Thermal Comfort in Social Housing

The Case of Socio Vivienda 1, Guayaquil-Ecuador

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Introduction

Housing situation in Guayaquil

Guayaquil is the largest and the most populated city in Ecuador, with around 3.8 million residents in the city and nearly 4.1 million in the metropolitan area, as well as the nation’s main port. In recent years, the city of Guayaquil has had a remarkable demand for urban land to satisfy the needs of housing due to the rapid population growth.

In many cases, this need of housing is most prominent in the city’s lowest-income sectors, for which both public agencies and private enterprises have responded with large-scale housing programs that occupy large tracts of land without considering the environmental impact that this implies.

In the last decade more than 50,000 housing units have been introduced to the market in about 6 different housing programs[1] developed by the different sectors

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[1] Housing programs by the municipality: Mucho Lote 1 (14152 units), Mucho Lote 2 (7761 units). Housing programs by the central government: Socio Vivienda etapa 1 and 2 (17000 families), Ciudad Victoria (8000 families).

such as the municipality, the central government and the private sectors. The amount of land used for this development is over 720 ha which gives us an idea of the urban sprawl effect that is happening in the city.

Another issue is that these housing programs were supposed to be for the low-income sector, but most of the time the reality is that the product turns out to be inaccessible for the poorest people who have no access to the formal financial sector and therefore do not have access to a loans to buy their own houses. As a result, the first programs such as Mucho Lote 1 did not succeed as was expected. Most of the first owners are middle income people who rent their houses to others, which turns the dwellings into a way of making business for this sector of the population, far from achieving the goal of reducing the housing need for the poorest people in the city.

Geography and Climate

The city of Guayaquil is located in the southern hemisphere 2.15° South and 79.88° West, at an average elevation of 4 meters above sea level. It is situated on the western bank of the Guayas River, which flows into the Pacific Ocean at the Gulf of Guayaquil.

It has two distinct seasons: one is hot and humid, known as winter and it runs from December until May. Winter takes place when the warm marine current of El Niño advances from the North near the coast to Peru. From June to the beginning of December, climate changes and becomes fresh and dry and this season is called the summer. (Rivero, 1999).

The best-known classification for global climatic zones is given by Köppen, who determines the climates near the Equator as "rainy tropical climates" and includes both the climate of the rainforest as well as that of the savannah. However, years later, Atkinson (1953) and then Koenigsberger et al (1973), defined Equatorial climate as “hot.humid” in climates located between 15° N - 15° S. Therefore, the climate in the city of Guayaquil can be defined as “hot humid”.

Housing programs by the private sector: Ecocity (over 1000 units), Corporación Beata (6400 houses).

As Mentioned earlier in this paper the massive housing programs developed in Guayaquil over the last ten years have contributed to the urban sprawl and the city’s environmental impact. But, what about the house itself? What about the users? Do they achieve a minimum of comfort in this weather?

As stated above Guayaquil has a hot humid climate, in which the comfort zone is highly difficult to achieve. According to Givoni bioclimatic diagram (see figure 1), there is no month in the year where the comfort zone can be reached by itself. There is always the need to apply some strategies in order to achieve thermal comfort inside the buildings. Givoni gives the first recommendations to generate a climate response with passive techniques. These are dehumidification, ventilation, and in some cases the use of night ventilation and high inertia. The use of night ventilation and high inertia works well in hot dry climates, but it is not recommended in hot humid as the case of Guayaquil.

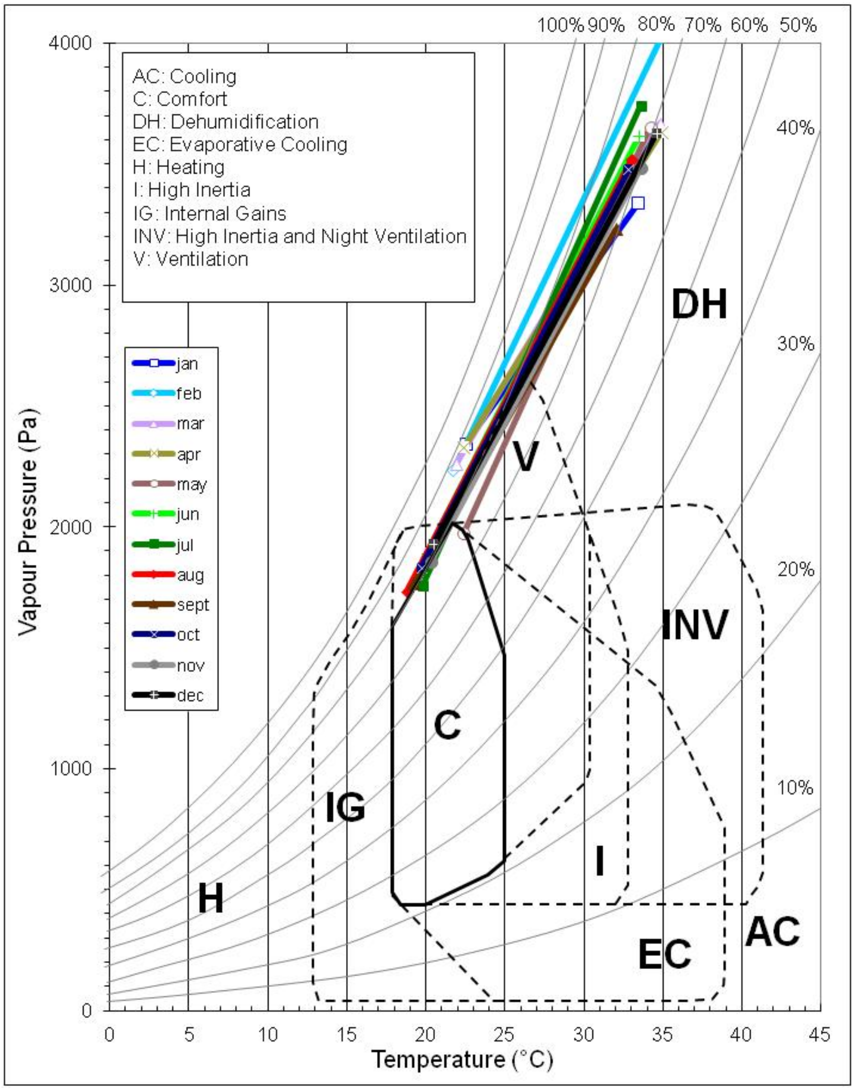


Figure 1. Givoni bioclimatic diagram for Guayaquil.

Academics believe that the developers of social housing do not take into account the indoor thermal comfort of the dwelling due to economic reasons. Most of the time, these houses are intended as a product that goes on sale in the market, and therefore the architectural trends are considered as important for marketing, trends that do not take the climatic conditions of the place into consideration and sometimes also sacrifice the well-being of the user.

It is also believed that there is a lack of information about the thermal performance and energy consumption of the social housing in the city of Guayaquil. Institutions such as the Ecuadorian Housing Bank (BEV), the Ministry of urban development and housing (MIDUVI) or themunicipality of Guayaquil do not have the staff trained in the field to develop these studies nor the financial resources to carry them out.

In this study, the first results of the analysis of the thermal performance of one housing unit that belongs to one of the central government social housing programs are presented. Field measurements and simulations have been made in order to evaluate indoor thermal comfort and then a parametric study has been carried out with the intention of achieving the best thermal situation.

Experimental Context

The Project

The case study is Socio Vivienda 1, a housing program for low-income people that was developed by the central government. The project is located in the Northwestern suburbs of the city, surrounded by an area of informal settlements on one side and by the land of the ESPOL, a local university, on the other side.

The project is developed on an area of 44.30 ha, subdivided in four phases. There are 2273 one family dwellings and 13 multi-story buildings in total. The program includes the following facilities:

- High school
- Elementary school
- Daycare centers
- Medical centre

- Medical sub center
- Police station
- Fire station
- Municipal market
- Recreational areas (parks, playgrounds, sports fields, etc)

This study is focused on the dwellings. They are simple one-story semi-detached houses. Each house is 38.41 m2. Two bedrooms, one common space where the kitchen is located and one bathroom (MIDUVI, 2012). The plan and facade can be seen in Figure 2. The materials used are hollow concrete blocks for the walls, metallic exterior doors, softwood interior doors, single glazed windows with mosquito nets and metal sheet with spray polyurethane foam for the roof.

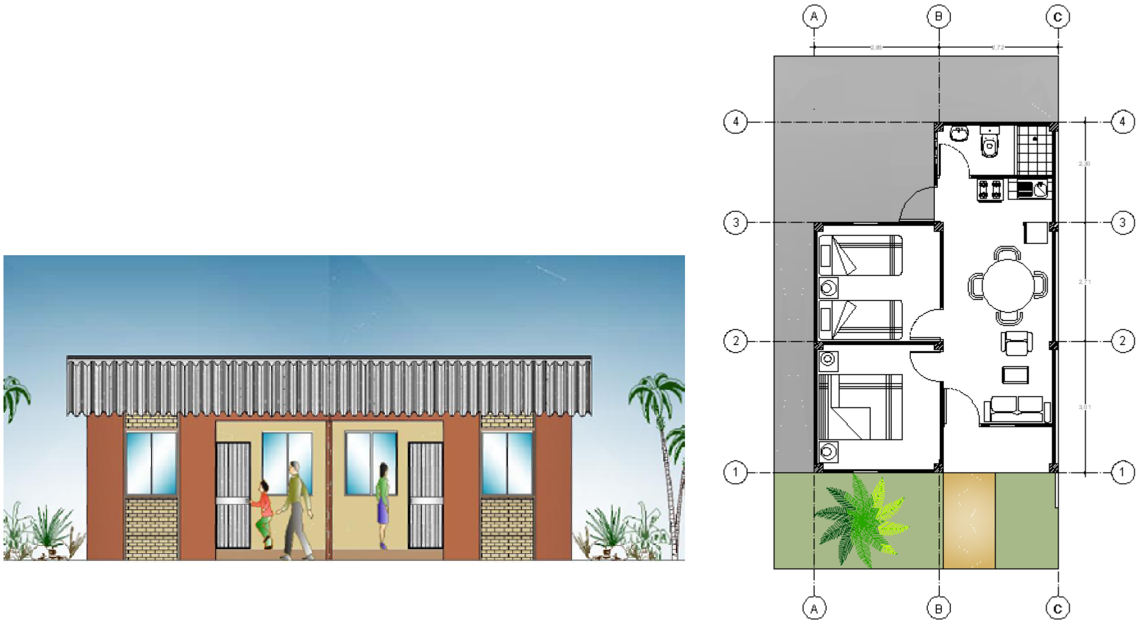


Figure 2. Façade of a semi-detached house and the correspondingt plan of one housing unit.
Source: final report of the Program Socio Vivienda made by MIDUVI. 2012.

Meteorological Conditions of the Experiment

Field measurements were carried out inside the house during one week in December 2012 from the 19th to the 26th. The measurement equipment was placed in the common space, just outside the bedrooms, on 2 meters height. The outdoor temperature for that period of time was taken from meteorological station in the airport of Guayaquil.

For the simulations, the climate data was taken from an average an average year based on the measurement period 1961-1990 given by the authorities of the

Instituto Nacional de Meteorología e Hidrología INAMHI[2]. Only one day was chosen for the computer simulations, in this case December 15th with average hourly temperatures the whole month.

The Tools

The equipment used for the field measurement was a Gemini Tinytag data logger. The thermal simulations were carried out using the Dynamic Energy Response of Buildings program, DEROB-LTH which last version was developed at Energy and Building Design, the Department of Architecture and Built Environment, Faculty of Engineering, Lund University.

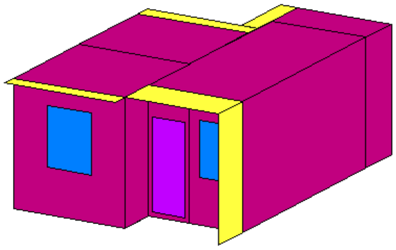
Method

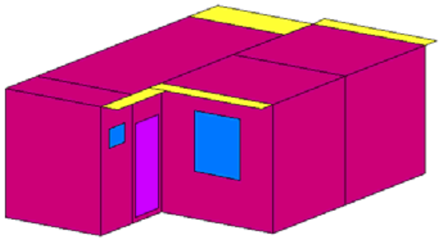
Field measurements

With the intention of checking the indoor thermal performance in real situations, field measurements of air temperature and relative humidity were done for a period of eight days, every 60 minutes. The measurement equipment was placed in the common space of the house (living /dining room and kitchen), just outside the bedroom doors. These results were used to calibrate the model in the computer simulations.

Computer simulations

In order to produce a comparative analysis of parametric variations, a base case was defined, considering a schedule of occupation, internal loads and physical properties of building materials. Because of software limitations the model was simplified to facilitate the simulations. The final model has a total area of 35 m2. The Derob model can be seen in Figure 3 and the dimensions used for the plan can be seen in Figure 4.





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[2] National institute of metheorolodgy and hydrology

Figure 3. Base case model constructed in *DEROB-LTH*

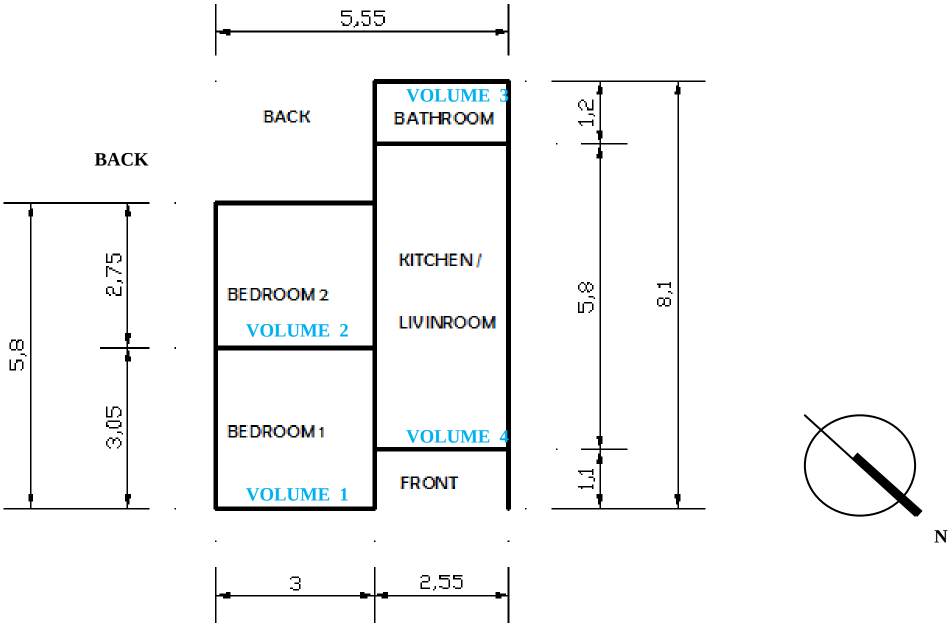


Figure 4. Exact dimensions of the base case model.

The materials used in the base case of the simulation are described in table 1. The shared wall between the two houses is simulated as an “adiabatic wall” that contains a high insulation, as it is assumed that there is no heat exchange between the two volumes.

TYPE	MATERIAL	THICKNESS (mm)	CONDUCTIVITY (W/m.k)	SPECIFIC HEAT (Wh/kg.K)	DENSITY (kg/m3)
wall	plaster	15	1,15	0,256	1800
	hollow concrete block	65	0,91	0,25	1200
	plaster	15	1,15	0,256	1800
roof	steel	2	50	0,13	7800
	polyurethane foam	5	0,026	0,5	30
adiabatic wall	mineral wool	500	0,04	0,24	50
	hollow concrete block	35	0,91	0,25	1200
	plaster	15	1,15	0,256	1800
window	single glass	4			
floor	tiles	5	0,95	0,25	2000
	mortar	10	1,15	0,256	1800
	concrete	120	1,7	0,25	2300
exterior door	steel	3	50	0,13	7800
interior door	soft wood (laurel)	50	0,14	0,76	500

Table 1. Materials and properties used in simulation.

The internal heat production (people, electrical appliances, etc.) is calculated with the value of 5W/m2 with a total of 176 watts per hour. (See table 2)

ELEMENT	AREA	AVERAGE VALUE W/m2 each hour*	WATTS/ HOUR
VOLUME 1	9,15	5	46
VOLUME 2	8,25	5	41
VOLUME 3	3,06	5	15
VOLUME 4	14,79	5	74
		TOTAL INTERNAL LOADS	**176**
* Given by Bo Adamson (1991) in Passive climatization of residential buildings in tropical climates			

Table 2. Internal loads

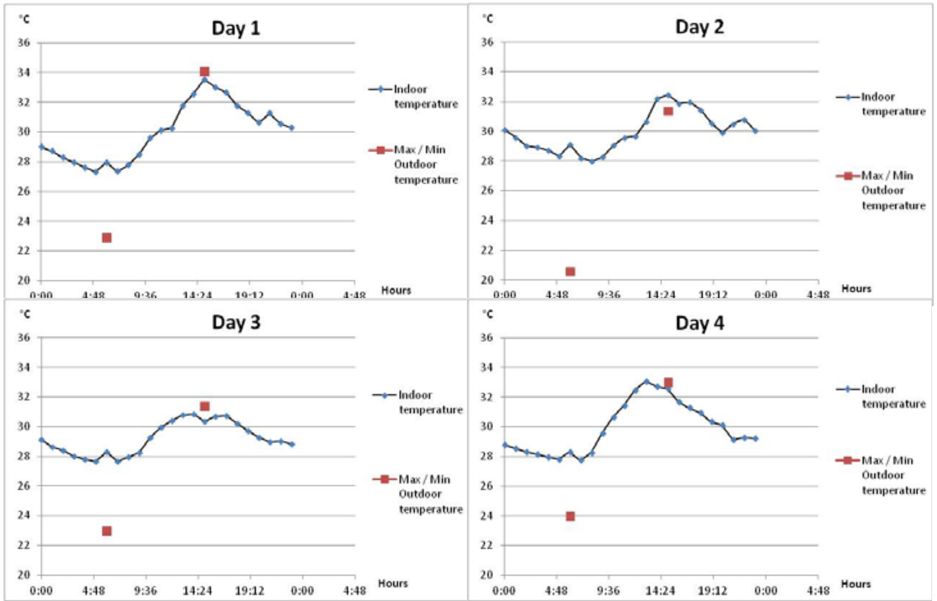
The base case was varied to produce a parametric study with the following cases:

- Variation of the solar absorptance of the roof
- Insulated walls
- Non -Insulated roof
- Adding ceiling
- Increase of roof overhang

Results

Field measurements

The measurements show that the building provides an insulated environment making the difference between the maximum and minimum air temperature lower than the outside temperature than can reach a 12 degrees oscillation, while indoors there is only 8 degrees of oscillation top. This is shown in the following figure:



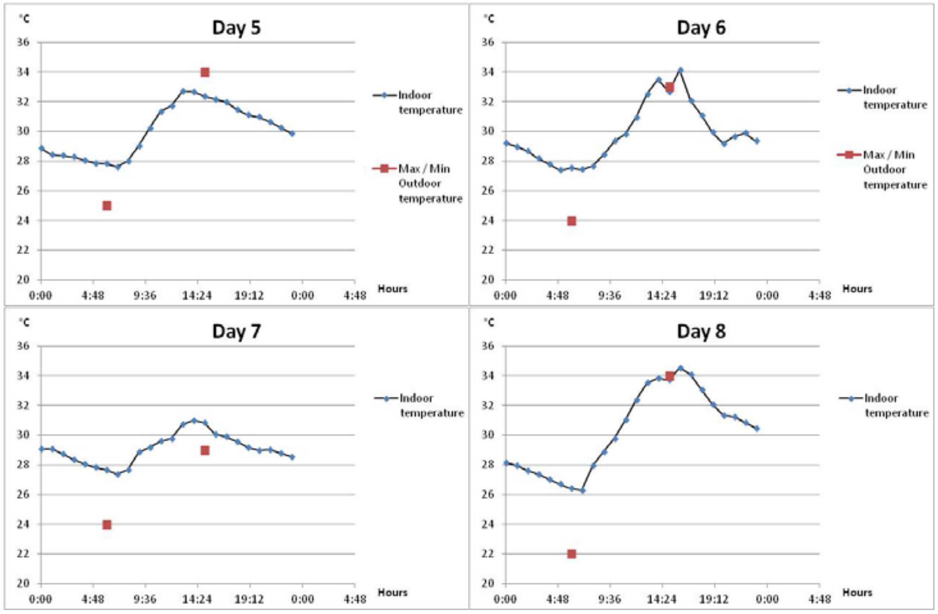


Figure 5. Indoor air temperature measurements vs. Max/Min outdoor temperature each day.

Figure 5 also shows that the temperature indoors is always warmer than the minimum temperature outside in each day, this can be because of the internal heat loads, but also because of the materials' thermal properties, which make the house store the heat accumulated during the day, and the lack of proper night ventilation.

Computer Simulations

The first results for the base case show that the temperature indoors was slightly warmer than outdoors. These simulations were done with a 50% opening of the windows in the model, fully open by day and closed during night. Because of the high ventilation rate results, it was decided to change to 25% opening of the openings, which represent approximately 10 air changes per hour during the day. This made more accurate the simulation.

Also, the simulated results are similar to the measurements although both the outdoor and indoor temperatures are lower, which shows that the measurement period was warmer than a normal December day.

In thispaper only the results of the volume 4 are shown, which correspond to the common space (living/dining room and kitchen).

Results of the parametric study

Contrary to what was thought before doing the simulations, the results show that there are no significant changes in the different cases. The only case that shows negative results in comparison with the base case is the case with insulated walls. It is assumed that the increase of insulation is not good for passive design because it retains the heat inside.

Figure number 6 shows that the best result was obtained with the reflecting roof case, in which only the colour of the exterior surface was changed to a light colour in order to reduce the solar absorptance. However, from a general point of view, one can notice that the different cases do not produce temperature changes of more than one degree. It is always just in decimals.

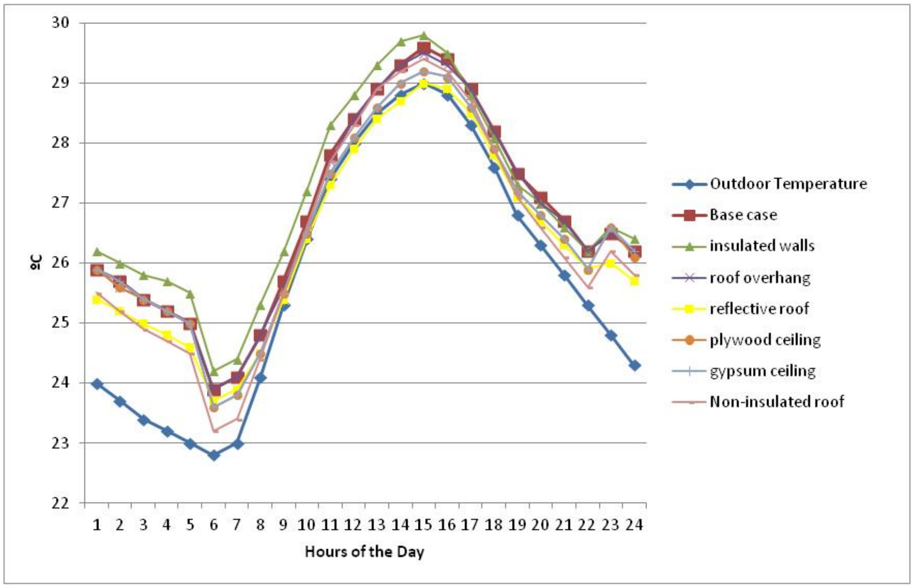


Figure 6. Results of air temperature from the parametric study.

Surface temperature on the top interior surface

Because the first set of results did not show any substantial difference (the variation of temperature is never bigger than one degree), it was decided to check the surface temperatures of top interior surface (roof or ceiling) in order to have an idea of the thermal sensation of the people in the house. The thermal sensation is affected both by the air temperature and surface temperatures and the highest surface temperature is normally in the roof.

Four cases were made including the base case in which an insulated roof is used. The other three cases are:

- *Ordinary roofs:* Corrugated metal sheets that are the traditional material of construction in low-income houses
- *Gypsum ceiling:* traditional material used for ceiling in Guayaquil.
- *Plywood ceiling:* an alternative material for ceiling.

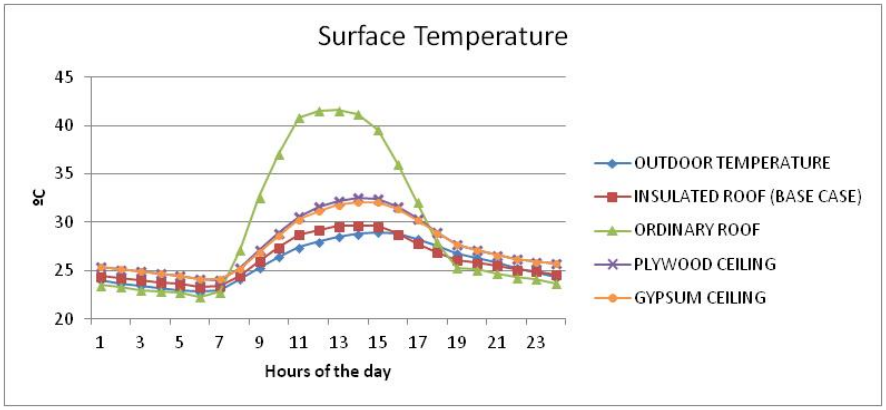


Figure 7. Surface temperature of the top interior surface.

As it can be seen in figure 7, the best result is obtained with the *insulated roof* without a ceiling, which corresponds to the base case. As expected, the *ordinary roof* has the higher surface temperature in the hottest part of the day. This means that the real typology of Socio Vivienda its working well with this material on the roof.

The simulation results show that it is not recommendable to put any kind of ceiling if the material of the roof is already insulated, contrary to the general assumption that introducing a ceiling in a building can improve the thermal performance in any situation. For passive design, if an insulated roof is used, a ceiling should not be utilized.

Conclusions

Thermal comfort is defined by ISO 7730 as 'that mental condition that expresses satisfaction with the thermal environment'. Although this definition gives us a subjective idea of what thermal comfort is, it is very difficult to estimate physical parameters (Kvisgaard, 1997). For this reason, thermal comfort is usually defined as an interval or determined as a "comfort zone" where the 80 or 90% of the population experience comfort. This comfort zone for hot humid climates, as the one in Guayaquil, can be established to be between 21ºC to 30ºC (Aynsley, 1980).

The results of the field measurements show that when there is high temperature outside, the building does not get to keep the comfort zone indoors. Nevertheless, the simulations show that there are some alternatives to improve the indoor performance in order to achieve the desired comfort for passive (naturally ventilated) buildings, for example:

- Insulated roof (or adding a ceiling if the roof is not insulated)
- Light-coloured roof
- Sufficient overhangs to avoid insolation
- Provide for good cross ventilation
- Non-insulated walls

To have a good interior climate has a significant effect on the health and well-being of people. Therefore, thermal comfort should not only be considered as a luxurious desire of a limited population, but should be a something that everyone can achieve in their homes. For architects, itis imperative to keep this in mind when it comes to creating new habitable spaces.

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