfort compared to confined masonry

Nahomi Lynn Castro Barrientos[1,*], Vladimir Simon Montoya Torres[2]

[1]Faculty of Engineering, Professional Academic School of Architecture, Universidad Continental, Peru
[2]Faculty of Engineering, Continental University, Peru
*Corresponding Author: 70400298@continental.edu.pe

Abstract Thermal comfort is a fundamental aspect in the quality of life of users in homes. The vernacular architecture of the Peruvian jungle, represented by malocas (wooden houses), is characterized by natural ventilation and shading elements that allow greater thermal comfort in these hot and humid climates. However, the preference for confined masonry houses is gradually displacing this valuable construction tradition, leading to the loss of recognition and appreciation of the benefits of the vernacular architecture of the Peruvian jungle. In Villa Rica, wooden housing and confined masonry housing are two common options in housing construction, but their thermal behavior is different. Since the choice of construction material can significantly influence the level of thermal comfort. The present research seeks to evaluate and compare thermal comfort in wooden and confined masonry homes, using direct measurements and analysis, with international standards such as ASHRAE 55 and EN-16798 to analyze the Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied indices. (PPD) and with simulation tools such as CBE Thermal Comfort Tool and Rayman to model and calculate the physiological equivalent temperature (PET) and the standard effective temperature (SET) which are indicators of thermal sensation, in order to determine the revaluation of the vernacular architecture.

Keywords Vernacular Architecture, Thermal Comfort, PMV, PPD, PET, SET, Confined Masonry

1. Introduction

The vernacular architecture of the Peruvian jungle is based on the wisdom and experience accumulated by local communities over time. This design, the product of a deep understanding of the environment, provides a high level of thermal comfort to users. However, the preference for confined masonry houses, driven by their popularity, is gradually displacing this valuable building tradition. As a result, recognition and appreciation of the benefits offered by the vernacular architecture of the Peruvian jungle is being lost.[1]The high and low tropical jungle located at about 2,300 meters above sea level, presents high temperature conditions during the day such as high humidity and constant rains. Since ancient times, in these regions, the way of building their wooden homes with a one-meter elevation structure has been adapted to their needs for ventilation and natural shadows, being key elements to achieve greater thermal comfort in these climates.[2]While the construction of buildings with confined masonry may be more efficient in terms of techniques, modern materials and costs, this has led to the gradual loss of vernacular architecture and the benefits it brings to its environment and community.[3]In a context of climate change that is intensifying heat waves, the need to maintain adequate thermal comfort is more frequent, especially for people who reside in hot climates.[4] Many studies [[5], [6], [7]] have investigated the effectiveness of external personal cooling strategies in preserving energy and ensuring occupant thermal comfort at elevated indoor temperatures (28-30°C) that exceed those specified in conventional building codes. [[8],[9],[10],[11],[12], [13],[14], [15], [16], [17]] In addition, the measurement of thermo-hygrometric conditions seeks to maintain thermal comfort in rehabilitated buildings with a low energy cost.[18] In the VIS [19] monitoring allowsHistorical factsof the thermodynamic and energy variables of the buildings that quantify the air quality conditions inside the home and its thermal behavior [20] of the variables in two indices: 1) the Predicted Mean Vote (PMV), which indicates the thermal sensation on a scale of 7 values ranging from -3, or "very cold", to + 3, or "very hot", and 2) the Predicted Percentage Dissatisfied (PPD), which indicates the percentage of dissatisfied people in the atmosphere. In this Fanger model, the ideal thermal comfort situation is a PMV of 0, or "Neutral", and a PPD no greater than 20%, which is widely used by [[21],[22]] thermal comfort studies developed With the adaptive approach that are carried out in different periods depending on the current weather conditions [23] to achieve comfort standards and occupant behavior, another study proposed a methodology to obtain real information about thermal behavior and environmental quality in the homes.[24] considering balanced design standards and modern interior design trends using innovative green building materials.[25] The thermal comfort indices suitable for the study of climatic conditions in tourist places help in decision making in the approach to quality and thermal comfort.[26] The methods used statistically through linear regression refer to ASHRAE Standard 55-2017 and Anova of SPSS 24.[27] To do this, field measurements and data [28] must be available from indicators such as PMV, which is calculated from six variables: air temperature (Tair), relative humidity (Hr), air speed (Vair).), the mean radiant temperature (Tmr), the clothing level (Clo) and the metabolic rate (Met). [[29],[30],[31]] Indoor air quality values are influenced by several parameters, with temperature and humidity being themost significant contributors.[32] Bioclimatic buildings are designed based on the climatic characteristics of the region [33]. Architects can also benefit from this holistic approach to design spaces that adapt to the constantly changing climate and promote innovation in sustainable design.[34] Peru is classified into 9 climatic zones according to its hygrothermal characteristics. The district of Villa Rica has a humid subtropical climate [35] located in the province of Oxapampa, department of Pasco. Being known as “the land of the finest coffee in the world” for being a coffee producing area and having outstanding coffee farms in the region, in addition, the Oxapampa-Ashaninka-Yanesha Biosphere Reserve is located in coexistence with the Austro-German settlers and other settlers coming from other parts of Peru. In this sense, this research seeks to evaluate and compare thermal comfort in wooden and confined masonry homes, using direct measurements and analysis with simulation tools, using international standards such as ASHRAE 55 and EN-16798 to find the Predicted Mean Vote indices. (PMV) and the Predicted Percentage Dissatisfied (PPD) and simulation programs such as CBE Thermal Comfort Tool and Rayman to model and calculate the physiological equivalent temperature (PET) [36] and the standard effective temperature (SET) which are indicators of thermal sensation to determine the revaluation of vernacular architecture.

2. Methodology

Table1. Meanings of the Nomenclatures

Nomenclature	Meaning
Tair	Air Temperature
Tmr	Average radiant temperature
Will go	Airspeed
Hr	Relative humidity
met	Metabolic Rate
Clo	Clothing Insulation
Top	Operating Temperature
Td	Dew Temperature
Vp	Vapor pressure
W	Metabolic Activity
PMV	Average Predicted Vote
PPD	Maximum Percentage of People in Discomfort
PET	Perceived effective temperature
SET	Standard effective temperature

2.1. Experimental building

According to EM standard. 110 thermal and lighting comfort with energy efficiency the district of Villa Rica was classified as a humid tropical climate. Furthermore, according to Meteoblue it has altitude characteristics of 1481 meters above sea level and geographical coordinates of 10.74°S, 75.27°W average annual temperature of 20°C, average relative humidity of 89% and solar radiation of 3 to 5 kwh/m2.

Figure 1 shows the sunlight of a plan view of the homes in the urban area of Villa Rica. Regarding the predominant construction typology, there are homes with local material such as wood with a pitched gable roof covered with corrugated iron and others with a porticoed structural system with a confined masonry envelope with a pitched pitched roof.

Figure 1. Sunlighting of homes in the urban area of the Villa Rica district

A sample of housing was selected with some characteristics of the vernacular architecture of the jungle called “malocas” with an inclined gable roof with corrugated iron coverage (Type 1) as shown in Figure 2. The wooden house still maintains some characteristics architectural details of the location of the central door and windows on the sides and a wooden structure with a slight elevation with sloping roofs and another house with a porticoed structural system with a confined masonry envelope (Type 2) as seen in Figure 3. Both homes located in the Psj. The Libertadores on the left side of the Villa Rica contingency hospital. Housing type 1 has an area of 77.01m^2 and housing type 2 has an area of 134.32m^2. The monitored environment corresponds to the bedroom with an area of 5.81m^2 facing southeast in housing type 1 and in housing type 2 the bedroom has an area of 14.60 m^2facing southwest of the home.

The architectural distribution of the homes is shown below. Figure 4 shows the distribution of housing type 1 in which the study area (bedroom) with dimensions of 2.66*2.19 is indicated with shading. Furthermore, Figure 5 shows the distribution of housing type 2 in which the bedroom of interest is indicated with shading with dimensions of 4* 3.9 *2.0966*1.3775*2.9695*0.8948.

Figure 2. Similarities between the Vernacular homes of the jungle of Peru

Figure 3. Studio homes with different construction typologies

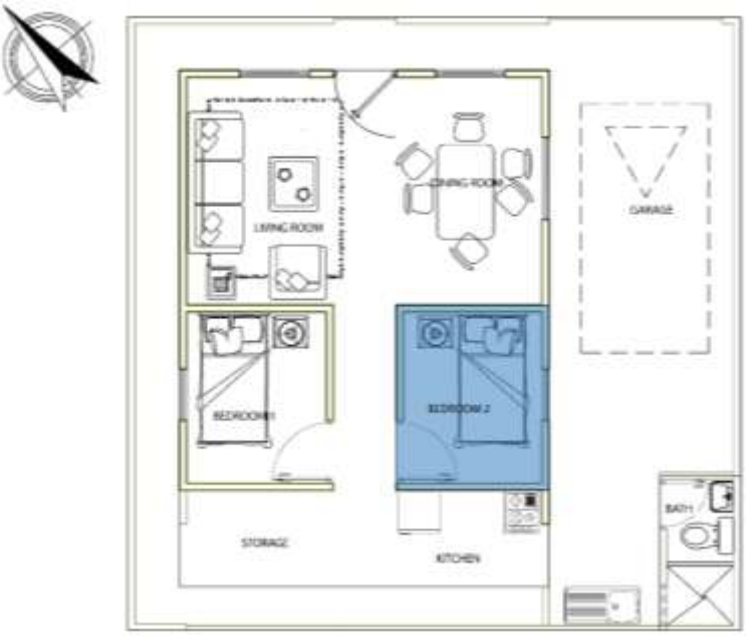

Figure 4. Distribution plan of the house with local wooden construction typology

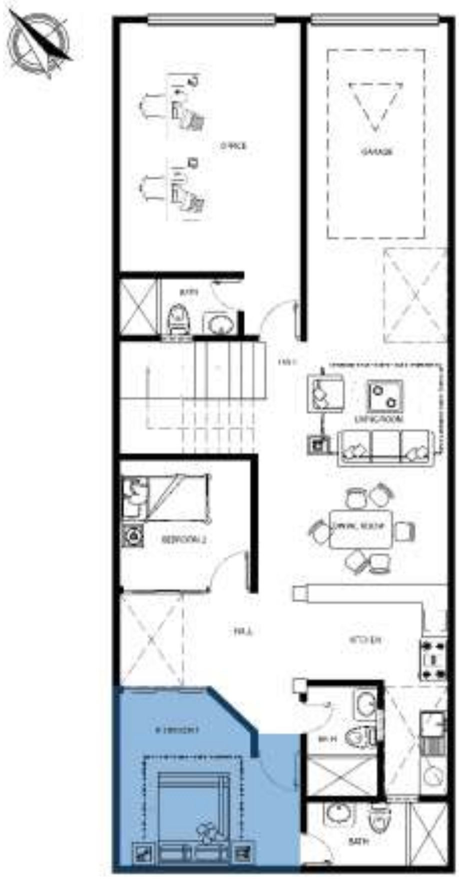

Figure 5. Distribution plan of the conventional confined masonry construction typology

2.2. Monitoring period

For the monitoring period, the first week of March was selected since according to the climate databases (Weather Api), this is a month of high percentage of humidity with intense rain and constant temperature within the year 2024. As It can be seen in figure 6 that the average annual temperature in this month is constant, which contrasts with other months where the humidity is low or the temperature is low, which makes this month interesting for research since it is an unusual climate. In addition, according to the Meteoblue climate station that provides annual, monthly, biweekly and daily data, reliable data is obtained for this research, where Villa Rica presents a high percentage of humidity as seen in figure 7, exceeding 80% to 100 %, this being important data for this study.

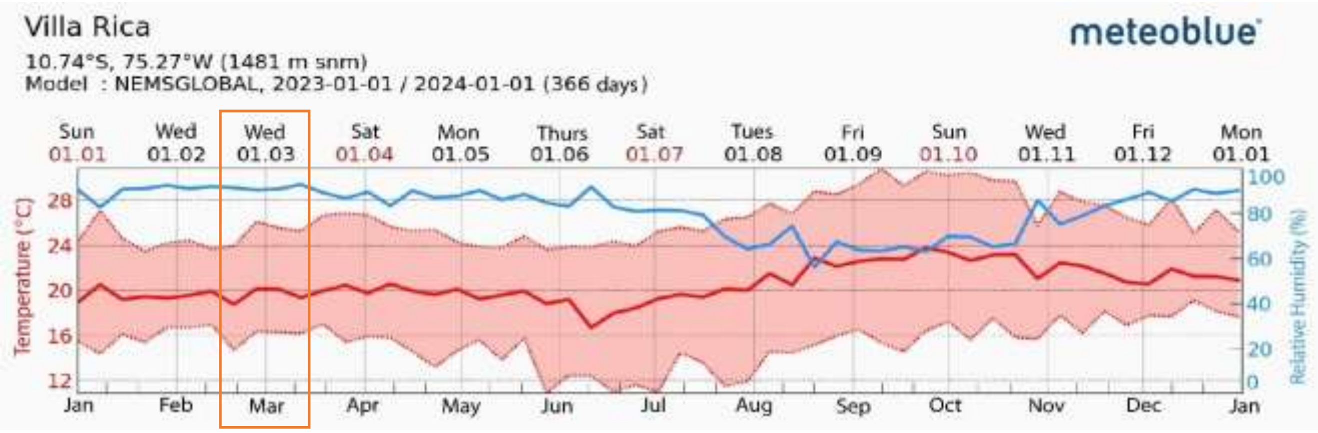

Figure 6. Temperature and Humidity graph

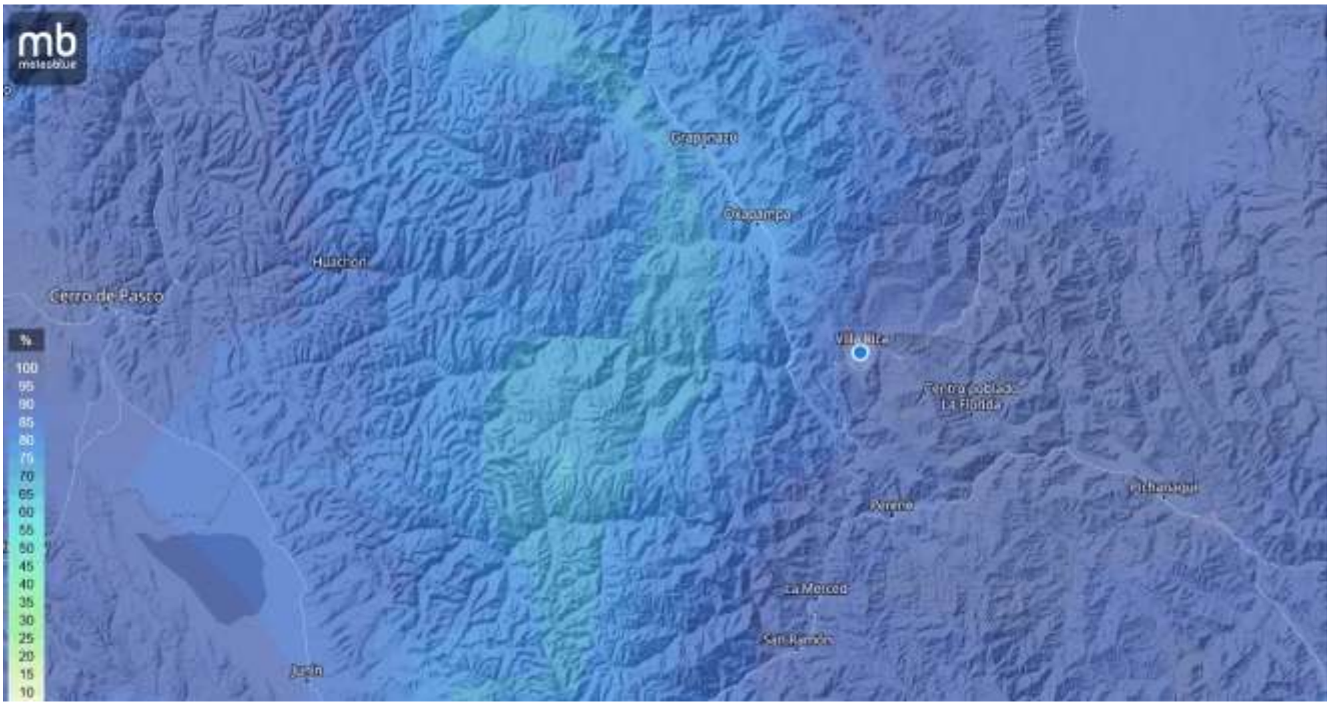

Figure 7. Humidity Map

2.3. Data collection

In accordance with the protocol established in the ISO 7726 standard (International Organization for Standardization, 2002), measurements of environmental variables were carried out with specialized instruments, air temperature (Tair) and relative humidity (Hr) data were taken. with the BENETECH GM1361+ Professional Data Logger Thermohygrometer Hygrometer, the air velocity (Vair) with the UNI-T UT363 Digital Anemometer and the mean radiant temperature (Tmr) with the industrial infrared thermometer 50 - 380°C. To take measurements in type 1 and type 2 homes, the manipulation of windows and doors was considered according to the user's convenience. The measuring instruments were located in the window: The digital anemometer was installed in the window to measure the air velocity (Vair). The digital thermohygrometer was placed under the window to measure air temperature (Tair) and relative humidity (Hr). Data was taken hourly and the hourly average was calculated for the first week of March. This procedure allowed us to collect precise information about the environmental conditions in both homes. In addition, measurements were taken of the 6 room plans of the type 1 home and the 8 room plans of the type 2 home with the industrial infrared thermometer every hour to find the average radiant temperature. Thus, the Tmr was calculated using the formula proposed by Dunkle (1963) and later adopted by the ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers).

$$Tmr = \left[\sum_{i=1}^{n} \frac{A_i}{A_t} \times (T_i + 273.15)^4\right]^{1/4} - 273.15 \qquad (1)$$

Where:

Ti = Surface temperature in °C.
Fp = View factor between the center point of the room and the surface
ε = Emissivity of the material

To obtain the operating temperature data, the air speed in meters per second, air temperature in degrees C° and radiant temperature in degrees C° were used, whose data were entered into the formula and solved through a programming language. Python" [37], which contains libraries that help solve advanced mathematical formulas with exact measurements. The operating temperature was found through the formula:

$$Top = A * ta + (1 - A) * Tmr \qquad (2)$$

Where:

Top = Operating temperature

A = Air velocity coefficient

Tair = Air temperature

Tmr = Mean radiant temperature

To obtain the dew temperature results, the relative humidity in percentage was used, and the air temperature in degrees C°, these data were entered into the formula and solved through the "python" language code.

$$Td = \frac{243.04 \times ln\left(\frac{HR}{100}\right) + 17.625 \times T}{17.625 - \left(\frac{HR}{100}\right) - \frac{17.625 \times T}{T + 243.04}} \qquad (3)$$

Where:

Td= Dew temperature

Tair = Air temperature

Hr = Relative Humidity

With the dew temperature data, the vapor pressure was found, whose data were entered into the formula and results through the "python" language code.

$$VP = 6.112 \times e^{\left(\frac{17.67 \times Td}{Td + 243.5}\right)} \qquad (4)$$

Where:

Vp= Vapor pressure

Td= Dew temperature

The result of metabolic activity in W/person was also obtained, whose data were entered into the formula and results through the "python" language code.

$$W = 70 \times Met \qquad (5)$$

Where:

W = Metabolic Activity

Met = Metabolic Rate

2.4. Data processing

With the data obtained during the week, a typical day was created consisting of the hourly averages of each variable. Subsequently, the values of this typical day were entered into the CBE Thermal Comfort Tool simulation tool, with the ASHRAE 55 standard the PMV, PPD, SET and sensation of thermal comfort were obtained and with EN 16798-1, the PMV was obtained, PPD and category level [38]. In addition, Rayman software was used for greater effectiveness in the results, where the PMV, SET and PET were obtained. [39]

2.4.1. CBE Thermal Comfort

To obtain thermal comfort data under the ASHRAE 55 and EN 16798 standard, air temperature in degrees C°, relative humidity in percentage, wind speed in m/s, average radiant temperature in degrees C° and operating temperature were used. in degrees C°. The parameters offered by the CBE Thermal Comfort program were also used for the Met (Metabolic Rate), which was considered 0.7 while sleeping and 1.2 when awake and standing relaxed, recommended according to I. Silva.[40]

For Clo (Clothing Insulation), the parameters of 0.74 were used for sweatpants with a long-sleeved polo shirt and 1.0 for resting with typical indoor winter clothing. With these data, thermal comfort indices such as PMV, PPD and SET were found.

2.4.2. Rayman

In this software, the following measurements were taken: Date (day, month, year), time, latitude, longitude, height (masl), time zone, air temperature (C°), dew temperature (C°), with the which could be found the vapor pressure in hectopascals (hPa), relative humidity (%), air speed (m/s), cloudiness in octas [41], average radiant temperature (C°), user size, user weight, user age, user sex, clothing fit (clo) and metabolic activity (W). With these data, the thermal comfort indices PMV (Predicted Mean Vote), PET (Psychological Equivalent Temperature) and SET (Standard Effective Temperature) were found.[42]

Table 2 shows the typical day with the hourly average values of each climatic variable (Tair, Tmr, Vair, Hr) during the first week of March for housing type 1, built with wood. This table includes all the data obtained through measurements and formulas.

Table 2. Average of data taken during a week in each hour of the Madera home

Date	Hour	Tair	tmr	Will go	Hr	M et	Clo	Top	Td	Vp	W
Mar 01 - Mar 07	00:00	17.5	19.1	0.1	86%	0.7	1	18.9	15.10	17.18	49
Mar 01 - Mar 07	01:00	16.8	18.3	0.2	84%	0.7	1	18	14.1	16.10	49
Mar 01 - Mar 07	02:00	16.9	18.4	0.1	85%	0.7	1	18.3	14.4	16.42	49
Mar 01 - Mar 07	03:00	16.7	18.3	0.2	87%	0.7	1	17.98	14.5	16.53	49
Mar 01 - Mar 07	04:00	16.8	18.6	0.1	85%	0.7	1	18.42	14.3	16.31	49
Mar 01 - Mar 07	05:00	16.7	18.5	0.1	85%	0.7	1	18.32	14.2	16.21	49
Mar 01 - Mar 07	06:00	17.5	18.9	0.0	85%	1.2	1	18.9	14.9	16.96	84
Mar 01 - Mar 07	07:00	17.9	19.9	0.1	83%	1.2	1	19.7	15	17.07	84
Mar 01 - Mar 07	08:00	19.3	21.8	0.0	82%	1.2	0.74	21.8	16.1	18.32	84
Mar 01 - Mar 07	09:00	20.8	23.4	0.1	78%	1.2	0.74	23.14	16.8	19.16	84
Mar 01 - Mar 07	10:00	21.6	23.9	0.1	77%	1.2	0.74	23.67	17.4	19.90	84
Mar 01 - Mar 07	11:00	22.4	24.6	0.2	78%	1.2	0.74	24.16	18.4	21.20	84
Mar 01 - Mar 07	12:00	24.3	26.2	0.0	75%	1.2	0.74	26.2	19.6	22.85	84
Mar 01 - Mar 07	13:00	24.5	26.3	0.0	71%	1.2	0.74	26.3	18.9	21.87	84
Mar 01 - Mar 07	14:00	23.1	25.7	0.1	72%	1.2	0.74	25.44	17.8	20.40	84
Mar 01 - Mar 07	15:00	22.5	25.7	0.2	70%	1.2	0.74	25.06	16.8	19.16	84
Mar 01 - Mar 07	16:00	23.1	25.8	0.2	69%	1.2	0.74	25.26	17.1	19.52	84
Mar 01 - Mar 07	17:00	23.4	25.6	0.2	71%	1.2	0.74	25.16	17.8	20.41	84
Mar 01 - Mar 07	18:00	21.4	23.4	0.2	82%	1.2	0.74	23	18.2	20.93	84
Mar 01 - Mar 07	19:00	19.4	21.2	0.0	83%	1.2	0.74	21.2	16.4	18.67	84
Mar 01 - Mar 07	20:00	18.6	19.9	0.1	81%	1.2	0.74	19.64	15.3	17.40	84
Mar 01 - Mar 07	21:00	18.1	19.3	0.1	85%	1.2	0.74	19.18	15.5	17.63	84
Mar 01 - Mar 07	22:00	17.8	20.0	0.1	83%	0.7	1	19.78	14.9	16.96	49
Mar 01 - Mar 07	23:00	18.3	19.6	0.1	82%	0.7	1	19.47	15.2	17.29	49

Table 3 shows the typical day of the hourly average values of each variable (Tair, Tmr, Vair, Hr) during the first week of March for housing type 2, built with confined masonry. The table contains the data through measurements and formulas, providing a complete view of the climatic conditions with the user's perception within the space.

Table 3: Average of data taken during a week at each hour of the Confined Masonry home

Date	Hour	Tair	Tmr	Will go	Hr	Met	Clo	Top	Td	Vp	W
Mar 01 -Mar 07	00:00:00	18.5	20.3	0.1	91%	0.7	1	20.12	17.00	19.40	49
Mar 01 -Mar 07	01:00:00	17.8	19.5	0.1	91%	0.7	1	19.33	16.3	18.56	49
Mar 01 -Mar 07	02:00:00	17.4	19.2	0.1	92%	0.7	1	19.02	16.1	18.32	49
Mar 01 -Mar 07	03:00:00	17.9	20.1	0.2	93%	0.7	1	19.66	16.8	19.16	49
Mar 01 -Mar 07	04:00:00	17.8	20.2	0.1	92%	0.7	1	19.96	16.5	18.79	49
Mar 01 -Mar 07	05:00:00	17.9	20.5	0.1	93%	0.7	1	20.24	16.8	19.16	49
Mar 01 -Mar 07	06:00:00	17.1	18.5	0.1	92%	1.2	1	18.4	15.8	17.97	84
Mar 01 -Mar 07	07:00:00	19.2	21.1	0.0	90%	1.2	1	21.1	17.5	20.03	84
Mar 01 -Mar 07	08:00:00	21.9	24.3	0.0	84%	1.2	0.74	23.3	19.1	22.15	84
Mar 01 -Mar 07	09:00:00	22.3	23.9	0.0	81%	1.2	0.74	23.9	18.9	21.87	84
Mar 01 -Mar 07	10:00:00	23.5	25.8	0.0	79%	1.2	0.74	25.6	19.6	22.85	84
Mar 01 -Mar 07	11:00:00	24.6	26.8	0.1	82%	1.2	0.74	26.58	21.3	25.38	84
Mar 01 -Mar 07	12:00:00	25.4	27.7	0.1	79%	1.2	0.74	27.29	21.5	25.69	84
Mar 01 -Mar 07	13:00:00	25.9	28	0.1	73%	1.2	0.74	27.7	20.7	24.46	84
Mar 01 -Mar 07	14:00:00	24.8	27.1	0.2	74%	1.2	0.74	26.64	19.9	23.28	84
Mar 01 -Mar 07	15:00:00	25.6	28	0.0	72%	1.2	0.74	28	20.2	23.72	84

Mar 01 -Mar 07	16:00:00	26.1	28.4	0.1	71%	1.2	0.74	28.17	20.4	24.01	84
Mar 01 -Mar 07	17:00:00	25.9	27.8	0.1	79%	1.2	0.74	27.61	22	26.49	84
Mar 01 -Mar 07	18:00:00	23.8	25.6	0.0	85%	1.2	0.74	25.6	21.1	25.07	84
Mar 01 -Mar 07	19:00:00	21	22.9	0.0	87%	1.2	0.74	22.9	18.8	21.73	84
Mar 01 -Mar 07	20:00:00	18.2	19.8	0.0	91%	1.2	0.74	19.8	16.7	19.03	84
Mar 01 -Mar 07	21:00:00	18.4	20	0.0	90%	1.2	0.74	20	16.7	19.03	84
Mar 01 -Mar 07	22:00:00	19.4	21.7	0.0	91%	0.7	1	21.7	17.9	20.54	49
Mar 01 -Mar 07	23:00:00	19.5	21.6	0.0	90%	0.7	1	21.39	17.8	20.41	49

3. Results

The result of the thermal simulation in the ASHRAE 55 standard is shown as thermal sensation and EN-16798 by categories (I = excellent, II = normal, III = acceptable and IV = not acceptable), through which environmental variables are obtained. with their respective weights of PPD, PMV, SET and PET. At PPD < 5%: Optimal thermal comfort, PPD = 5% to 10%: Moderate thermal comfort, PPD = 10% to 15%: Acceptable thermal comfort and PPD > 15%: Unacceptable thermal comfort. At the PMV< -3 = Very cold, -3 ≤ PMV < -1=Cold, -1 ≤ PMV < 1 = Cool,1 ≤ PMV < 3 = Slightly cool,3 ≤ PMV < 5 = Comfort, 5 ≤ PMV < 7 = Slightly hot, 7 ≤ PMV < 9 = Hot and PMV ≥ 9 = Extremely hot. [31] In SET >37.5 = °C Very hot, 37.5°C - 34.5°C = hot, 34.5°C - 30°C = Warm, uncomfortable, 30°C - 25.6°C = slightly unacceptable, 25.6° C - 22.2°C = comfortable and acceptable, 17.5°C - 22.2°C = slightly unacceptable, 14.5°C - 17.5°C = Cold and unacceptable and 10°C - 14.5°C = Very cold, very unacceptable.[43]In the PET, the weight and height of the user are determined, where the male (1.70 m and 70 kl) and woman (1.60 m and 55 kl) in the case studied, where PET < 4°C = Very cold, stress due to extreme cold, 4°C ≤ PET < 8°C = Cold, 8°C ≤ PET < 13°C = Cool, 13°C ≤ PET < 18°C = Slightly cool, 18°C ≤ PET < 23°C = Comfort, 23 °C ≤ PET < 29°C = Slightly hot, 29°C ≤ PET < 35°C = Hot, 35°C ≤ PET < 41°C = Very hot and PET ≥ 41°C = Extremely hot, extreme heat stress . As a result of all that has been explained, it is shown in detail by hour of the typical day during a week of house with vernacular characteristics in table 4 and in table 5 is shown the details of the thermal comfort of the confined masonry. [44]

Table 4: Thermal comfort result in housing type 1 (Wooden housing)

MEASUREMENT SCHEDULE		CBE Thermal Comfort Tool							Rayman				
		ASHRAE 55				EN-16798							
DATE	HOUR	PMV	PPD	SET	SENSATION	PMV	PPD	c	PMV-V	PMV-M	SET	PET-V	PET-M
01 - 07	00:00	-3.22	100%	20.3	COLD	-3.54	100%	IV	-0.5	-23	18.6	twenty	twenty
01 - 07	01:00	-3.88	100%	18.8	COLD	-4.33	100%	IV	-0.9	-2.9	17.1	18.9	18.9
01 - 07	02:00	-3.48	100%	19.7	COLD	-3.82	100%	IV	-0.6	-2.5	17.9	19.4	19.4
01 - 07	03:00	-3.86	100%	18.8	COLD	-4.34	100%	IV	-0.9	-2.9	17	18.9	18.9
01 - 07	04:00	-3.43	100%	19.9	COLD	-3.81	100%	IV	-0.6	-2.5	17.9	19.5	19.5
01 - 07	05:00	-3.47	100%	19.8	COLD	-3.85	100%	IV	-0.6	-2.5	17.8	19.4	19.4
01 - 07	06:00	-0.39	8%	22.9	NEUTRAL	-0.59	12%	III	0.1	-0.5	20	17.9	17.9
01 - 07	07:00	-0.3	7%	23.8	NEUTRAL	-0.61	13%	III	0.2	-0.4	19.2	18.4	18.4
01 - 07	08:00	-0.14	5%	23.8	NEUTRAL	-0.55	11%	III	0.1	-0.6	22.6	18	17.9
01 - 07	09:00	0.08	5%	25.3	NEUTRAL	-0.33	7%	II	0.4	-0.2	22.5	19.2	19.1
01 - 07	10:00	0.21	6%	25.8	NEUTRAL	-0.15	5%	I	0.5	0	23.2	19.7	19.6
01 - 07	11:00	0.1	5%	26.5	NEUTRAL	-0.13	5%	I	0.5	0	23.3	19.9	19.8
01 - 07	12:00	1.02	27%	28.8	Slightly Warm	0.72	16%	IV	1	0.7	26.9	21.6	21.5
01 - 07	13:00	1.01	27%	28.6	Slightly Warm	0.73	16%	IV	1	0.7	27	21.7	21.5
01 - 07	14:00	0.64	13%	27.6	Slightly Warm	0.27	13%	II	0.8	0.4	24.9	21	20.8
01 - 07	15:00	0.28	7%	27.2	NEUTRAL	-0.04	5%	I	0.6	0	23.8	20.4	20.3
01 - 07	16:00	0.33	7%	27.3	NEUTRAL	0.07	5%	I	0.7	0.2	24.2	20.7	20.5
01 - 07	17:00	0.3	7%	27.3	NEUTRAL	0.12	5%	I	0.7	0.2	24.3	20.7	20.6
01 - 07	18:00	-0.18	6%	25.2	NEUTRAL	-0.42	9%	II	0.3	-0.3	22.1	19.1	19
01 - 07	19:00	-0.3	7%	23.1	NEUTRAL	-0.59	12%	III	0.1	-0.6	22.3	17.7	17.7
01 - 07	20:00	-0.82	19%	21.3	Slightly Cool	-1.06	29%	IV	-0.2	-0.9	19.6	16.8	16.8

01 - 07	21:00	-0.92	23%	20.9	Slightly Cool	-1.19	35%	IV	-0.2	-1	19	16.4	16.4
01 - 07	22:00	-2.88	98%	21.2	COLD	-3.33	100%	IV	-0.3	-2.1	19.2	20.5	20.5
01 - 07	23:00	-3.02	99%	20.9	COLD	-3.28	100%	IV	-0.3	-2.1	19.2	20.5	20.5

Table 5: Thermal comfort result in type 2 housing (Confined masonry)

MEASUREMENT SCHEDULE		CBE Thermal Comfort Tool							Rayman				
		ASHRAE 55				EN-16798							
DATE	HOUR	PMV	PPD	SET	SENSATION	PMV	PPD	c	PMV-V	PMV-M	SET	PET-V	PET-M
01-07	00:00	-2.67	96%	21.6	Cold	-3.04	99%	IV	-0.2	-1.9	19.8	21	21
01-07	01:00	-3	99%	20.8	Cold	-3.36	100%	IV	-0.4	-2.1	19	20.3	20.3
01-07	02:00	-3.12	100%	20.5	Cold	-3.5	100%	IV	-0.4	-2.2	18.6	20	20
01-07	03:00	-3.08	99%	20.6	Cold	-3.7	100%	IV	-0.5	-2.4	18.7	20.3	20.3
01-07	04:00	-2.73	97%	21.4	Cold	-3.23	100%	IV	-0.3	-2	19.3	20.7	20.7
01-07	05:00	-2.61	95%	21.7	Cold	-3.14	100%	IV	-0.2	-1.9	19.6	20.9	20.9
01-07	06:00	-0.55	11%	22.5	Slightly Cool	-0.81	19%	IV	0	-0.6	18.1	17.7	17.7
01-07	07:00	-0.15	5%	25.6	Neutral	-0.12	5%	I	0.4	-0.1	22	19.2	19.2
01-07	08:00	0.28	7%	25.7	Neutral	0.17	6%	I	0.6	0.1	25	20	20
01-07	09:00	0.43	9%	26.3	Slightly Warm	0.17	6%	I	0.6	0.1	24.9	19.9	19.8
01-07	10:00	0.88	21%	28.3	Slightly Warm	0.57	12%	III	0.9	0.5	26.4	21.2	21.1
01-07	11:00	1.03	28%	29.9	Slightly Warm	0.71	16%	IV	1.1	0.8	26.2	21.9	21.8
01-07	12:00	1.2	35%	30.5	Slightly Warm	0.93	23%	IV	1.3	1	27.2	22.8	22.6
01-07	13:00	1.26	38%	30.5	Slightly Warm	1	26%	IV	1.4	1.1	27.6	23	22.8
01-07	14:00	0.72	16%	29.3	Slightly Warm	0.57	12%	III	1	0.6	25.9	21.9	21.8
01-07	15:00	1.49	fifty%	30.8	Slightly Warm	1.11	31%	IV	1.3	1.1	28.4	22.9	22.7
01-07	16:00	1.37	44%	30.9	Slightly Warm	1.07	29%	IV	1.54	1.2	27.8	23.3	23.1
01-07	17:00	1.29	40%	30.9	Slightly Warm	1.02	27%	IV	1.4	1.1	27.5	23	22.8
01-07	18:00	0.92	23%	28.8	Slightly Warm	0.63	13%	III	1	0.6	26.5	21.3	21.1
01-07	19:00	0.19	6%	25.3	Neutral	-0.12	5%	I	0.4	-0.1	23.9	19.1	19
01-07	20:00	-0.64	14%	21.6	Slightly Cool	-0.91	22%	IV	-0.2	-0.9	21	16.7	16.7
01-07	21:00	-0.59	12%	21.8	Slightly Cool	-0.86	20%	IV	-0.1	-0.9	21.3	16.9	16.8
01-07	22:00	-1.97	75%	23.1	cool	-2.56	95%	IV	0	-1.5	22.2	21.9	21.9
01-07	23:00	-2.11	81%	22.8	cool	-2.56	95%	IV	0.1	-1.5	22.4	22	22

Through the ASHRAE 55 and EN-16798 standard in type 1 housing, it is shown that from 6:00 a.m. to 11:00 a.m. and from 3:00 p.m. to 7:00 p.m. the user's PMV reaches a neutral state with acceptable category.

In this home it is perceived that the man can be more comfortable in the room during the day and even at night unlike the woman who mostly reaches a comfortable state during the day.

However, it is perceived that at 2:00 p.m. its state is slightly warm according to ASHRAE -55, but because it has a normal category range of II and a PMV-Male of 0.8, it is considered an hour of neutral state. The aforementioned is presented in figure 8 where the PMV during the day reaches 12 hours in a neutral state.

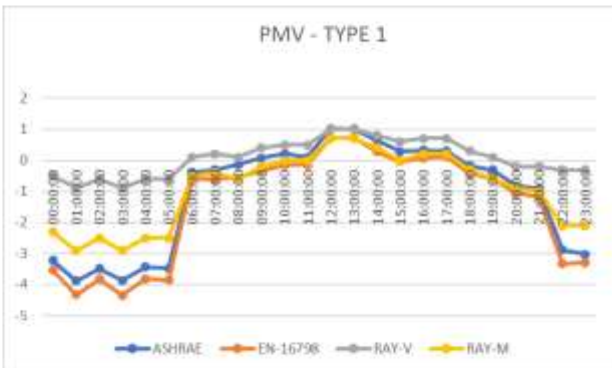

Figure 8. Graph of the PMV Index – Wooden housing in ASHRAE, EN -16798 and Rayman.

In housing type 2, the PMV was found, through the ASHRAE 55 standard and it shows that from 7:00 a.m. to 9:00 a.m. in the morning and at 7:00 p.m. at night the user's temperature reaches a neutral state. The EN-16798 standard shows that from 7:00 a.m. to 10:00 a.m. in the morning and at 6:00 p.m. and 7:00 p.m. at night the user's temperature reaches a category of excellent to acceptable.

In this home it is perceived that the man can be more comfortable in the room during the day and even at night unlike the woman who can reach a comfortable state mostly during the day.

However, it is perceived that at 10:00 in the morning and 2:00 p.m. its state is slightly warm according to ASHRAE -55 but because it has a category III range it is acceptable according to EN-16798 and a PMV-Male of cshows that 7 hours a day, housing type 2 is in a neutral state.

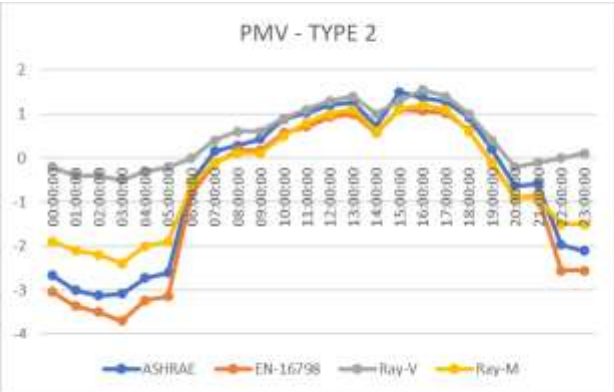

Figure 9. Graph of the PMV Index – Confined masonry housing in the ASHRAE, EN -16798 and Rayman.

The PPD was found through the ASHRAE 55 and EN-16798 standard that in housing type 1 from 6:00 a.m. to 11:00 a.m. and from 3:00 p.m. to 7:00 p.m. there are an average percentage of people in discomfort of 6%.

Furthermore, at 2:00 p.m. the state of the home is slightly warm according to ASHRAE -55, but because it has a PPD of 14% and an acceptable category range of III, it is considered an hour of neutral state. ANDFigure 10 shows that during the day there are 12 hours that are within the acceptable range in housing type 1.

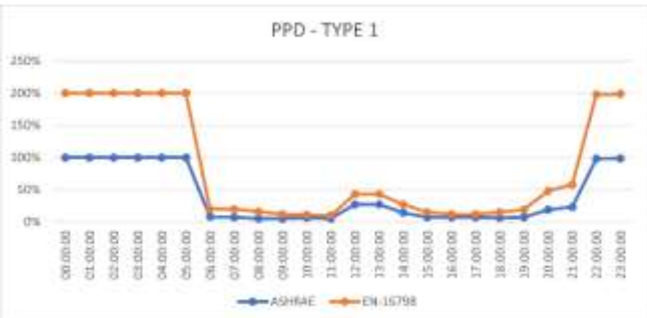

Figure 10. Graph of the PPD Index – Wooden housing in ASHRAE and EN -16798

The PPD was found through the ASHRAE 55 standard, it shows that from 7:00 a.m. to 9:00 a.m. in the morning and at 7:00 p.m. at night the average percentage of people in discomfort is 9% in type 2 housing. The EN-16798 standard shows that from 7:00 a.m. to 10:00 a.m. in the morning and at 2:00 p.m. and 7:00 p.m. there is an average of 7% people in discomfort having a category of excellent to acceptable.

In addition, it is perceived that at 10:00 in the morning, 14:00 in the afternoon and 18:00 at night its state is slightly warm with a PPD of 21% and 23% according to ASHRAE -55 but because it has a category III range it is acceptable according to EN-16798 and with 12% and 13% of people in discomfort due to what is established as comfortable hours. It is seen in figure 11 that in housing type 2 during the day there are 7 hours within the acceptable range.

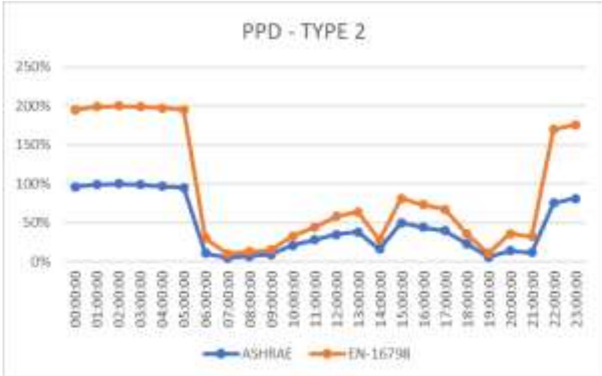

Figure 11.PPD Index Graph – Confined Masonry Housing in ASHRAE and EN -16798

Through the ASHRAE 55 standard, it is observed that from 6:00 a.m. to 11:00 a.m. and from 3:00 p.m. to 7:00 p.m. at night there is an average standard effective temperature (SET) of 25.28°C. In the Rayman software from 6:00 a.m. to 11:00 a.m. and from 3:00 p.m. to 7:00 p.m. at night there is an average standard effective temperature (SET) of 22.5°C.

Furthermore, it is perceived that at 2:00 p.m. its state is slightly warm according to ASHRAE -55 but because it has a category III range it is acceptable according to EN-16798 and a SET of 24.9°C. Figure 12 shows that the SET obtained is within the acceptable weighting, it is stated that 12 hours of the day are in a comfortable state in housing type 1.

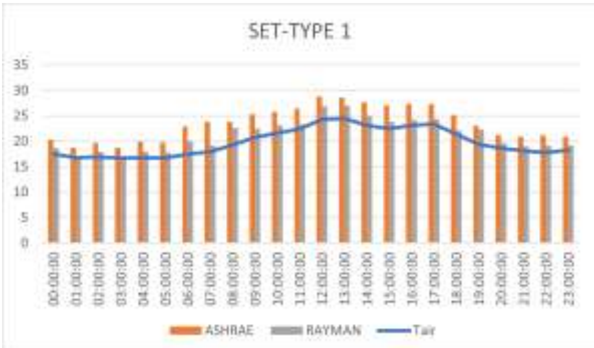

Figure 12. Graph of the SET Index – Wooden housing in ASHRAE and Rayman

Through the ASHRAE standard, it is observed that from 6:00 a.m. to 11:00 a.m. and from 3:00 p.m. to 7:00 p.m. at night an average standard effective temperature (SET) of 25.6°C is reached. In the Rayman software at 7:00, 8:00, 9:00 in the morning and at 7:00 p.m. the average standard effective temperature (SET) is 23.95°C, where the type 2 home reaches a comfortable state at those times. hours.

In addition, it is perceived that at 10:00 in the morning, 2:00 p.m. and 6:00 p.m. its state is slightly warm according to ASHRAE -55 but because it has a category III range that is acceptable according to EN-16798 with SET 26.6°C It is stated that they are comfortable hours. Figure 13 shows that the SET obtained is within the acceptable weighting, it is stated that 7 hours of the day are in a comfortable state in housing type 2.

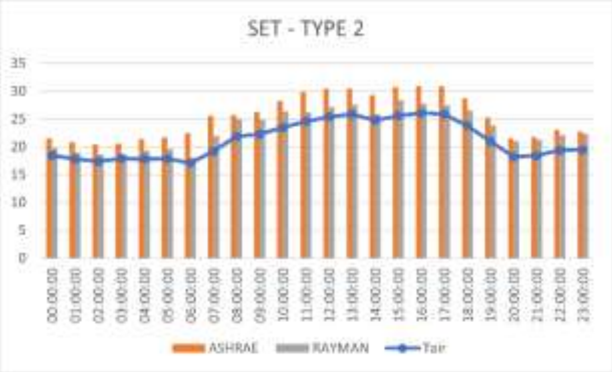

Figure 13.SET Index Chart – Confined Masonry Housing at ASHRAE and Rayman

Through the Rayman software, the standard effective temperature (PET) was found, where the male user perceives it from 06:00 to 11:00 in the morning and from 15:00 in the afternoon to 19:00 at night. The average PET for men is 19.25°C and for women it is 19.6°C, which means that at those hours the user perceives the space of the type 1 home as comfortable.

Furthermore, it is perceived that at 2:00 p.m. the PET-Male is 21°C and the PET-Woman is 20.8°C, which means that at those times the user also perceives the space as comfortable. Everything mentioned is seen in image 14.

Figure 14. Graph of the PET Index – Wooden Housing in the Rayman Male and Female.

Through the Rayman software, the standard effective temperature (PET) was found, where the male and female user perceive that from 7:00, 8:00, 9:00, in the morning and at 7:00 p.m. at night the average PET is 19. 5 °C which means that at those hours the user perceives the space of the type 2 home as comfortable.

Furthermore, it is perceived that at 10:00 in the morning, 2:00 p.m. and 6:00 p.m. the PET-Male is 21.46°C and PET-Woman is 21.3°C, which means that at those times the user also perceives the space. as comfortable as shown in figure 15.

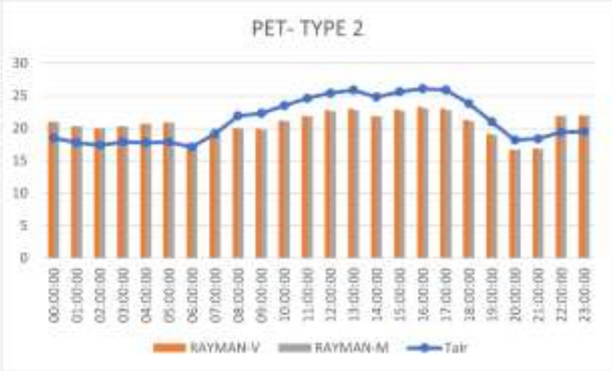

Figure 15. Graph of the PET Index – Confined masonry housing in the Rayman Male and Female.

4. Discussion

Research on multifamily VIS in Colombia and homes in Villa Rica in hot climates has revealed that the incorporation of industrialized materials, such as fired brick, concrete blocks and metal sheet, has generated serious thermal comfort problems within the buildings. living spaces in a warm climate, the main cause of the levels of thermal dissatisfaction in its occupants is not the lack of economic resources but the importance of bioclimatic design and the revaluation of vernacular architecture for a structure that guarantees adequate levels of thermal comfort, lighting and quality of life in homes with a hot-humid climate. It is clarified that Colombian social housing and Villa Rica housing require interventions that improve the level of thermal comfort and guarantee health, of which the best solutions to existing housing from an economic and sustainable point of view are cooling strategies. passive, such as natural cross ventilation, in addition to the importance of the construction material of buildings and sustainable design with vernacular architecture due to the impacts on the environment, quality of life, construction of buildings, production and use of the materials, which remain in harmony with the environment, such as the construction of malocas in hot climates with local materials, help to cool the environment in order to release water and allow air to pass through the floor planking, in addition to the strong inclination. of the ceilings and their wide heights between the floor and the roof, which are elements that favor the flow of winds, as well as protection against rain. This sustainable construction demonstrates harmony with the environment, in an ecological, functional and economic context.

5. Conclusion

In conclusion, with the data obtained in the ASHRAE 55 and EN-16798-1 standards together with the CBE Thermal Comfort Tool and Rayman simulation tools, comfort indices such as PMV (Predicted Mean Vote), PPD (Predicted Percentage Dissatisfied) are obtained.), SET (Standard Effective Temperature) and PET (Physiologically Equivalent Temperature) that between 24 hours of a day, 12 hours of the day and the afternoon reaches a comfortable state in the wooden house unlike the 7 hours that reaches the confined masonry house, considering that both houses do not have any bioclimatic design. Therefore, sustainable construction and bioclimatic design are essential to improve the quality of life in homes in hot-humid climates. Although the incorporation of industrialized materials has become too popular, it has generated thermal comfort problems, therefore, to overcome these challenges, it is necessary to apply sustainable design principles and revalue vernacular architecture, for example the over-elevation of the construction and the inclination of the roofs. They are elements that promote air renewal and protection against rain, continually cooling the interior and offering comfort for the user. These results have important implications for the design of housing in hot-humid climates and for sustainable construction in general.

In this comparative study between a wooden house and a masonry house confined in the city of Villa Rica, it was observed that the wooden house presented a higher degree of thermal comfort. This can be attributed to the insulating properties of wood, which help regulate indoor temperature and reduce the need for artificial air conditioning systems, which in turn improves the energy efficiency of the building. This leads to the revaluation of vernacular housing in the jungle since it attributes greater thermal comfort compared to confined masonry housing. In conclusion, the application of standards, indices and modeling tools in architectural design, along with the selection of appropriate materials, such as wood in the case of Villa Rica, are essential to create built environments that provide thermal comfort and energy efficiency, thus contributing to the sustainability and well-being of users. Highlighting the importance of vernacular housing, the next research is carried out where a design is proposed in hot humid climates based on the data obtained in this research.

6. References

[1] S. Schroeder, "exploration of the theoryvernacular and the informal production of public space: Piura case, Peru," AUS, no. 34, pp. 53–62, Jan. 2024, doi: 10.4206/aus. 2023.n34-07.

[2] M.Wieser, S. Onnis, and G. Meli, "Thermal performance of lightened earth enclosures Possibilities of application in the Peruvian territory," Revista De Arquitectura/Revista De Arquitectura, vol. 22, no. 1, Dec. 2019, doi: 10.14718/revarq.2020.2633.

[3] RM North, "La Maloca: Architecturesustainable Amazonian vernacular," Consensus, vol. 17, no. 1, pp. 129–142, Jan. 2012, [Online]. Available: http://revistas.unife.edu.pe/index.php/consensus/article/view/942

[4] AND.Arens, MA Humphreys, R. De Dear, and H. Zhang, "Are 'class A' temperature requirements realistic or desirable?," Building and Environment, vol. 45, no. 1, pp. 4–10, Jan. 2010, doi: 10.1016/j.buildenv.2009.03.014.

[5] APGagge and RR Gonzalez, "Physiological and physical factors associated with warm discomfort in sedentary man," Environmental Research, vol. 7, no. 2, pp. 230–242, Apr. 1974, doi: 10.1016/0013-9351(74)90154-6.

[6] T.-H.Lei, L. Lan, and F. Wang, "Indoor thermal comfort research using human participants: Guidelines and a checklist for experimental design," Journal of Thermal Biology, vol. 113, p. 103506, Apr. 2023, doi: 10.1016/j.jtherbio.2023.103506.

[7] A.MGreenfield, BK Alba, GEW Giersch, and AD Seeley, "Sex differences in thermal sensitivity and perception: Implications for behavioral and autonomic thermoregulation," Physiology & Behavior, vol. 263, p. 114126, May 2023, doi: 10.1016/j.physbeh.2023.114126.

[8] AND.Zhai, Y. Zhang, H. Zhang, W. Pasut, E. Arens, and Q. Meng, "Human comfort and perceived air quality in warm and humid environments with ceiling fans," Building and Environment, vol. 90, pp. 178–185, Aug. 2015, doi: 10.1016/j.buildenv.2015.04.003.

[9] N.Udayraj, Z. Li, Y. Ke, F. Wang, and B. Yang, "Personal cooling strategies to improve thermal comfort in warm indoor environments: Comparison of a conventional desk fan and air ventilation clothing," Energy and Buildings, vol. 174, pp. 439–451, Sep. 2018, doi: 10.1016/j.enbuild.2018.06.065.

[10] A.K.Melikov, R. Cermak, and M. Majer, "Personalized ventilation: evaluation of different air terminal devices," Energy and Buildings, vol. 34, no. 8, pp. 829–836, Sep. 2002, doi: 10.1016/s0378-7788(02)00102-0.

[11] H. Yang, Y. Deng, B. Cao, and Y. Zhu, "Study on the local and overall thermal perceptions under nonuniform thermal exposure using a cooling chair," Building and Environment, vol. 176, p. 106864, Jun. 2020, doi: 10.1016/j.buildenv.2020.106864.

[12] Y. Ke, F. Wang, P.Xu, and B. Yang, "On the use of a novel nanoporous polyethylene (nanoPE) passive cooling material for personal thermal comfort management under uniform indoor environments," Building and Environment, vol. 145, pp. 85–95, Nov. 2018, doi: 10.1016/j.buildenv.2018.09.021.

[13] F. Wang and W.Song, "An investigation of thermophysiological responses of humans while using four personal cooling strategies during heatwaves," Journal of Thermal Biology, vol. 70, pp. 37–44, Dec. 2017, doi: 10.1016/j.jtherbio.2017.05.007.

[14] F. Wang et al., "On the use of personal cooling suits to mitigate heat strain of mascot actors in a hot and humid environment," Energy and Buildings, vol. 205, p. 109561, Dec. 2019, doi: 10.1016/j.enbuild.2019.109561.

[13] Q.Mustakallio, Z. Bolashikov, K. Kostov, A. Melikov, and R. Kosonen, "Thermal environment in simulated offices with convective and radiant cooling systems under cooling (summer) mode of operation," Building and Environment, vol. 100, pp. 82–91, May 2016, doi: 10.1016/j.buildenv.2016.02.001.

[16] x.Wan, F. Wang, and N. Udayraj, "Numerical analysis of cooling effect of hybrid cooling clothing incorporated with phase change material (PCM) packs and air ventilation fans," International Journal of Heat and Mass Transfer/International Journal of Heat and Mass Transfer, vol. 126, pp. 636–648, Nov. 2018, doi: 10.1016/j.ijheatmasstransfer.2018.05.155.

[17] H. Zhang, E.Arens, and Y. Zhai, "A review of the corrective power of personal comfort systems in non-neutral environmental environments," Building and Environment, vol. 91, pp. 15–41, Sep. 2015, doi: 10.1016/j.buildenv.2015.03.013.

[18] c.Monné-Bailo, C. Cabello-Matud, CJ García-Ballano, and A. Ruiz-Varona, "Thermal evaluation of the building envelope: rehabilitated building versus non-rehabilitated.," Case Studies in Construction Materials, vol. 20, p. e02846, Jul. 2024, doi: 10.1016/j.cscm.2023.e02846.

[19] W. Giraldo-Castañeda, JDCzajkowski, and AF Gómez, "Thermal comfort in multifamily social housing in warm climates in Colombia," Revista De Arquitectura/Revista De Arquitectura, vol. 23, no. 1, Jan. 2021, doi: 10.14718/revarq.2021.2938.

[20] T.Sharmin, M. Gül, X. Li, V. Ganev, I. Nikolaidis, and M. Al-Hussein, "Monitoring building energy consumption, thermal performance, and indoor air quality in a cold climate region," Sustainable Cities and Society, vol. 13, pp. 57–68, Oct. 2014, doi: 10.1016/j.scs.2014.04.009.

[21] S. Carlucci, L. Bai, R. DeDear, and L. Yang, "Review of adaptive thermal comfort models in built environmental regulatory documents," Building and Environment, vol. 137, pp. 73–89, Jun. 2018, doi:

10.1016/j.buildenv.2018.03.053.
[22] RF Rupp, NG Vásquez, and R.Lamberts, “A review of human thermal comfort in the built environment,” Energy and Buildings, vol. 105, pp. 178–205, Oct. 2015, doi: 10.1016/j.enbuild.2015.07.047.
[23] R.-MJ C, F.-M. F, A.-GJ J, and B.-M. G, “Methodological Proposal to Develop Adaptive Thermal Comfort Studies Under Laboratory Controlled Conditions,” Civil Engineering and Architecture, vol. 8, no. 6, pp. 1202–1216, Dec. 2020, doi: 10.13189/cea.2020.080605.
[24] C. Alonso, I. Oteiza, F. Martín-Consuegra, and B. Frutos, “Methodological proposal for monitoring energy refurbishment. Indoor environmental quality in two case studies of social housing in Madrid, Spain,” Energy and Buildings, vol. 155, pp. 492–502, Nov. 2017, doi: 10.1016/j.enbuild.2017.09.042.
[25] v.Abyzov, I. Bulakh, I. Ustinova, O. Safronova, V. Safronov, and N. Semyroz, “Sustainable Design in Architecture (The Case Study of the Educational Process at Universities in Poland and Ukraine),” Civil Engineering and Architecture, vol. 11, no. 3, pp. 1255–1266, May 2023, doi: 10.13189/cea.2023.110311.
[26] MA Inga, HSBHuanuco, JLP Garcia, and CRP Garcia, “Achieving Thermal Comfort through the Design of a Tourist Hotel – (Huancayo),” Civil Engineering and Architecture, vol. 12, no. 2, pp. 668–684, Mar. 2024, doi: 10.13189/cea.2024.120202.
[27] TO.Sekatia, E. Setyowati, and G. Hardiman, “On the Comparison of Thermal Comfort Performances in Dutch Style Churches with Low Ventilation in Hot-Humid Tropical Region,” Civil Engineering and Architecture, vol. 8, no. 6, pp. 1419–1435, Dec. 2020, doi: 10.13189/cea.2020.080625.
[28] SV Luján, CV Arrebola, AR Sánchez, PA Benito, and MG Cortina, “Experimental comparativestudy of the thermal performance of the façade of a building refurbished using ETICS, and quantification of improvements,” Sustainable Cities and Society, vol. 51, p. 101713, Nov. 2019, doi: 10.1016/j.scs.2019.101713.
[29] v.Olgyay, DESIGN WITH CLIMATE Bioclimatic approach to architectural regionalism, 1 Edition. Barcelona: Editorial Gustavo Gili, 2004. [Online]. Available: https://editorialgg.com/media/catalog/product/9/7/9788425214882_inside.pdf
[30] DHK Lee and B.Givoni, “Man, Climate, and Architecture,” Geographical Review, vol. 61, no. 2 P. 318, Apr. 1971, doi: 10.2307/214009.
[31] E. W. Shaw, “Thermal Comfort: analysis and applications in environmental engineering, by PO Fanger. 244 pp. DANISH TECHNICAL PRESS. Copenhagen, Denmark, 1970. Danish Kr. 76, 50,” Royal Society of Health Journal, vol. 92, no. 3, p. 164, Jun. 1972, doi: 10.1177/146642407209200337.
[32] J.Malchaire, “Human thermal environments: The effects of hot, moderate and cold environments on human health—comfort and performance: The principles and the practice,” Safety Science, vol. 18, no. 1, pp. 67–68, Aug. 1994, doi: 10.1016/0925-7535(94)90046-9.
[33] S.Sakenova, U. Konbr, T. Kisselyova, Z. Aimagambetova, G. Mugzhanova, and D. Amandykova, “Conformation Factors of Building Bioclimatic Microclimate,” Civil Engineering and Architecture, vol. 12, no. 1, pp. 350–360, Jan. 2024, doi: 10.13189/cea.2024.120126.
[3. 4] K.Fatima, “Sustainable and Resilient Architecture: Prioritizing Climate Change Adaptation,” Civil Engineering and Architecture, vol. 12, no. 1, pp. 577–585, Jan. 2024, doi: 10.13189/cea.2024.120141.
[35] G. Obregón et al., “Climate scenarios for Peru to 2030,” 2009. https://hdl.handle.net/20.500.12542/3219
[36] R.A.Elraouf, A. Elmokadem, N. Megahed, OA Eleinen, and S. Eltarabily, “The impact of urban geometry on outdoor thermal comfort in a hot-humid climate,” Building and Environment, vol. 225, p. 109632, Nov. 2022, doi: 10.1016/j.buildenv.2022.109632.
[37] M.Lahdour et al., “ERSN-OpenMC-Py: A python-based open-source software for OpenMC Monte Carlo code,” Computer Physics Communications, p. 109121, Feb. 2024, doi: 10.1016/j.cpc.2024.109121.
[38] F.Tartarini, S. Schiavon, T. Cheung, and T. Hoyt, “CBE Thermal Comfort Tool: Online tool for thermal comfort calculations and visualizations,” SoftwareX, vol. 12, p. 100563, Jul. 2020, doi: 10.1016/j.softx.2020.100563.
[39] A. Matzarakis and F. Rutz, “RayMan: A TOOL FOR RESEARCH AND EDUCATION IN APPLIED CLIMATOLOGY,” ResearchGate, Jan. 2006, [Online]. Available: https://www.researchgate.net/publication/233759055_RayMan_A_TOOL_FOR_RESEARCH_AND_EDUCATION_IN_APPLIED_CLIMATOLOGY
[40] I. Silva, P.Mendonça, and C. Maia, “Thermal Comfort in the Modern Movement – Consequences of Constructive Definition on the Summer Behavior of a Housing Building in Porto, Portugal,” IOP Conference Series. Materials Science and Engineering, vol. 1054, no. 1 p. 012010, Feb. 2021, doi: 10.1088/1757-899x/1054/1/012010.
[41] R.Stull, “UBC ATSC 113 - Cloud Coverage,” The University of British Columbia (UBC, Aug. 2018. https://www.eoas.ubc.ca/courses/atsc113/flying/met_concepts/01-met_concepts/01c-cloud_coverage /index.html (accessed Jun. 19, 2024).
[42] TO.Matzarakis, H. Mayer, and MG Iziomon, “Applications of a universal thermal index: physiological equivalent temperature,” International Journal of Biometeorology, vol. 43, no. 2, pp. 76–84, Oct. 1999, doi: 10.1007/s004840050119.
[43]. Yasunobu Nishi APG. Effective Temperature Scale Useful for Hypo- and Hyperbaric Environments. Aviation Space and Environmental Medicine. 1977;48(2): 97-107. [Links]
[44]. Mohammad Reza Mansouri Daneshvar AB, Taghi Tavousi. Assessment of bioclimatic comfort conditions based on Physiologically Equivalent Temperature (PET) using the Raman Model in Iran. Central European Journal of Geosciences. 2013;5(1): 53-60. [Links]