Assessing the thermal performance of a conventional architecture in a dry warm climate

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Abstract

In this article, we present the results of the evaluation of the thermal performance of a conventional home in a dry warm climate, a case study in Bucaramanga, Colombia. This simulation, evaluation, and analysis make it necessary since currently in the case study area there is no thermal assessment of the dwellings, which are old houses built with resistive and mechanical analyses, but without regard to thermal behavior or thermal housing comfort. This evaluation is done by means of software simulation. Thus, a valid simulation identifies the weather data present in a dry warm climate zone and determines the geographical location and behavior in the solar diagram. Likewise, the thermal characterization of the soil and the construction materials of support and envelopes of the architecture is performed, to establish its thermal transmittance, thermal resistance, and thermal capacity. As a result of the research, the thermal behavior of the house is presented by means of the calculations made that determine the thermal behavior of the envelopes, energy load balancing, and housing thermal comfort based on the ASHRAE 55 standard by Fanger's method. Consequently, with the above, the results of the simulation and a detailed analysis of the recorded data are presented in the document.

Keywords: Evaluation thermic; Comfort; balance thermic; simulation and transmittance.

1. Preparation

Residential and commercial constructions in developed nations account for around 40% of total energy consumption, outperforming other major sectors such as industry and transportation [1], [2]. In 2019, primary energy use in Colombia's homes accounted for 20% of the country's total demand [3]. Obviously, the construction sector has a direct impact on society, the environment and the economy [4], [5].

Building design is not only an aesthetic form and concept [6],[7],[8], but also a holistic process that contains an accurate selection of structure materials that can diminish building energy consumption and the implementation of passive design strategies[9], [10], [11]. During their typical natural life of 50 ages or more[12], Contemporary buildings will be subject to a meteorological state that will be progressively hotter and more unstable [13], [14], [15].

From this point of view, it is imperative to understand the energy performance of buildings done precise energy and thermal analysis [16], [17]. The use of unconventional energies, the energy landscape, the likelihood of reviewing Regulations and Building Codes[18], the increase in the purchase of air conditioning

equipment, the trend of increase in housing construction, among other causes, motivated different authors to assess residential buildings to examine thermal-energy behavior, comfort situation, energy use [19]–[24].

Therefore, to assess the thermal presentation and energy efficacy of buildings and buildings, numerous simulation programs are used globally that carry out these activities [25]–[28].

The objective of this study is to estimate the thermal behavior of a conventional house case study in dry warm climate, using DesignBuilder software, initiating by the climatic identification of the area [29], followed by the thermal-fisque characterization of soil materials and construction envelopes, in order to analyze according to the ASHRAE 55 standard [30] the parameters of comfort or discomfort present is housing.

2.   Methodology

A thermal analysis of a case study house was carried out, by means of simulations in the current state of construction. This analysis aimed to determine the current thermal behavior of the case study house, which is a conventional house in dry warm climate, which is located in Bucaramanga, Santander, Colombia. The total area of the house is 126m2 and comprises two floors, each is divided into housing spaces of different sizes such as bedrooms, bathrooms kitchen and others.

For the study of the architecture to be evaluated, the method of validation in specialized software that allows the calculation of thermal loads is used [31], because, without a computational tool, the evaluative calculation by the large number of variables to be considered and iterations for its lowest error percentage is not feasible [32].

There are currently a wide diversity of computational tools for the study of thermal loads such as vpClima[33], CYPEcaD MEP[34], OpenStudio[35], Ecotect Software de Sustainable Construction Design[36], Energyplus[37], Designbuilder [38], among others. For this case study the methodology was based on the analysis of thermal-energy performance by simulation using Design Builder software.

2.1. Identification

Initially for the base case, the identification of building materials is carried out, with a total area of 126m2, comprising two floors. The first floor involves of a breathing room, a kitchen, a bedroom and a bathroom. For the second floor, you have access by stairs starting from the first floor giving way to two bedrooms and a bathroom.

a) Side view of the ceiling beams and wooden laminate supporting mud shingles

b) Top view of the roof mud shingles medium cane

c) Bottom view of the ceiling beams and wooden laminate

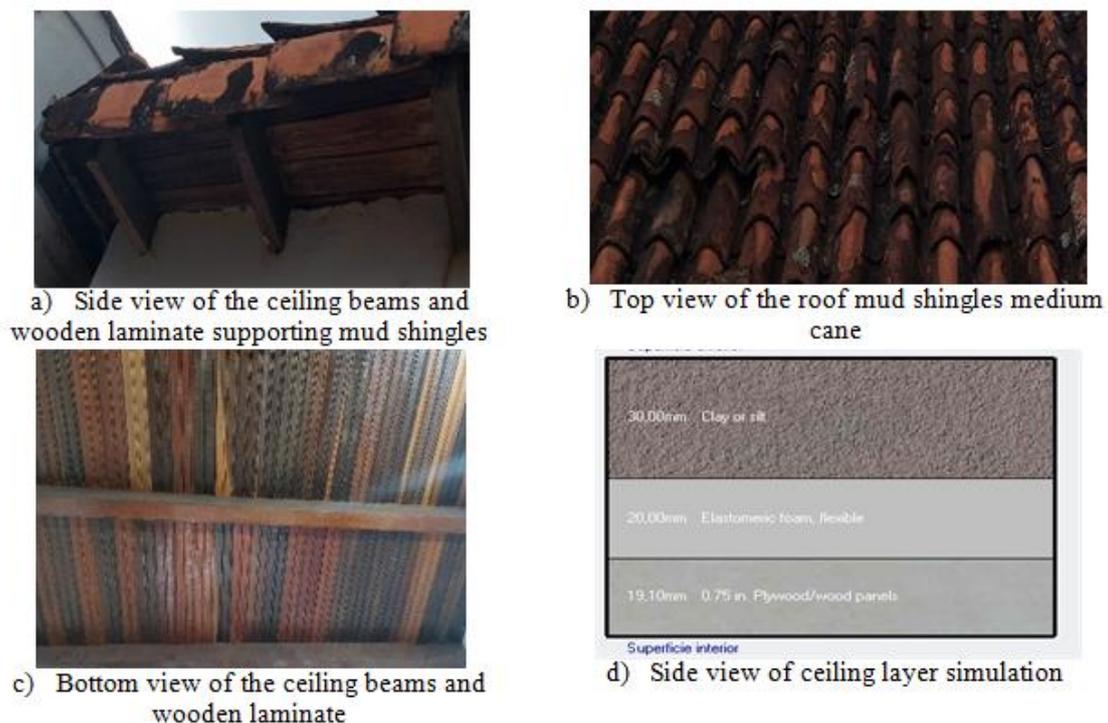d) Side view of ceiling layer simulation

Figure 1. State construction of the current roof of the studio house composed of wood, elastomeric waterproofing enclosure and mud shingles

The present case study is a construction that used the traditional building material in Colombia as follows: the ceiling is made of wooden beams that support sheets of wood thickness of 1.9cm, with an elastomeric waterproofing envelope of 2cm supporting mud shingles type medium cane with thickness of 3cm (see Fig. 1).

The floor layers in the area are composed of mixture of sand, gravel and stone, cement biker; 7cm cement fiber and ceramic as shown in Fig. 2a. Partition walls include plaster, brick and cement (Fig. 2b). The exterior walls are prefabricated concrete blocks composed of stucco [39], concrete and steel, and the exterior window is made of 6mm clear glass. In Table 1mentions the length of the layer conforming to each of the structural envelopes of the house.

a) View composition layers construction floor

b) View composition layers of the interior walls

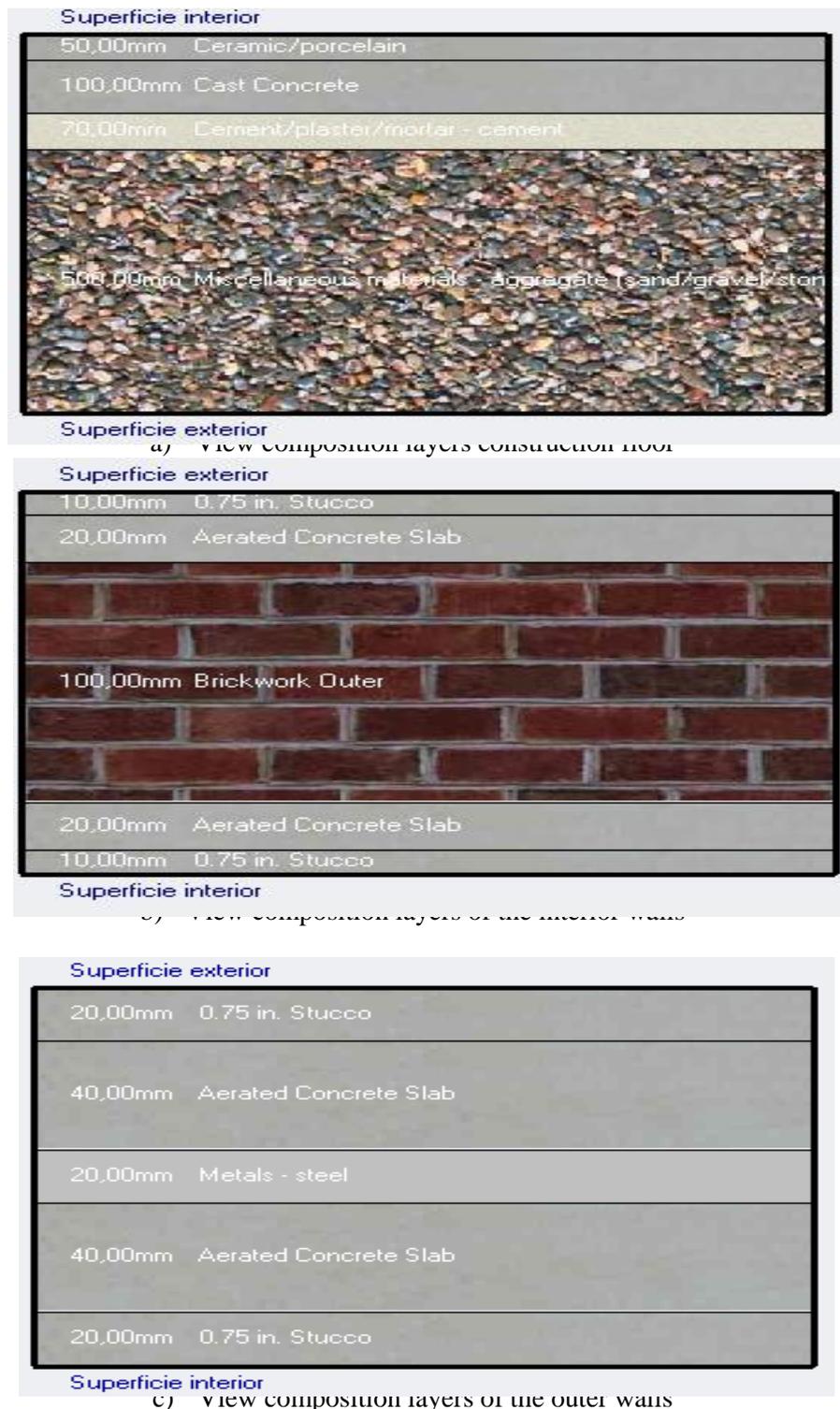c) View composition layers of the outer walls

Figure 2. Composition of outer and inner envelopes of the case study

Table 1. Identification of the materials that make up the structure and evolvents of the architecture

Type of Enclosure		Outer Walls	Internal Walls	soil	roof
cloak 1	Material	stucco	stucco	Mixing sand, gravel, stone	clay
	thickness (cm)	2	1	50	3
cloak 2	Material	Concreto	Cement	Cement mortar	And foam Elastomeric, flexible
	thickness (cm)	4	2	10	2
cloak3	Material	iron	brick h10	Cement board	plywood panels
	thickness (cm)	2	10	7	1,91
cloak 4	Material	concrete	cement	Ceramica, porcelain	-
	thickness (cm)	4	2	5	-
cloak 5	Material	stucco	Stucco	-	-
	thickness (cm)	2	1	-	-

2.2. Simulation

The architecture is simulated based on the weather data present in dry warm climate and identification of the geographical location in which the case study is located[40] (See Figure 3 in addition to this is the thermal characterization of the enclosures that make up the construction structure of the house as shown in *Table 2* .
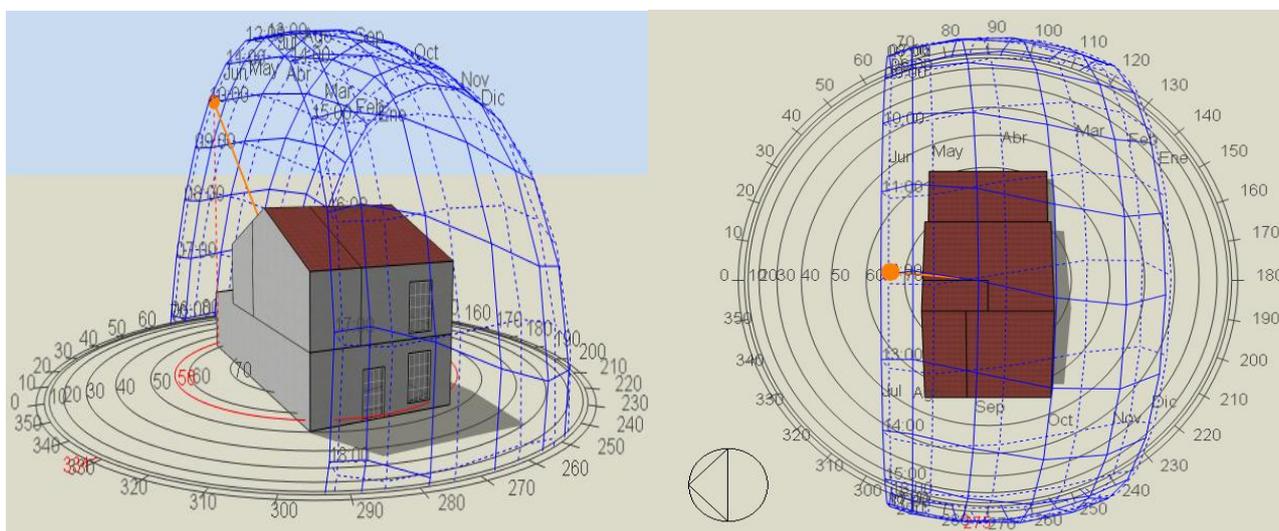

Figure 3. Geographic location and orientation of the case study architecture

Table 2 Thermal characterization of the enclosures of the houses to be studied.

Type of Enclosure				
Thermal data	Outer Walls	Internal Walls	Soil	Roof
value U (W/m²*K)	1,266	1,553	1,21	1,637
Value R (m²*K/W)	0,79	0,644	0,819	0,81
Surface-to-surface U value (W/m2*K)	1,887	2,605	1,643	1,135
Fenestration				
	6mm clear glass			
Total solar transmission (SHGC)	0,62			
Light transmission	0,57			
U (W / m² K)	5,778			

U (W/m²*K)	Thermal transmittance
Value R (m²*K/W)	Thermal resistance
Value C (J/m2*K)	Heat capacity of the Components

The thermal performance assessment of conventional architecture in dry warm climate is complemented by the analysis of comfort and set point hours completed to determine the housing comfort of the home.

3. Results

The interior thermal performance of the house analyzes the thermal-physical properties of structural envelopes such as average climate behavior per hour in a day[41], to determine the internal gains of the case study (See Figure 4).
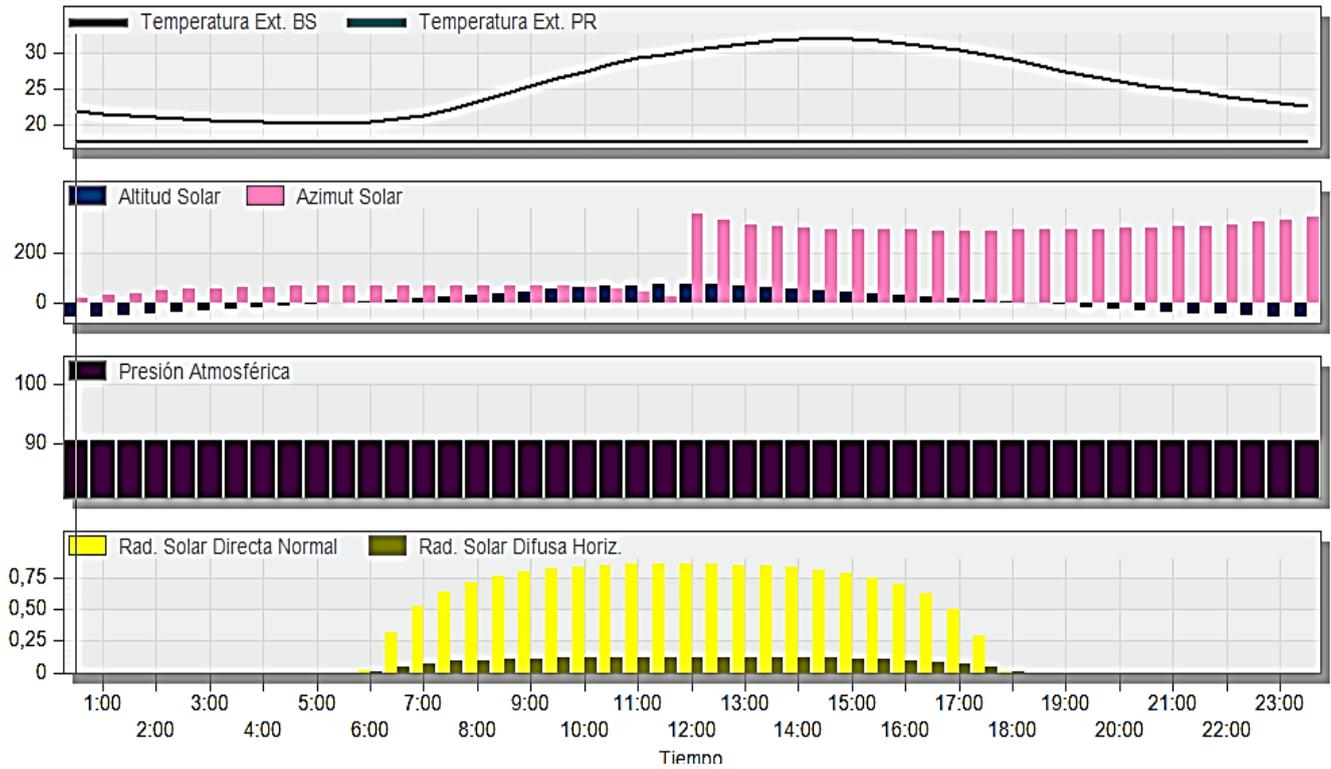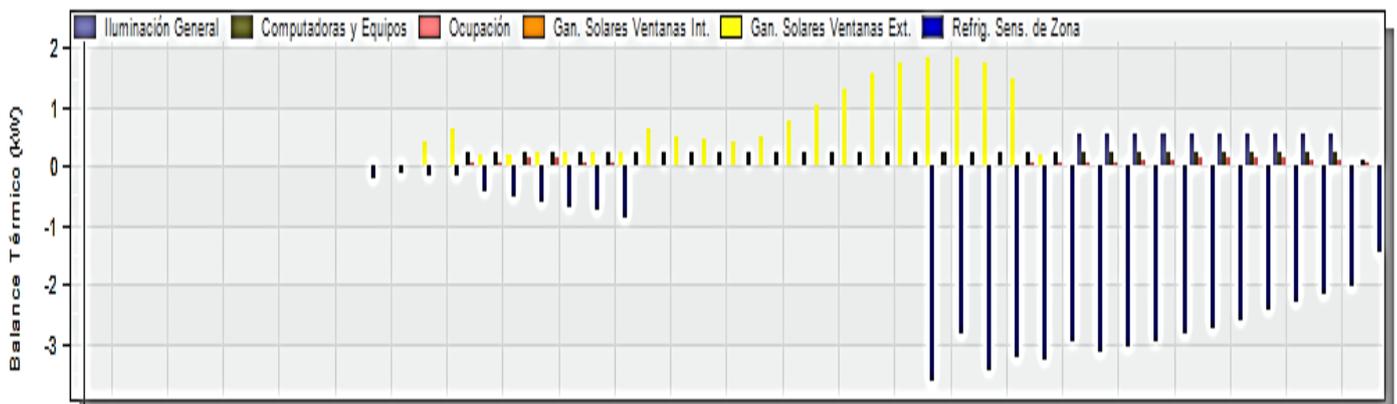

Figure 4. Weather behavior of case study housing

Based on the weather data in which the architecture is exposed, gain data taking into account the thermal balance of the influential factors, the loads of the system such as sensitive cooling and total cooling, ending with the latent load (all this in KW).

a)   Thermal balance

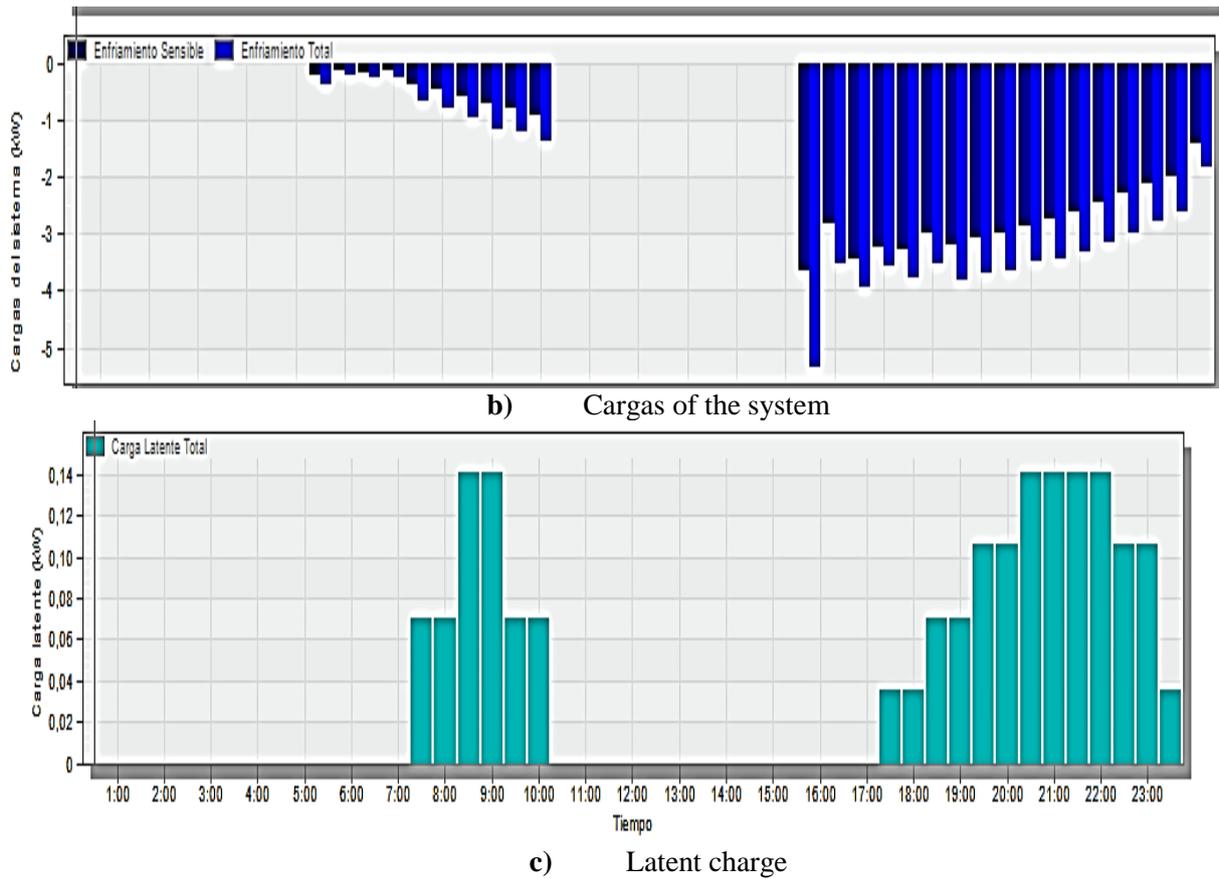**b)** Cargas of the system

c) Latent charge

Figure 5. Internal thermal gains from architecture

The thermal sensation is modified from person to person in the same area and instantly, so it is thought that even when the expected average vote value (PMV) is neutral, there is a percentage of dissatisfied people. Adding to the above Fanger's method[42], proposes relationship for the evaluation of thermal dissatisfaction called "estimated percentage of dissatisfied" (PPD). The PPD indicates the percentage of people who will eventually feel excessive heat or excessive cold in a given environment[43]. PPD is a function of PMV Figure 6. the function of PPD Vs PMV crossed with the current design condition.
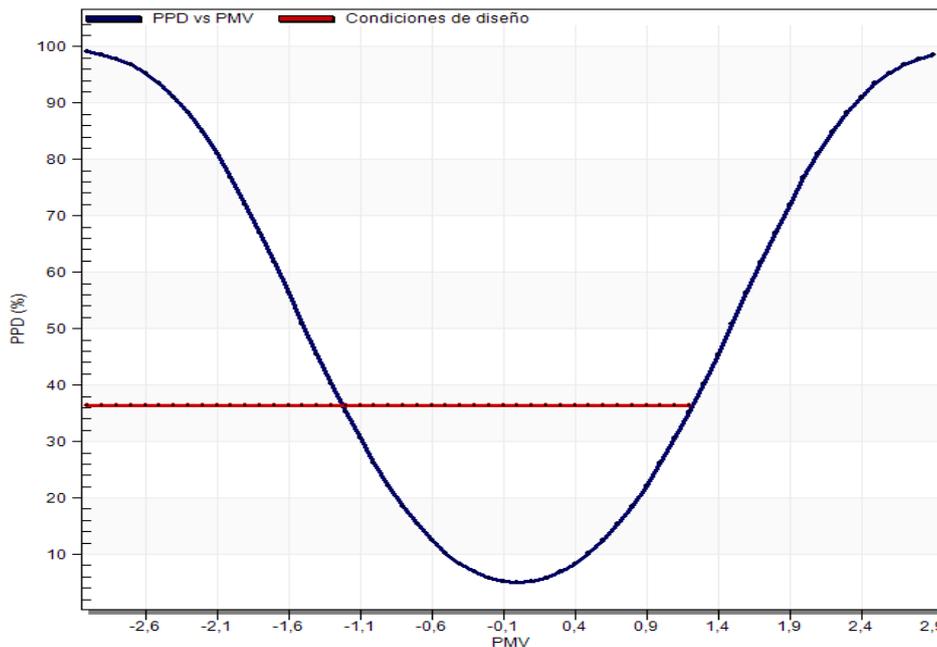

Figure 6. Graph of the thermal comfort of the house case study with the provision of the PPD VS PMV crossed with the design conditions

4.   Discussion

The thermal balance has a load gain in KW inside the house, which represents an elevation of temperatures inside it. Consequently, to the above, this thermal gain is presented in large part by the heat transfer obtained between the outside and inside of the enveloping walls by means of transmittance and solar gains (see Figure 7).
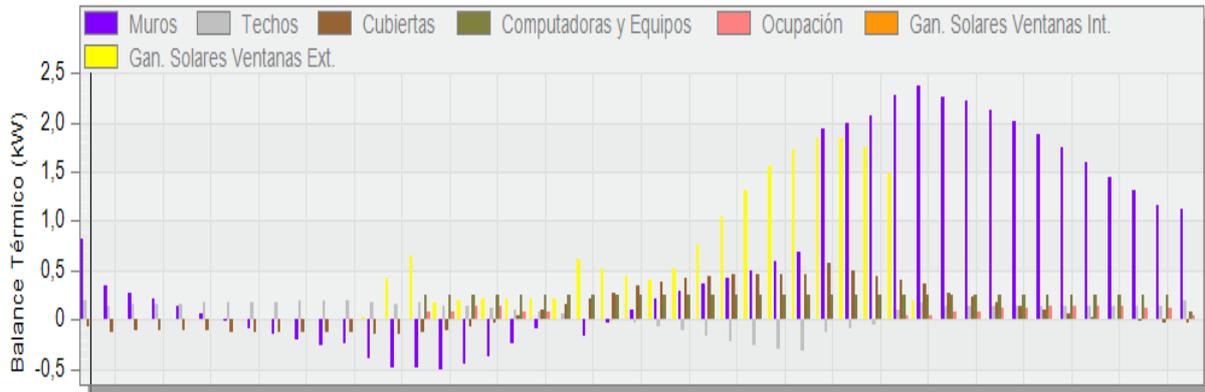

Figure 7**.** Internal gains plus solar gains in studio architecture

Using PPD Vs PMV[44], [45], rendering to ASHRAE 55[46], establishes that thermal comfort is achieved on the basis of a satisfaction rate of the inhabitants greater than 80%. The excess share of people can feel 10% body dissatisfaction. To comply with this standard, the recommended thermal frontier at the 7-point PMV level is between -0.5 and 0.5. PPD can fluctuate between 5% and 100%, but comfort ranges meets standards, no occupied spots in the area should be above 20% PPD [46]. Based on this, the housing disconfort is determined in this house, since the PPD is at intersection with the PPD vs PMV function at 36.35% and the PMV at -1.4 per thermal sensation of heat and 1.1 by the thermal sensation of cold (See Figure 8.).
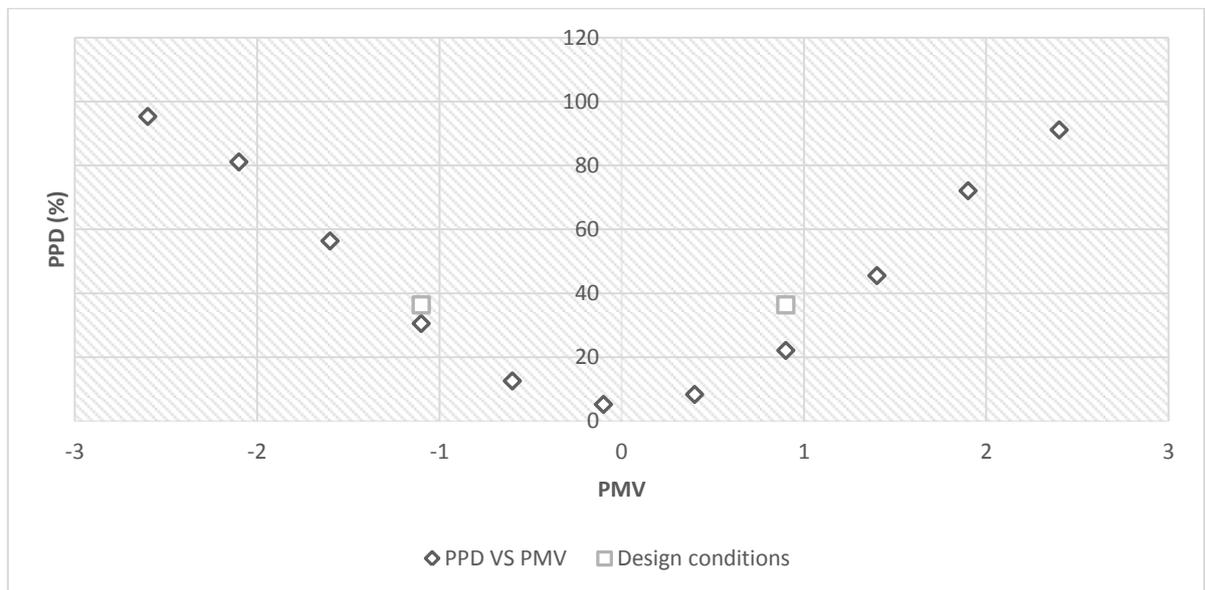

Figure 8**.** Graph of the intersection points of the PPD Vs PMV function in relation to the design conditions

5.   Conclusion

It is presented to a conventional townhouse of dry warm climate case study in the city of Bucaramanga, which, is built with common materials of the area thought only of mechanical and structural resistance since this area is a seismic nest of Latin America for its location close to several geological faults[47]-[48]-[49]-[50]. It is performed characterization of thermal constants such as thermal transmittance, thermal resistance and thermal compactness of the structural components of the case study.

Subsequent testing takes into account the variables already identified to decrease the error rate in computational tool calculations.

The latent loads if presented is its maximum points when the inhabitants are inside the house, since when analyzing the architecture as a single-family home it is assumed that the people who inhabit it will be only in hours outside of working hours, so some variables oscillate depending on the solar moment and the occupation and activity of equipment.

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