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Analysis of the thermal sensation in single-family home from microclimatic monitoring: Case study Bucaramanga Colombia

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ABSTRACT

The present work describes the experimentation of monitoring for the finding of the heat index and the individual thermal sensation, where the behavior of the real temperature in the exterior and interior of a conventional single-family house with a warm and temperate climate in Colombia was analyzed. The detailed monitoring campaign is carried out for 2880 hours, where the conditions of the interior area of the house and the local climatic conditions of the area are recorded, through the implementation of a thermohydrometers registration system. The methodology for the calculation of the sensation of heat and thermal comfort was determined under the adjusted equation of cooling power of Leonardo Hill and Morikofer-Davos, applied in the analyses of the Institute of Hydrology, Meteorology and Environmental Studies - IDEAM. The results showed a thermal sensation of dissatisfaction of 97.7%, because with the monitored temperature the thermal sensation is calculated yielding in 1382.4 hours with very hot, 1151.6 hours of hot and 280.8 hours of warm thermal sensation.

Keywords: Heat Index, Thermal Sensation, Monitoring, Microclimate, Thermal Discomfort

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1. Introduccion

Urban microclimate features include variations in outside air temperature, surface temperature, humidity, wind speed, and wind direction. [1], Likewise, thermal comfort is a fundamental part when designing and planning the construction of a conventional home.[1]–[4]. The urban microclimate intervenes in an important way in the energy consumption of the buildings and in the sensation of thermal comfort of the interior and exterior spaces[5], [6]. It is for this reason that greater attention has now been paid to bioclimatic urbanism around the world, because there is a need to increase energy efficiency in homes [7], [8].

The study of the microclimatic conditions of a city has been the subject of analysis by different researchers around the world, being research axes the different parameters and variables that condition the climate at local levels [7], [8]. In Colombia, most housing projects do not consider aspects of thermal comfort during their design. According to the Colombian Council of Sustainable Construction, in the country most of the "green" projects are for commercial or office use, but it is lagging in residential buildings, due to a greater extentto the costs generated by the inclusion of sustainable aspects in these homes [9].

It is for this reason that although there are advances in relation to the study of thermal comfort, in this article we want to analyze the heat index and thermal sensation for a single-family home in a Latin American city witha hot dry climate, which according to the state of the art there are no studies focused on the thermal sensation in this type of climate and area. For the monitoring, the interior and exterior of the house will be taken into account, the monitoring will be based on the study of the hygrothermal variables (Temperature and relative humidity), in a conventional house located in the metropolitan area of the city of Bucaramanga, Colombia.

At last measurement and data acquisition system was implemented by means of thermohygrometer sensors, which is composed of eight sensors located inside and outside the selected house and a Datalogger that stores the data of the variables in intervals of 5 minutes for 30 days. With the information acquired, the analysis of the results of temperature and relative humidity was carried out, through the treatment of this information to establish the behavior of the temperature and subsequent is found with the methodology that applies experimental, quantitative and qualitative method; developed by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), the heat index and the hours of each of the thermal sensations according to the hygrothermal variables.

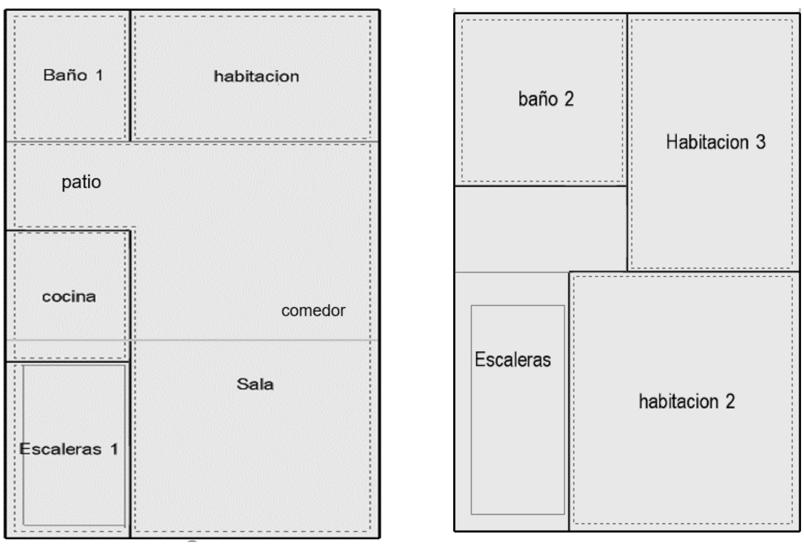
2. Material and method

2.1. Morphology of the case study

The case study has been developed on a conventional architecture that presents defined characteristics such as the typology of housing classified as single-family located in the metropolitan area of Bucaramanga capital of the department of Santander, Colombia. It is located in the northeast of the country on the eastern mountain range. The morphology of the place is dendritic [9]. Bucaramanga has a monsoon climate, that is, it can make the difference between the period of dry and cool winds with that of hot and humid winds with heavy rainfall (according to Köppen Am climate classification [10]) and is classified by the IDEAM as follows: Lower altitude areas of the city with a hot dry climate [11]. The climate classification in the case study is a hot dry climate where the temperature varies between 20°C and 36°C [12]

2.1.1. Geometric description

The house has a total area of 126 ^{m2} which are distributed on two levels. On the ground floor it has 1 bedroom with private bathroom, kitchen, living room and a patio area in the intermediate space between the room and the kitchen, it also has direct access from the living room to the upper floor through the stairs leading to present 2 bedrooms and 1 bathroom. (see Figure 1).



a) Spatial distributionfirst level.

b) Spatial distribution of the second level.

Figure 1. Spatial distribution plane

2.1.2. Constructive description

The construction system of the architecture is composed as follows:

2.1.2.1. Exterior walls

The envelope of the house is composed of exterior sandwich walls made up of 3 layers of different materials (See Figure 2). Table 1 presents the materials used in each layer with their respective thickness and characterization.

Table 1. Construction materials and their characteristics of the exterior walls

Exterior Walls	Layer 1	Layer 2	Layer 3
Material	Plastic cement	Burnt brick	Plastic cement
Thickness (m)	0,025	0,1	0,025
Conductivity (W/m-K)	1,4	0,85	1,4
Specific heat (J/Kg-k)	650	840	650
Density (Kg/m3)	2100	1500	2100
Steam factor	150	150	150
Vapor resistivity (mns/g.m)	10	50	10
Thermal absortance (emissivity)	0,9	0,9	0,9
Solar absorptive	0,6	0,6	0,6
Visible absortance	0,6	0,6	0,6
Roughness	slightly rough -3	slightly rough -3	slightly rough -3

Figure 2. Composition of the layers of the outer wall

Once the materials and their characteristics that compose it have been defined, the exterior wall is characterized thermally and physically in general as presented in Table 2 Thermal characterization of the outer wall2.

Table 2. Thermal characterization of the outer wall2

Concept	Units of measurement	Value
Thickness	m	0,15
Heat transfer coefficient by convention	W/m2-k	2,152
Coefficient of heat transfer by radiation	W/ m2-k	5,54
Surface resistance	m2-k/W	0,13
Surface-to-surface U-value	w/ m2-k	2,324
Thermal absortance (emissivity)	-	0,9
R-value	m2-K/w	0,430
U-value	w/ m2-k	2,324

2.1.2.2. Partition walls

The internal partition or non-structural walls are those responsible for distributing the spaces in the house, so they do not fulfill support or resistance functions. The partition walls are composed of bricks of depth of 0.12 m with an interior and exterior coating of plastic cement of 0.02m (see Figure 3). Table 3 the materials that make up the layers and their characteristics.

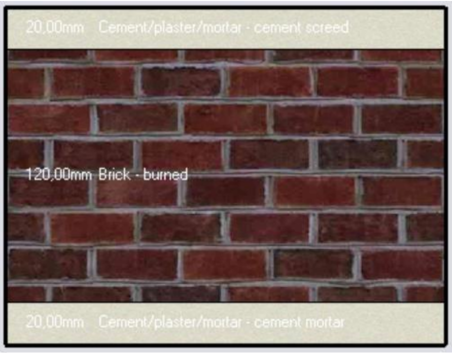


Figure 3. Composition of the layers of non-structural walls.

Table 3. Construction materials and their characteristics of the exterior walls.

Exterior Walls	**Layer 1**	**Layer 2**	**Layer 3**
Material	Plastic cement	Burnt brick	Plastic cement
Thickness (m)	0,02	0,12	0,02
Conductivity (W/m-K)	1,4	0,85	1,4
Specific heat (J/Kg-k)	650	840	650
Density (Kg/m3)	2100	1500	2100
Steam factor	150	150	150
Vapor resistivity (mns/g.m)	10	50	10
Thermal absortance (emissivity)	0,9	0,9	0,9
Solar absorptive	0,6	0,6	0,6
Visible absortance	0,6	0,6	0,6
Roughness	slightly rough -3	slightly rough -3	slightly rough -3

The characterization of the materials present in the composition of the partition walls of the housing, are presented in Table 4 Thermal-physical characterization of non-structural or partition walls 4.

Table 4. Thermal-physical characterization of non-structural or partition walls4.

Concept	**Units of measurement**	**Value**
Thickness	m	0,16
Heat transfer coefficient by convention	W/$^{m2-k}$	2,152
Coefficient of heat transfer by radiation	W/ $^{m2-k}$	5,54
Surface resistance	m2-k/W	0,13
Surface-to-surface U-value	w/ $^{m2-k}$	2,256
Thermal absortance (emissivity)	-	0,9
R-value	m2-K/w	0,443
U-value	w/ $^{m2-k}$	2,256

2.1.2.3. Soil

The floor is composed of 3 layers being the surface where the house was built case study and composed of the following materials exposed in Table 5 with their respective characteristicsTable *5*.

Table 5. Construction materials and their soil characteristics

Soil	**Layer 1**	**Layer 2**	**Layer 3**
Material	Cast concrete	Plastic Cement	Ceramic Earthenware
Thickness (m)	0,07	0,02	0,02
Conductivity (W/m-K)	1,4	0,72	1,3
Specific heat (J/Kg-k)	840	840	840
Density (Kg/m3)	2100	1860	2300
Steam factor	150	20	150
Vapor resistivity (mns/g.m)	120	10	2300
Thermal absortance (emissivity)	0,9	9	0,9
Solar absorptive	0,6	0,6	0,4
Visible absortance	0,6	0,6	0,4

The soil has been analyzed from the materials used for the foundation of this and is presented in the Figure 4

Figure 4. Composition of soil layers

Once the materials of the layers that make up the soil have been characterized, Table 6. Thermal-physical characterization of the soil where the soil is thermally and physically characterized.

Table 6. Thermal-physical characterization of the soil

Concept	**Units of measurement**	**Value**
Thickness	m	0,11
Heat transfer coefficient by convention	W/^{m2} -k	2,152
Coefficient of heat transfer by radiation	W/$^{m2-k}$	5,54
Surface resistance	m2-k/W	0,13
Surface-to-surface U-value	w/$^{m2-k}$	5,909
R-value	m2-K/w	0,429
U-value	w/$^{m2-k}$	2,33
Thermal absortance (emissivity)	-	0,9

2.1.2.4. Roof

The roof or roof is composed of 4 layers described in Table 7, where the outer part is covered by clay tiles that are attached to concrete and a PVC waterproofing that internally is supported by wooden panels seen in the.

Table 7. Constructive materials of the roof and their characteristics

Roof	Layer 1	Layer 2	Layer 3	Layer 4
Material	Wood panels	PVC waterproofing	Lightweight concrete	Clay tiles
Thickness (m)	0,0191	0,01	0,02	0,03
Conductivity (W/m-K)	0,1	0,17	0,38	1
Specific heat (J/Kg-k)	1880	900	1000	800
Density (Kg/m3)	450	1390	1200	2000
Steam factor	150	50000	150	150
Vapor resistivity (mns/g.m)	10	10	80	100
Thermal absortance (emissivity)	0,9	0,9	0,9	0,9
Solar absorptive	0,7	0,7	0,6	0,7
Visible absortance	0,7	0,7	0,6	0,7

Figure 5. Current state of the roof of the house case study and its design of the composition

Table 8. Thermal-physical characterization of the roof

Concept	Units of measurement	Value
Thickness	m	0,0791
Heat transfer coefficient by convention	W/^{m2} -k	4,46
Coefficient of heat transfer by radiation	W/$^{m2-k}$	5,54
Surface resistance	m2-k/W	0,1
Surface-to-surface U-value	w/$^{m2-k}$	3,008
R-value	m2-K/w	0,602
U-value	w/$^{m2-k}$	1,66
Thermal absortance (emissivity)	-	0,9

2.1.2.5. Glazing

The crystallization of the house consists of windows of simple glazing. They are composed of a generic type glass of 3 mm, in Table 9 the characteristics of this material are presented. The carpentry that surrounds the window is made of aluminum from the COR60 series of CORTIZO. Table *9*

Table 9. Characterization of the material of exterior windows

Fenestration 3 mm transparent glass	
Total Solar Transmission (SHGC)	0,861
Light transmission	0,898
U-value (W/ m² K)	5,894

2.2. Monitoring system

The hygrothermal monitoring system is distributed with eight sensors that cover the spaces of the house, considering the east and west locations both on the lower floor and the upper floor in the exterior and interior area. In the Figure 6 the scheme of the measurement, monitoring and data acquisition system implemented is presented, starting with eight wireless remote sensors, in charge of measuring the hygrothermal variables, the datalogger is the monitor in charge of projecting and storing the measured variables, finally a software to process and analyze the stored information.

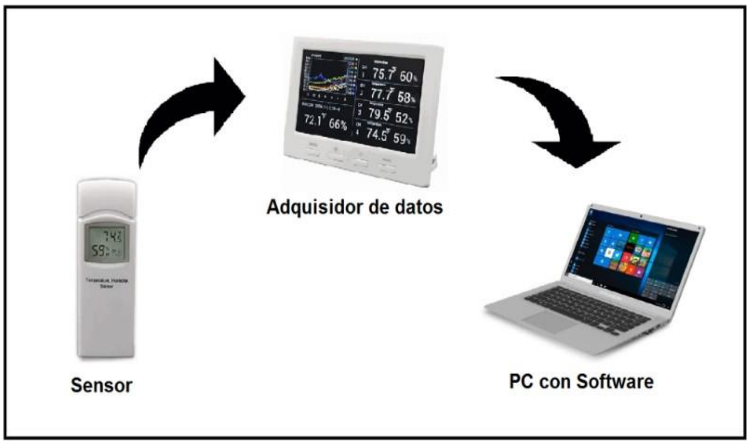


Figure 6. Diagram of the Hygrothermal monitoring system

2.2.1. Sensor localization

Coding is performed to represent each of the sensors (channels) in the locations that were installed, considering the characteristics of Table 10

Table 10. Orientation codes for thermohygrometer channels

Location	Code
East	E
West	O
Interior	I
Outside	EX
Floor 1	1
Floor 2	2

The following order is considered for channel encoding:

Cardinal point + Internal or external location + Floor (1 – 2) + Channel

Presents the location of each sensor and the corresponding period of the hygrothermal monitoring process:

Table 11. Details of the distribution of the sensors in the different locations and their constructive characteristics

Sensor distribution	**Location**
Channel 1 (EE21)	East zone, External wall – Floor 2
Channel 2 (EI22)	East zone, Internal wall – Floor 2
Channel 3 (OI23)	West zone, Internal wall – Floor 2
Channel 4 (OE24)	West zone, External wall – Floor 2
Channel 5 (EE15)	East zone, External wall – Floor 1
Channel 6 (EI16)	East zone, Internal wall – Floor 1
Channel 7 (II17)	Central area, (Intermediate of the house)
Channel 8 (OI18)	West zone, Internal wall – Floor 1

Three sensors are installed on the outside of the house and are located in the east and west orientations, because these are the envelopes that are exposed to the environment, recording data with intervals of 5 minutes, synchronized with the interior sensors. For the indoor environment, the same procedure is carried out as in the outdoor environment, and for these five sensors are used, whose recording and data storage is carried out with the same time interval, and simultaneously with those of the outdoor environment. The sensors were distributed in the walls of the two floors that the house has, where on the first floor three sensors were located, one located in the east another in the west and the remaining intermediate area of the house. On the second floor they were located in the same way in the east and west zone, as presented in the Figure 7.

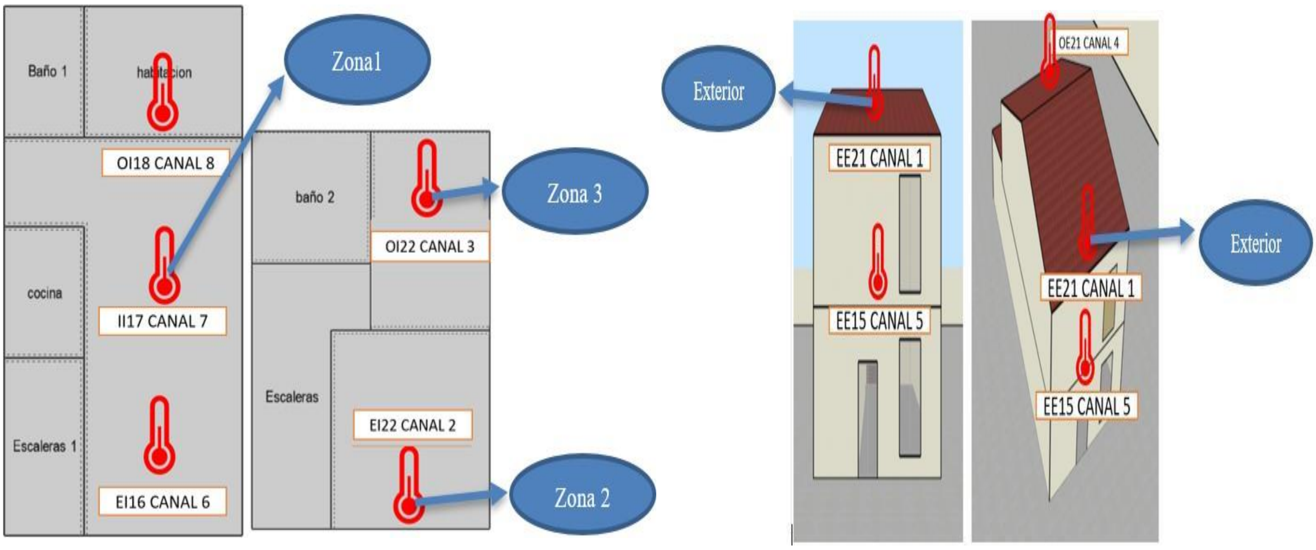


Figure 7. Location of sensors inside and outside (Classification of zones)

3. Results

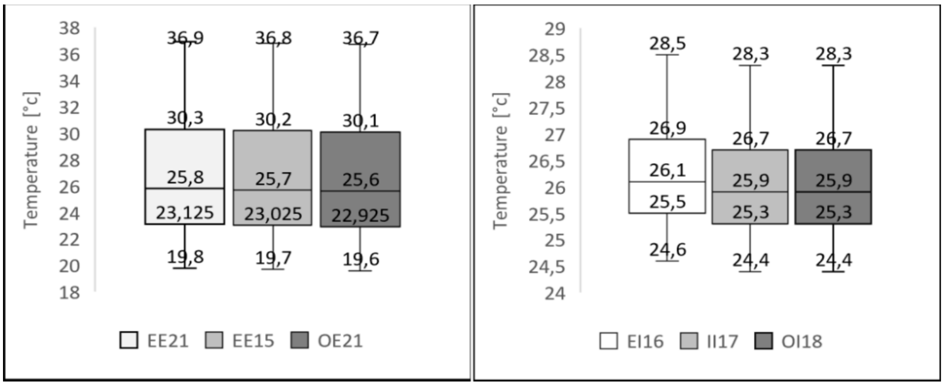
3.1. Temperature and humidity monitoring

The data collected in the monitoring phase were reported in order to characterize the behavior of the main representative parameters of the internal microclimate and analysis of the heat index, with respect to the variation of the external microclimatic parameters. One of the points that affect the heat index and the thermal sensation (ST) calculated by the temperature of the environment is the internal gain due to the people who inhabit the house, affecting the microclimate of the interior of the building [13]. In this sense, in order to analyze the effect on the microclimate, during the preliminary follow-up a study has been carried out without local variation of the internal thermal loads with a density of 5 people in the house, because the monitoring was carried out in times of pandemic.

Analyzing the behavior of the temperatures, a similar conduct is presented among the sensors present outside, in the same way a similar behavior in the temperature registered in the sensors of plant one, by which a comparison was made to determine if it is necessary for the next phase to analyze each of the sensors or the same temperature can be assumed between the similar sensors.

Thus, the external sensors will be purchased between them, leaving in the measurement of the microclimatic data a percentage difference that oscillates between 0% and 0.5% with the data obtained between sensors. In the same way, the comparison of the values of the temperatures recorded by each of the sensors outside is made, where the temperature difference between them is 0.1°c, maximum values of 36.8°c and minimum values in temperatures of 19.7°c and an average value in the monitoring time of 26.68 are also recorded.

In the same way, the behavior is compared with the values recorded by the sensors of the first floor (Channel 6-EI16, Channel 7 II17, Channel 8 - OI18), which were compared to determine their difference, where a similar behavior between them is evident, presenting a percentage difference between them of 0.35% with minimum value and 0.85% maximum. It also makes the comparison of the values of the temperatures recorded by each of the sensors of the first floor, where they are presented between 0.1 °C and 0.2 ° C, maximum values of 28.5 ° c and minimum values in temperatures of 19.7 ° c and an average value in the monitoring time of 24.4 °.



a) Outside b) Floor 1

Figure 8. Zone temperature comparison

Based on the Figure 8 as its difference between the exterior sensors is with a tendency to zero and its temperature difference is 0.1 °C between them, it is established that they are practically the same measured value, so a single area measured with the EE21 sensor located in the upper area of the house is determined. Similarly, the data recorded in the three sensors of floor 1 has a minimum difference, which is determined by asingle area analyzed with the II17 sensor located in the central area of floor 1 of the house.

In the record of the temperatures of plant 2 there is a notable difference between the sensors installed where it is determined that the maximum, minimum and average value of the temperature in zone 2 are 32.8, 26.4 and 29.3 respectively, in the same way in zone 3 there are maximum temperatures of 32.4 °c, minimum of 28.8°C, having an average temperature in the monitoring of 29.7°C.

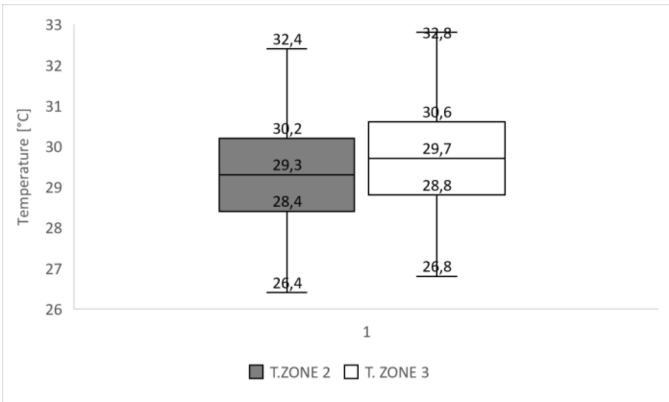


Figure 9. Average temperatures Zone 2 and Zone 3

Based on Figure 9 the outdoor analysis areas are determined, floor1 being zone 1, floor 2 east as zone 2 and floor 2 west as zone 3. The temperature behavior of the selected areas is presented in the Figure 10.

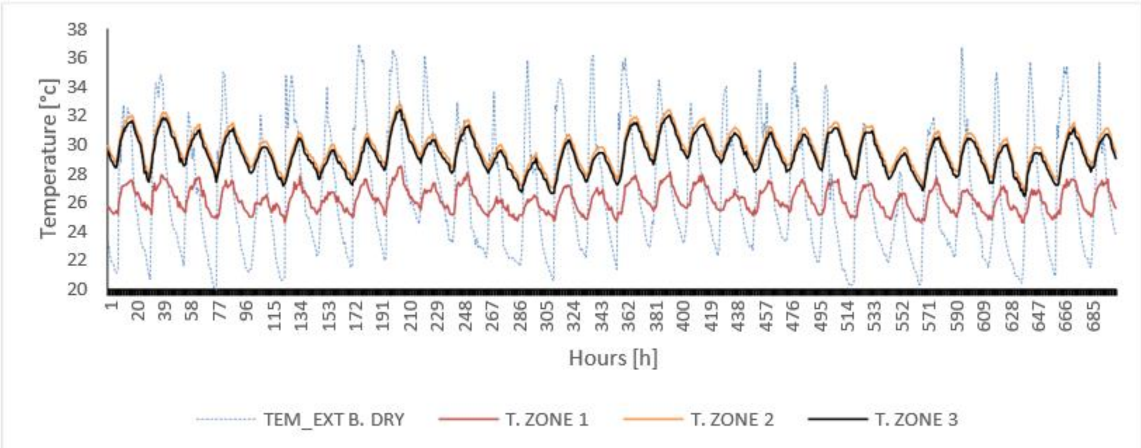


Figure 10. Recorded temperature

4. Discussion

4.1. Heat Index and thermal sensation

The methodologies of the analysis of the thermal sensation studied, in large part are formulated and adapted to the various seasons that occur throughout the year (spring, summer, autumn and winter)[14]–[17]. According to this, the methodology most appropriate to the case study area (Bucaramanga, Colombia), was based on the following criteria: The chosen method is not strictly applied for areas with a diversity of climatic seasons, due to the proximity to the Equator line in which the monitoring was carried out.[18]. Of equal importance, the method must include the main monitored study variables such as temperature and relative humidity, which influence the thermal sensation of a given area. Finally, we wanted the results to describe in a qualitative way the thermal sensation through those established by a quantitative method that provides support to the implemented methodology.

The Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM), as a national institution for the understanding of Colombia's climate, not only uses different climatic classifications when considering physical variables (such as temperature, relative humidity, solar radiation, etc.), but also includes biological variables such as vegetation types and natural ecosystems. Due to the geographical characteristics of the country, it can be considered as an "indicator", which makes it possible to branch out climatic zones. Thus, the IDEAM presents a methodology that brings together all the characteristics mentioned above for the study of human comfort, which has as its starting point the analysis in relation to climatic comfort. As an added value,it is based on the altitude of a given area to define the thermal sensation perceived by its inhabitants. To calculatethe sensation of heat and thermal comfort, Leonardo Hill and Morikofer-Davos adjusted Cooling Power Equation [19]–[21] was determined, which presents differences in its structure, based on a bioclimaticclassification defined by a heat index (CI) and not by a cooling power index (H). Additionally, the relative humidity variable was incorporated and, the base values of the original formula were adapted to achieve concreteresults according to the variation of temperature with height, this methodology has three formulas depending on the height at sea level that the base area has, in addition, the influence of the wind is taken into account. Thecase study has an altitude of 925 m, therefore, the model is used, thus respecting the parameter established in the expression to determine the thermal sensation experienced inside and outside the house.

Model 1. (height <1000 mamsl)

$$IC = (36{,}5 - T)\,(0{,}05 + 0{,}04\sqrt{\bar{v}} + \frac{HR}{250}) \qquad (1)$$

Model 2. (1000 mamsl < height< 2000 mamsl)

$$IC = (34{,}5 - T)\,(0{,}05 + 0{,}06\sqrt{\bar{v}} + \frac{HR}{180}) \qquad (2)$$

Model 3. (height > 2000 mamsl)

$$IC = (33{,}5 - T)\,(0{,}05 + 0{,}18\sqrt{\bar{v}} + \frac{HR}{160}) \qquad (3)$$

Where:

$\boldsymbol{IC}$: Heat index

$\boldsymbol{T}$**:** Air temperature (°C)

$\boldsymbol{HR}$**:** Relative Humidity (%)

$\boldsymbol{v}$**:** Wind speed (m/s)

Once the heat index is obtained, the thermal sensation experienced by the population located in the study area is determined according to Table 12.

Table 12. Classification of the thermal sensation according to the heat index

Experienced sensation	IC
Uncomfortably Hot	0 - 3,0
Hot	3,1 - 5,0
Warm	5,1 - 7,0
Pleasant	7,1 - 11,0
Something cold	11,1 - 13,0
Cold	13,1 - 15,0
Very cold	> 15.0

The thermal sensation was calculated in each of the areas monitored in the house (exterior, zone 1, zone 2 and zone 3), for which the thermal sensation index was calculated in the 720 hours of monitoring for each of the areas, with a total of 2880 hours analyzed. The wind chill is evaluated following the heat index equation of Model 1 ((1) to identify the quantitative valuethat allows selecting a qualitative result of thermal sensation from the table in Table 12. Classification of the thermal sensation according to the heat index. As a result, the value of the CI is graphed in relation to the thermalsensation in each hour of monitoring in the selected areas. (See Figure 11, Figura. 12, Figure 13, Figure 14)

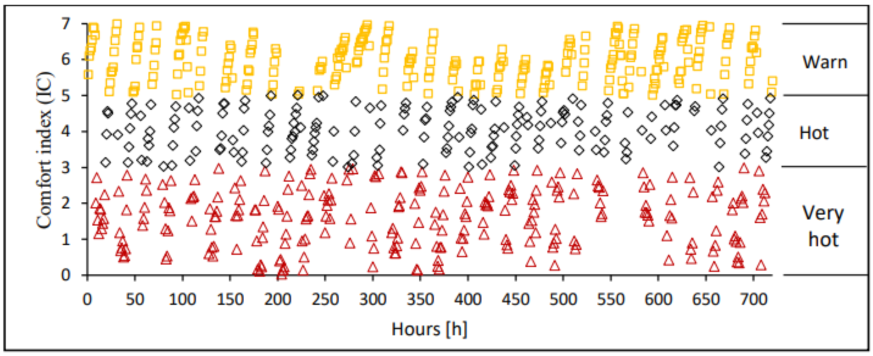


Figure 11. Heat index of hours calculated outside

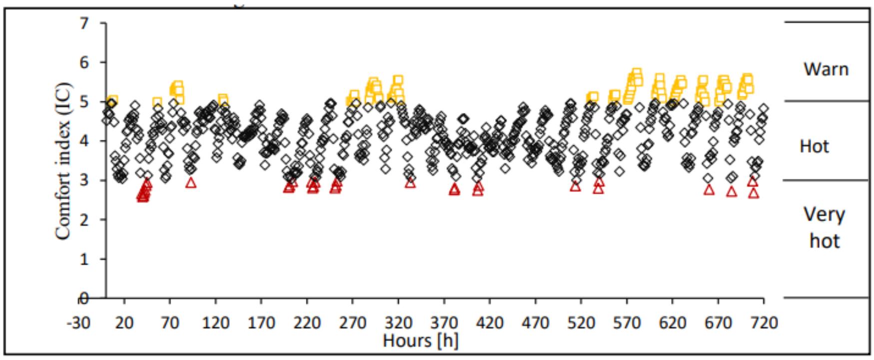


Figura 12. Heat index of the hours calculated in zone 1 inside the house

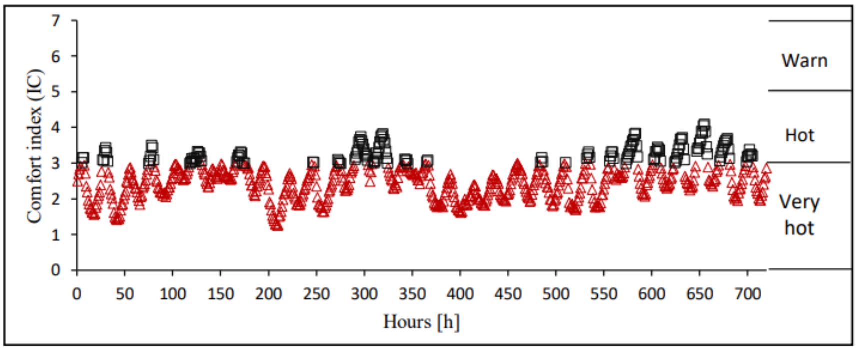


Figure 13 Heat index of the hours calculated in zone 2 inside the house

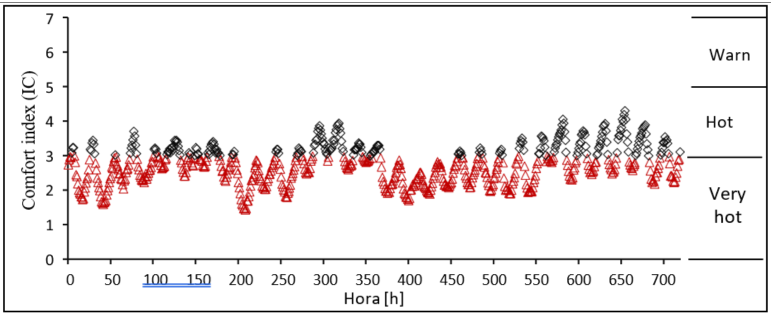


Figure 14. Heat index of the hours calculated in zone 3 inside the house

The percentage of hours is quantified from the hours of thermal sensation selected qualitatively from the thermal sensation index, which for the case of the present study was only warm, hot and very hot. In the Figure 15 to Figure 17 the percentage of hours in which a certain heat index is presented, in the same way the number of hours of this thermal sensation during the total time of the monitoring is presented.

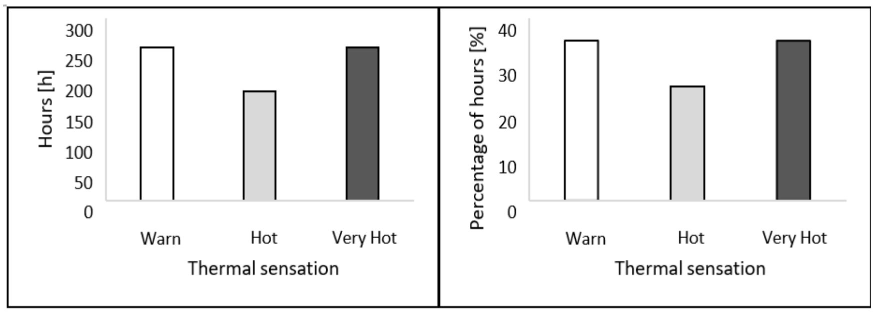


Figure 15. Hours and percentages of thermal sensation outside

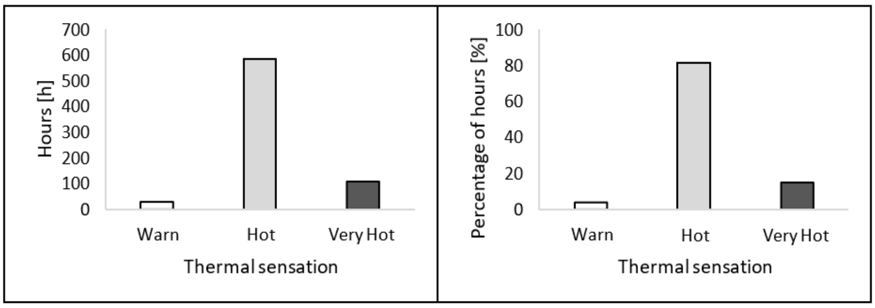


Figure 16. Hours and percentages of thermal sensation Zone 1

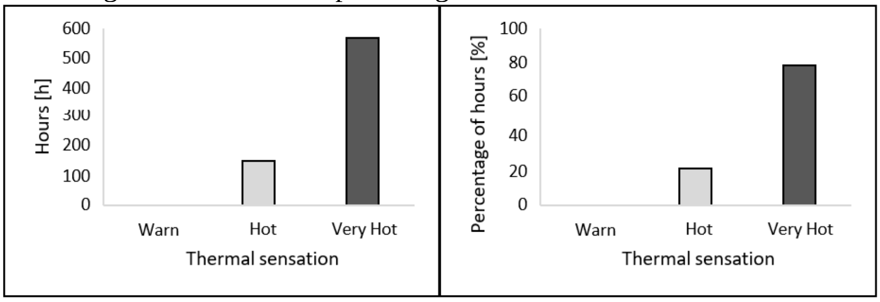


Figure 17. Hours and percentages of thermal sensation Zone 2

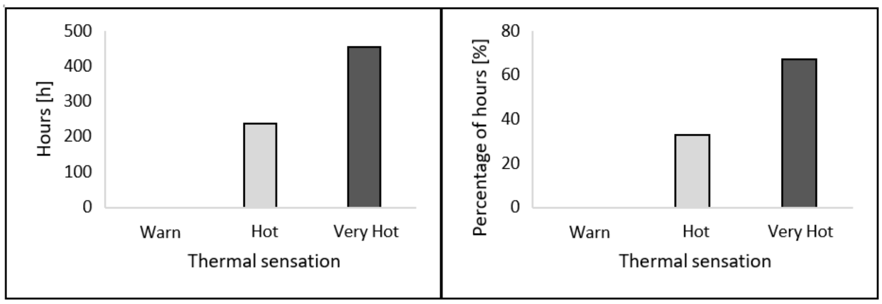


Figure 17 Hours and percentages of thermal sensation Zone 3

5. Discussion

The monitoring of the single-family house by means of registration systems with thermohygrometers, allowed to analyze the direct relationship between the relative humidity and dry bulb temperature. The record presented temperatures outside the house with a maximum value of 36.8°C and a minimum of 19.7°C with an average of 26.7°C and relative humidity ranging between 89% and 35%. From these registered values of the exterior climate of the house, the interior was also recorded, where floor 1 has a maximum temperature of 28.3 ° C and a minimum of 24.4 ° C this maintains an internal temperature that has an average of 26 ° C, having maximum temperature variations of 4 ° C, while on floor 2, a maximum value of 32.8°C and a minimum of 26.8°C are recorded, with variations between them of 6°C. All temperatures register a direct diversification with the variation of the outside temperature, I feel the temperature of the environment the main factor for the variation of the temperature inside the house.

On the other hand, the thermal sensation analysis is an analysis that starts from the acquisition of data in the site where you want to analyze, so from the recorded temperature and relative humidity data the calculation of the heat index is made.). The method contemplates the variety of the climates of Colombia, being this adjusted specifically for this territory [20]. The heat index according to its thermal sensation classification presented in the Figure 11 evidences a percentage of 35% in warm and very hot sensation this represented 252 hours, while hot occurs in 25% with a representation of 180 hours presented in the Figure 15. Similarly in zone 1 located on floor 1 presents the points of the heat index in the Figura. 12 where there is a greater dispersion of the sensation of hot heat with 583 hours, followed by 108 hours of warm sensation and 28.8 hours very hot, this represented in the Figure *16* with 81%, 15% and 4% respectively of the total monitoring. On floor 2, the heat index was calculated in zone 2 and zone 3 where they present similar values of the CIs andpercentages of thermal sensation over time. The hourly CI exhibited 568.8 hours with a very hot TS being 79% while the hot ST occurred in 151.2 hours representing 21% of the data analyzed in Figure 13. In the same wayin the Figure 14 and Figure 17 there was evidence of a very hot 67% of ST being 453.6 hours and 33% of SThot being 237.4 hours of the monitored time. The interior thermal comfort is directly reflected by the temperatureand humidity of the environment where it is monitored, but in turn these are a consequence of the outside temperature

6. Conclusions

The work presented aims, first, to perform non-destructive monitoring on site, to establish the real data of temperature and relative humidity in a conventional single-family home in the metropolitan area of the city of Bucaramanga, based on the analysis of the data collected during said monitoring, some specific considerations related to behavior were derived.

The internal data of the monitored house present temperatures consistent with the outside temperature, which represents for floor 1 a maximum internal variation of 2 ° from hour to hour, but reduced with respect to the outside temperature presented a difference at times of maximum temperatures of 8 ° C, while on floor 2 varies the outside temperature in a similar way maintaining differences of 4 ° C in maximum temperature points. This reflects that the area where the highest temperature is recorded at all times is in the interior area of floor 2, this as a result of the fact that most of the surface of the roof is reflected by the sun in most of the day, and likewise it is maintained at the temperature on the walls and ceiling behaving like a heat storage system.

With the application of the heat index method applied by the IDEAM allows to obtain a quantitative result by means of the mathematical equation to find the heat index and relate it to a qualitative value, this allowed to detect the dispersion of heat sensation, where in the external environment a high dispersion was found between the warm sensations, hot and very hot, but on the second floor the heat index decreases in the greatest of the hours of monitoring presented hot and very hot indices, this thermal sensation is related to the high temperatures and low relative humidity that occur both outside and inside the house generating percentages of thermal discomfort greater than 90% of the time monitored inside the house. Finally, it is important to explore generic, passive and active solutions that allow

7. References

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