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# EVALUATION OF THE THERMAL PERFORMANCE OF HISTORIC BUILDING WITH NEW USE IN THE CITY OF PELOTAS

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## ABSTRACT

The objective of this research is to evaluate the thermal performance of an historic building located downtown Pelotas, RS, Brazil. It was originally built for residential use, and nowadays it is occupied by the public use. The evaluation was achieved by the computer simulation method and it uses the Design Builder software (3.0.0.064 version). The chosen index for the analysis is the adaptive model from De Dear and Brager for ASHRAE Standard 55 (2004). For 90% acceptability, results were 50.50% of hours in comfort for occupancy hours. And for 80% acceptability, results were 66.86% of the hours in comfort.

## INTRODUCTION

The city of Pelotas is considered as heritage of Rio Grande do Sul State with its amount of eclectic style buildings that resemble wealth times resulting from the economy based on the trade of jerky beef. Many of these buildings, which were built for residential purpose, are still being used and have kept their architectural features over time. Its architectural heritage counts on around 1000 buildings of historic interest protected by Municipal Law 4.568/2000. The constructions surrounding Park Coronel Pedro Osório, downtown the city, are the most significant in Pelotas.

Due to such architectural and historic features of the city, it becomes relevant to evaluate a building from the XIX century in order to understand its thermal performance. That may be another reason why these buildings must be preserved, since thermal comfortable environments consume less energy for its air conditioning.

The building in study is the old Residence of Charqueador José Vieira Vianna, also known as House 2. Located at Park Coronel Pedro Osório, number 2, it is nowadays, the address of the Municipal Department of Culture.

The House construction dates from before 1830 and it suffered a great intervention in 1880, when it changed from a Luso-Brazilian style to an eclectic style residence. It was overthrown in 12/15/1977[1] and the last time it was restored was in 2005 by program MONUMENTA[2].

It has been more than 140 years since the original construction of the building was overthrown. In the meantime, it was occupied by several uses and it had various owners. This inconstancy of uses and owners as well as the inadequate or urgent maintenance, modified and, sometimes, damaged the architectural features of the building. Much of the information was not even recorded in the beginning of the construction, as the distribution of the bricks in the walls. This information, since it is important for computer simulation, was deduced from specific bibliographies which date from the time of the construction.

*Figure 1 - House 02 – Municipal Department of Culture*

[1] Listed Building is known as 'building overthrown' in Brazil and it is an administrative act accomplished by the Public Power, which objective is to preserve historic, cultural, architectural, environmental and also the affective heritage to the population, preventing such heritage from destruction and/or mischaracterization. (Source: IPHAN)

[2] MONUMENTA is a strategical program of the Ministry of Culture. It acts in historic cities protected by the Institute of National Historic Artistic Heritage (Iphan). Its purpose is to act in such an integrated manner in each one of these locals, promoting restoration works and restoring overthrown buildings located in the areas of the project. (Source: Ministry of Culture)

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As nowadays, it is a building which is occupied by the public use and it was chosen as object of study for a master thesis. House 2 is being evaluated as for its thermal performance and for that, analysis of the surveys and restoration projects of the building for modeling and simulation with software DesignBuilder were accomplished. The surveys of the building and the projects of restoration were obtained together with SeCult (Municipal Department of Culture of Pelotas) and these were the files used for modeling, together with other information obtained in the local.

Pelotas is located in the south of Brazil and it has a subtropical humid climate that determines hot summers and very cold winters. The mean yearly temperature is 17.6°C, where in the coldest month the minimum mean temperature is 8.6°C, and in the hottest month the maximum mean temperature is 28.2°C. This climate characteristic is an important condition when considering issues of comfort in buildings, thus the enclosure shall keep internal temperatures milder than external temperatures. Considering that the building is naturally ventilated, and no artificial conditioning system is installed, users fit their comfort through clothing which is adequate to the time of the year, wearing lighter clothes in the summer and warmer clothes in the winter. Small mechanical ventilation and heating apparatus like fans and heaters are used when the temperature is rigorous, providing more comfort to the activities developed.

## BUILDING CHARACTERISTICS

It is a solid brick masonry building. On the ground floor it is possible to find external walls from 0.36 to 0.92 meters thickness, and internal walls from 0.21 to 0.76 meters. Walls plastering is lime based. The ground of all building is Wood floor, except some ambient on the ground floor that are made of hydraulic tiles. The ground and second floor present wood ceiling. The covering of the building is composed of "capa-canal" ceramic tile, with wood structure.

From small samples of bricks and plastering obtained in the place, it was possible to determine the density of the apparent mass of these materials, to calculate the walls transmittance. The essay is described in 'walls' as follows.

## SIMULATION

**Configuration of the model and Simulation of the thermal performance**

The objective of this work is to evaluate the thermal performance of the historic building. For this purpose, software DesignBuilder version 3.0.0.064 was used for computer simulation. This software allows the thermal performance evaluation and simulates naturally conditioned spaces. The climate file (BRA_Santa.Maria.839360_SWERA.epw) of Santa Maria was used in this study. Santa Maria and Pelotas are located in the same bioclimatic zone. Therefore, according to Brazilian norm (NBR 15.220 – 3), which states the Brazilian bioclimatic zoning, it is possible to use it, since Pelotas does not have its own file.

All hours of the year were simulated, making different analyses possible. The first, considering all hours of the year, with 8760 hours, and the second one, with working hour of SeCult only, resulting in 2.610 hours data.

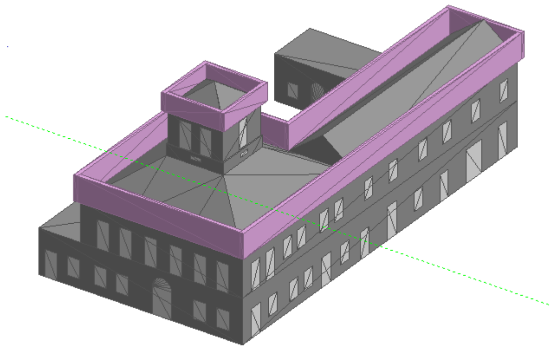

*Figure 2 - Model 3D in Design Builder*

**Simplifications and Conventions**

The objective of the simulation is to simplify the object of study in order to obtain results for analysis. As it is the study of a historic building, with peculiar features, some simplifications of the constructive characteristics had to be achieved to model the building, as for instance, standardization of the walls thicknesses. The thickness of internal and external walls of the building show great variation.

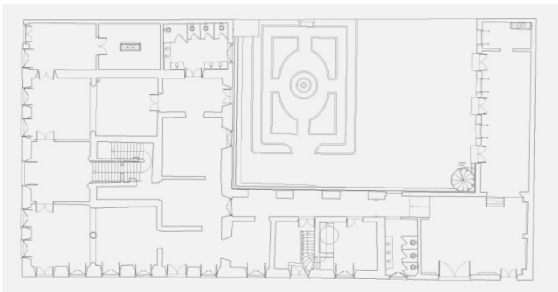

*Figure 3 – Ground floor – restoration project floor plan*

Therefore, it was decided to model the external walls of the ground with 0.60 m and the second floor with 0.40 m thickness and the internal walls with 0.20 m and the second floor with 0.15 m, and characterize the layers with real thicknesses in the configuration of materials of the program. (Figure 4)

*Figure 4 – Floor plan simplified ground*

Equivalence calculation was made to the layers of bricks, where the heterogeneous layer of brick and mortar was replaced for a homogeneous layer of a material with characteristics that are equivalent to the original layer.

Other conventions were adopted, thus, besides several characteristics of the building, the program limits modeling.

**Roof**

The building shows “capa-canal” clay roofing tile, with wood structure.

The covering of the house was modeled as block, where the tile thickness used was obtained by the project of restoration, and the structure of the roof, laths, rafters and scissors was not considered, thus it occupies the area of air layer and it has little contact with the tiles and ceiling.

**Walls**

The walls are composed of solid ceramic bricks, with mortar and lime-based plaster.
Essays for density apparent calculation of the materials were achieved by using brick and mortar samples of the building as reference. First, the volumes of the samples were obtained by immersion. Weights were obtained through precision scale. And by formula

$$\rho = M/V \qquad (1)$$

the density of the materials were obtained.

Brick – ρ =1.800Kg/m³.
Mortar – ρ = 1.990Kg/m³.
The walls were configured by their thickness and by dimensions of the bricks of reference, deducing its arrangement based on Breymann (1885). The brick of reference has 0.06 x 0.14 x 0.28 m. (Figure 5)

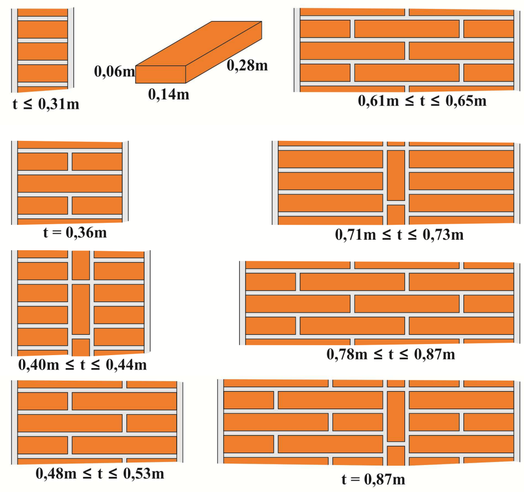


*Figure 5 – Composition of the different thicknesses of the walls*

For configuration in software DesignBuilder, the values obtained in the thickness calculation were adopted. Wall thicknesses of 0.15, 0.22, 0.35, 0.36, 0.42, 0.50, 0.63, 0.68, 0.72, 0.78, 0.82 and 0.87m were configured. These dimensions were chosen because they are more frequent and represent all the others approximately.

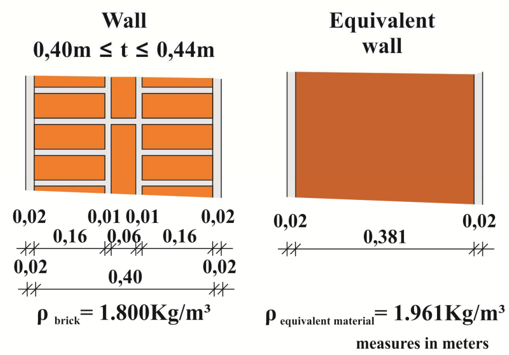


*Figure 6 – original and equivalent wall*

As the walls are composed of heterogeneous layers (ceramic bricks and mortar and lime-based plaster), it is necessary to make the calculation of equivalence to obtain the characteristics of an ideal material, homogeneous, with the same performance the real wall shows. The methodology of equivalence calculation was based on the work of Ordenes et al. (2003). Then, from these calculations, and knowing the value of the thermal transmittance (U) of 1.76 W/m²K, an apparent equivalent density was adopted (ρ) for the brick and plaster equals to 1961 kg/m³, obtaining an equivalent thickness, in this case, 0.381m. These values are adopted for the wall which thickness is equal 0.44m, as shown in Figure 6.

Absorptance used for external faces of the walls was 0.4, with relation to an external painting of light color.

### Floors

The building has two types of floors, flooring and hydraulic tiles. Hydraulic tile is used on the ground and in terraces. The flooring is used in part of the ground and in the entire second floor.

The hydraulic tile was simplified with a layer of hydraulic tile of 0.01 m and a layer of light concrete of 0.07 m.

On the ground floor, the flooring was considered with wood, air and land layer. (Figure 7)

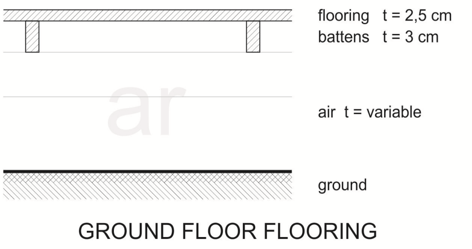


*Figure 7 – flooring of the ground*

On the second floor, the flooring was considered along with the ceiling. Through architectural survey accomplished for restoration, it was observed that the thicknesses between the floor and the ceiling vary from one ambient to another. For simulation, these thicknesses were simplified.

Still on the second floor, there are two external areas with terrace. In these areas, during one of the interventions of restoration, precast slabs settled with hydraulic tiles were achieved. The same methodology with equivalent thickness was used on the precast slab. (figure 8)

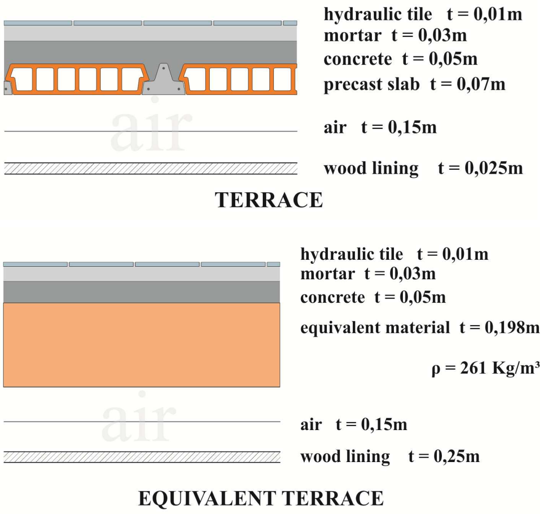


*Figure 8 – Terrace and equivalent terrace*

### Windows

The windows of the building are made of wood and glass outdoors and wood indoors. They have two leaves, which make them open 100% for ventilation. The openings were modeled with their dimensions and percentage of glass according to the survey of restoration. The wooden window was configured as internal solar protector.

*Figure 9 – Window of the House*

### Schedule

The working schedule was configured according to the schedules of SeCult, from 8:00am to 05:00pm, from Monday to Friday throughout the year.

As option for the control of windows shading, over hours of more direct solar radiation incidence, schedules were created to specific working of windows of each one of the façade directions. In the summer period, from October to March, four operations were established. In the west façade, they were kept closed from 02:00pm. In the south façade, the windows were closed from 04:00pm. The schedule to keep the windows with east solar direction closed was from 08:00am to 10:00am. But in the north direction, the windows remained opened during the whole period.

In the winter, a schedule was created to windows glasses close, keeping the wooden windows opened making passive solar heating feasible and avoiding great loss of heat outwards.

### Thermal gains

For calculation of thermal gains, a survey on the number and type of bulbs and quantity of computers and other equipments was accomplished in the local.

Some compartments of the building ate not much used and others are not used, including blocked access by panels of the previous compartment. Nevertheless, bulbs and their power for calculation of the thermal gain with lighting were considered.

The power with lighting, considered by the radiant fraction of the specific type of bulb, and the gains with the equipments were defined for each ambient from the surveys.

**Occupancy**

The occupancy was calculated the same way as the thermal gains were. First, a survey on the number of people that occupy the House during working hours was fulfilled. Two areas are art galleries and had their occupancy calculation based on NBR 9077. The number of occupants was defined to each ambient individually.

The type of activity performed by the occupants is also important to the configuration of the occupancy and it was considered as light office service, Met value equals 1. Winter wearing value equals 1 Clo and Summer wearing equals 0.5 Clo (the winter wearing value is equal 1 Clo and summer wearing is equal 0.5clo)

**Natural ventilation**

Natural ventilation was configured by schedule. The windows are opened to allow ventilation from the setpoint temperature. Wood-wickets configured as solar protector were configured with percentage of air flux permeability (airflow permeability) of 11%, calculated from the window opening as Figure 10 shows.

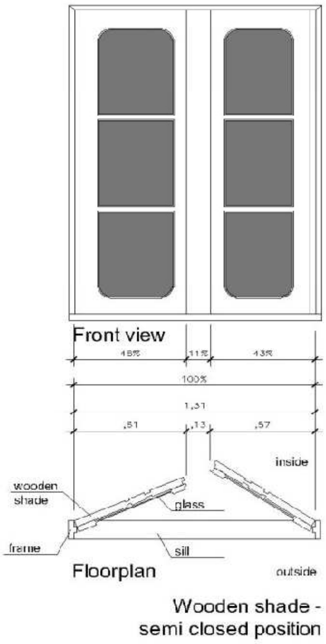


*Figure 10 - window shade airflow permeability*

**Setpoint of temperature**

The ventilation temperature setpoint of 25°C was based on the work of Martins (2009). The system of natural ventilation promotes the opening of the windows when the exterior temperature is inferior to the interior temperature of rooms and inferior to 25°C.

**Ground temperature**

Soil temperature was obtained through Slab, assistant program of EnergyPlus, which calculates the monthly mean temperature of the soil from the internal air mean temperature and the external mean temperature.

**Modelling challenges**

The greatest challenges found during the simulation process of the Casarão, were related to modeling. The building has different thicknesses of external and internal walls, situation that cannot be represented in the modeling in DesignBuilder. The walls were, therefore, modeled with equal thicknesses and later configured in aba 'construction' with individual characteristics of each one. The surveys obtained show that the walls are not orthogonal, where a simplification to facilitate the modeling and avoid conflict between adjacent surfaces of different blocks of the building is necessary. In the specific case of simulating building in Brazil, the generation of all materials to use in the process is demanded, thus the library in the program is very different from the reality here.

Windows were modeled from the percentage of glass and frames, and the working system was configured from the percentage of opening for ventilation.

The process would be easier and more accurate if modeling allowed that even non-parallel surfaces could be joined, forming one unique block. Drawing walls of different thicknesses and not necessarily perpendicular, would guarantee walls overlapping.

## RESULT ANALYSIS

The data obtained were evaluated from adaptive model De Dear and Brager, to ASHRAE Norm 55. Such model considers the external temperature as reference to naturally ventilated ambient. The users must have free access to windows that must open outwards and have the possibility to adapt their clothing as well. Therefore, the mean air temperature and the radiant temperature are used to calculate the operative temperature and stipulate the acceptable levels of comfort to 80 and 90% of people satisfied, considering the external temperature. Mean external temperature shall be between 10 and 30°C. In order to stipulate operative temperature of comfort the following formula is used:

$$T_{oc} = 18.9 + 0.255T_{ext} \quad . \quad (2)$$

To determine 90% of people satisfied, the operative temperature of comfort is the interval of $T_{oc}$ -2.2°C and $T_{oc}$ +2.5°C and to 80% of people satisfied it is $T_{oc}$ -3.2°C and $T_{oc}$ +3.5°C.

For first analysis, the results were from all hours of the year, to 90% of people satisfied, resulting in

48.70% of hours inside the acceptable limits of comfort, with 13% of discomfort by cold and 38.30% of discomfort by heat. Considering the limits of temperature stipulated to the interior of the building, the external temperature throughout the year was in the limits in 20.25% of the time. (Figure 11)

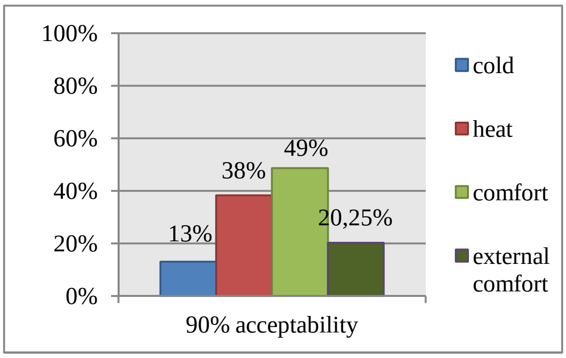


*Figure 11 – hours of comfort to 90% of people satisfied*

Considering the hours in which the building is occupied only, and 90% of people satisfied, the results were 50.50% of hours in comfort, 10.69% of discomfort by cold and 38.81% of discomfort by heat. The external temperature was in the acceptable limits in 18.24% of occupancy hours (Figure 12).

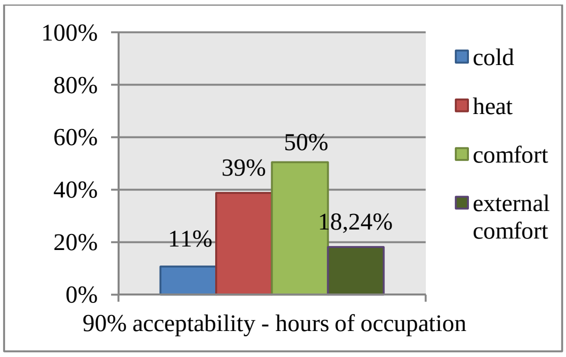


*Figure 12 - hours of occupancy in comfort to 90% of people satisfied*

The analysis, considering 80% of people satisfied for all hours of the year, resulted in 66.3% of hours in the acceptable limits of comfort, 7.2% in discomfort by cold and 26.6% of discomfort by heat. In 28.21% of hours, the external temperature was kept in the acceptable limits. (Figure 13)

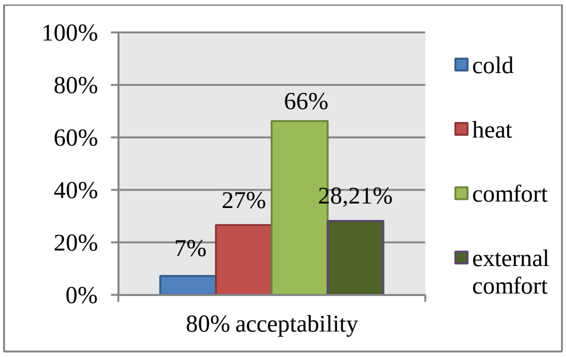


*Figure 13 - hours of comfort to 80% of people satisfied*

To 80% of people satisfied in the working hours the results did not have a significant difference. In 66.86% of the hours, the building remained in comfort, in 5.79% in discomfort by cold and in 27.36% in discomfort by heat and the external temperature had 26.32% of the time in the limits. (Figure 14)

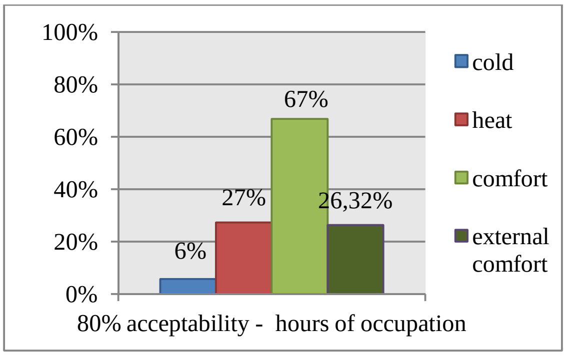


*Figure 14 – Hours of occupancy in comfort to 80% of people satisfied*

The results show that in all situations the acceptable limits happen most of the time. The comparison with external temperatures presents a significant difference between the exterior and the interior of the building, where the interior favors milder temperatures.

When evaluating monthly results with relation to occupancy hours for 90% acceptability, it is possible to verify that the building responds to season climate variations. It is in the summer, from December to March, that the greatest discomfort because of heat is observed. In January, it is possible to verify discomfort because of heat in 74% of occupancy hours. And, in the winter, from June to September, discomfort because of cold happens. June and July present discomfort because of cold in 50% of the time. (Figure 15)

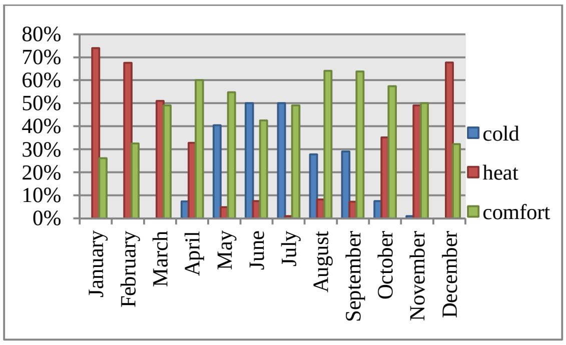


*Figure 15 – Monthly results for 90% acceptability*

Considering 80% of acceptability, where tolerance is greater, it is possible to verify milder results, but still responding to specific climate variations of the region. January presents discomfort because of heat in 60% of occupancy hours. And June shows discomfort because of cold in 42% of the time, as Figure 16 shows.

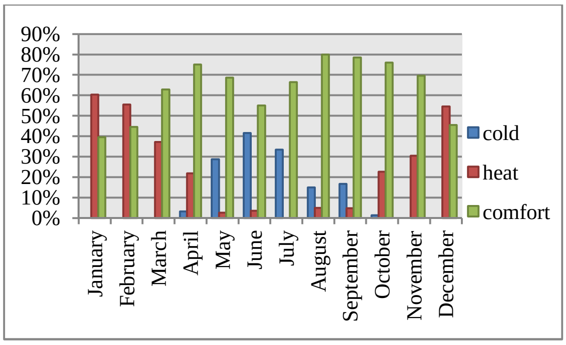


*Figure 16 –monthly results for 80% of acceptability*

## CONCLUSION

The building is nearly 180 years, it passed through several interventions along these two centuries, witnessed the arising and decadence of jerky beef in the region and it remained almost unscathed to the actions of climate change. Comparing or even considering the climate, use of spaces and clothing from that time demands a detailed historic study about the society, its costumes and local, which is not the objective of this study. Therefore, the results show a building with high levels of comfort, considering the current use. The constructive techniques, as for instance, the walls composed of great thickness are not commonly utilized in recent buildings that use reinforced concrete structure to support the weight of two or more floors.

The simulations obtained results between 48 and 66% in the acceptable limits of comfort, to naturally ventilate ambient. The results may be considered as very good, thus at least half of the year, internal environments remained thermally comfortable.

## NOMENCLATURE

ρ, density of apparent mass;
M, mass;
V, volume;
$T_{oc}$, Operative temperature of comfort;
$T_{ext}$, External monthly mean temperature;

## AKNOWLEDGEMENTS

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