DESIGNING "SUSTAINABLE HOUSES" BEFORE THE ESTABLISHMENT OF THIS CONCEPT

Leônidas Albano DA SILVA JÚNIOR
Universitat Politècnica de Catalunya, Spain, la@leonidasalbano.com

Marta Adriana Bustos ROMERO
Universidade de Brasília, Brazil, romero@unb.br

Alberto Hernandez NETO
Universidade de São Paulo, Brazil, ahneto@usp.br

Summary

The aim of this paper is to assess the efficiency of the sustainable strategies applied in the modern naturally-ventilated houses built in the 1950's and 1960's in Goiânia, located in middle-west of Brazil, thought the analysis of the applied passive thermal conditioning strategies. This study allows the analysis how sustainable issues have been treated before the establishment of this concept, helping us to reflect on the future from a historical perspective. Seven rooms in two houses were selected for in situ measurements and simulations. Indoor and outdoor air temperatures and relative humidity were measured with data loggers HT-500, during 91 days in three different months in 2011: June (low air temperatures and low relative humidity); September (high air temperatures and low relative humidity); and December (medium air temperatures and medium relative humidity). The measured dates are analysed allowing the comparison among different building comfort zones and also are used to calibrate the virtual model of the dynamic simulations. Three different building energy simulation program, EnergyPlus, Heliodon and Analysis Bio, are used to solve the energy balances and to evaluate possible limitations of the applied sustainable strategies in the cases. The main conclusion is that it is possible to identify, at the same time, technical limits of applied solutions that result in a thermal performance below his potential, and, a considerable reduction on the thermal demand of the modern naturally-ventilated houses.

Keywords: sustainable houses, thermal performance, naturally-ventilated houses, modern houses

1 Introduction

Before the establishment of the sustainable concept, the passive strategies were not treated as an important point in the sustainable roll, but it was just an architectural aspect inside on the architectural roll. Nowadays, sustainable strategies have not understood as architectural initiatives. However, the relation between this contemporary concept and the Brazilian modern architecture can be understood as a direct relationship. Although modern architecture is known as a product of a period characterized by a rupture with the tradition, history and the nature, the climate was the major factor in the Brazilian modern architecture, as Bruand (1997) states [1]. The climate and the tradition architecture elements were always present in the Brazilian modern architecture. However, the way as the "new architecture" is diffused for the country produces changes how historic and nature elements were treated in the architecture produced in the interior of the Brazil, as the modern naturally-ventilated houses built in the late 1950's and early 1960's in the city of Goiânia, capital of Goiás state, located in the Midwest of Brazil. (Lat. 16.41 S, Long. 49.25 W, Alt. 741 m/29,173.23 in).

This way, the paper studies the limitations of the application of sustainable strategies in housings designed before the establishment of this concept, comparing urban and architectural conditions focusing on calculating variations of internal hygrothermal conditions and estimating the periods of lack of comfort. Were considered the actual Brazilian normalization and the singularities indicated on the ResHB method about the internal thermal improvements, use of spaces and thermal zones differentiation [2].

The global informative evaluation method [3] was adopted defining two procedures of requirements and criteria verification: measurements and computer simulations. Seven rooms in two houses were selected (1 and 2), among the modern architectural heritage from the city of Goiânia. Indoor and outdoor air temperatures and relative humidity were measured with thermal hygrometric Data Loggers HT-500, during 91 days in three different months in 2011. The measurement and simulation period was defined considering the typical conditions of the reference year in accordance to the meteorological data from 1961–1990 [4, 5]: June (low air temperatures and low relative humidity); September (high air temperatures and low relative humidity); and December (medium air temperatures and medium relative humidity). All rooms of the houses were simulated with emphasis on the measured rooms. EnergyPlus Building Energy Simulation Program 4.0.0.024 was used to solve the energy balances and to evaluate the importance of the ventilation and the thermal mass in the buildings. Heliodon Program was used in the analysis of shaded openings. Analysis Bio Program was required to analyze the comfort level of the internal rooms using the measured data. Data from the measurements and simulations have been treated to allow comparison such as: year period, territorial scales (urban/ immediate surroundings), type of spaces (internal or external), different houses (1 and 2), functional sectors (social/intimate) and internal rooms (living room/ bedroom).

2 Case Studies

Goiânia is characterized by the continental and regular cyclic process of air mass displacements, implying a clear rainfall, causing the city climate to be formed by the composition of two main seasons: wet and dry (Aw according to Köppen) [6]. The dry season (May-September) is the most critical of the year, characterized by: temperature peaks, reaching 9,7 ºC (49.46 ºF) in June and 36,9 ºC (98.42 ºF) in September; and daily average air relative humidity below 65 %, reaching 11 % in September, as meteorological measured data shows. The solar irradiation in December is higher than in June, 3361 $W/m^2 \cdot day$ (1,066.13 $Btu/ft^2 \cdot h$) and 2708 $W/m^2 \cdot day$ (859 $Btu/ft^2 \cdot h$) respectively. But, because of the nebulosity of 80 % in December and 43 % in June, the insolation in December (161 h) is lower than in June (275 h) although the summer solstice daily hours are approximately 2 h more than winter solstice. Because this the south facade, struck by summer insolation, can be more transparent and free of solar protections. In opposite to the North facade, exposed to winter insolation, which should be well protected and more opaque.

According to ABNT NBR 15220-3 (2005) [7], the passive thermal conditioning strategies recommended are: in the summer, evaporating cooling, thermal mass for selective cooling and ventilation; in the winter, internal thermal inertia. This way, the characteristics of the surroundings have a greater influence in the environmental conditions during summer time, while the internal conditions of the buildings have bigger influence during wintertime.

The selected houses are: House Abdala Abrão, projected by David Libeskind and built in 1961 (House 1), and House Eurípedes Ferreira, projected by Eurico Godoy and built in the late 50s (House 2), both located at central area of the city, far from each other 280 m (306 yards) approximately. Both houses have 2 floors and a little service building on the back. Due to the topography, House 1 has the upper floor partially resting on the ground, allowing the main building access through this floor. Its intimate sector is located at the North side, oriented Northwest (Azimuth 343º), while the social areas are located at the South side. On House 2 is the opposite, the social areas are located at Northeast (Azimuth 44º) and the intimate at Southeast. As to shape, the design of House 1 is a square, with central covered patio while House 2 has an “L” shape. Externally both have a swimming pool, partially paved areas and permeable gardens with trees and grass.

3 Discussions and conclusions

The realized measurements identified, in both houses, June as a month with the best index with a good surround correction and good inside conditions. Even thought the location of the houses in the city, the application of evaporating cooling strategy as surround corrections actions, such as shading the external areas using vegetation, good soil permeability covered by grasses and the presence of water with the installation of swimming pools, showed a greater efficiency in the dry season.

For exception of the roof of the House 1, consisting of only one concrete slab layer, the thermal characteristics of the building envelope components of both cases appointed for a good design of external walls, roofs and openings, as shown in **Tab. 1**.

Tab. 1 *Thermal transmittance (U) and thermal delay (φ) of the building envelope components of the cases contrasting to ABNT NBR 15220-3 (2005) recommendations, between parentheses. (SF = floor surface; SV = ventilation surface)*

Components	Cases	Thermal characteristics and (ABNT recommendations)	
External walls	Both houses	$U = 2{,}25\ W/m^2{\cdot}K$ ($U \leq 2{,}2\ W/m^2{\cdot}K$)	$\varphi = 6{,}8h$ ($\varphi \geq 6{,}5h$)
Roof	House 1	$U = 2{,}95\ W/m^2{\cdot}K$ ($U \leq 2{,}0\ W/m^2{\cdot}K$)	$\varphi = 4{,}8h$ ($\varphi \geq 3{,}3h$)
	House 2	$U = 0{,}94\ W/m^2{\cdot}K$ ($U \leq 2{,}0\ W/m^2{\cdot}K$)	$\varphi = 12{,}2h$ ($\varphi \geq 3{,}3h$)
Openings	Both houses	$15\%{\cdot}SF < SV < 25\%{\cdot}SF$, except social sector $SV > 30\%{\cdot}SF$ ($15\%{\cdot}SF < SV < 25\%{\cdot}SF$)	

The simulations done with EnergyPlus Program pointed the elements of thermal inertia as the factor of higher intervention rate on the thermal performance of the studied cases. The principal architectural components about its influence were: the ceiling and the walls. The internal ceiling was pointed as the main responsible for heat accumulation during sun exposure and for the thermal delay on the buildings, resulting it to be the main re-emitter of heat during the last hours of insolation, increasing the temperatures in this period of the day. The walls were the responsible for heat emission during the first daily hours, reducing the peaks of minimum air temperature during this time of the day. Variations in the ventilation were carried out proving the importance of the selective ventilation in the period that the internal air temperature was higher than the external air temperature, contributing for air changes and improving interior air quality. Besides it the study evidences the needs of the night ventilation in this climate to contribute to reduce the effect of the thermal mass in the interior environment mainly in September, a month with high air temperatures and low air relative humidity, therefore, high diary thermal amplitudes.

The studies conducted from the Heliodon Program revealing the importance of the external walls at north façade of House 1. The greater solar protection efficiency is achieved by the buildings own shade, while the applied “brise soleil” become unnecessary. At House 2, the studies of insolation demonstrated the necessity of solar protection, mostly at the social areas, which receives direct insolation all day long during the year.

The simulations done with AnalisisBio Program pointed that passive solutions result in a zero energy demand in June. December presents more uncomfortable hours because the surround corrections are thought for dry seasons. Because this, the problem in December is the air humidity and it is not the air temperature. Although this, the most critic period of the year was September, when the conditioning air was used in the bedroom of the House 1, the unique utilization of the active system.

The architectural aim seems to be similar to the contemporary sustainable aim although it is possible to identify, at the same time, technical limits of applied solutions that result in a thermal performance below his potential, and, a considerable reduction on the thermal demand of the modern naturally-ventilated houses.

References

[1] Bruand, Yves, (1997). *Arquitetura Contemporânea no Brasil.* 3nd ed. São Paulo, BR: Perspectiva.

[2] ASHRAE. 2005. *ASHRAE Handbook-Fundamentals.* Atlanta: American Society of Heating Refrigeration and Air Conditioning Engineers, Inc.

[3] ABNT. ABNT NBR 15575-1:2008. 2008. *Residential Buildings up to 5 storied – Performance. Part 1: General requirements.* Rio de Janeiro: Associação Brasileira de Normas Técnicas.

[4] INMET. 2009. *Normais climatológicas do Brasil 1961-1990.* Brasília: Instituto Nacional de Meteorologia.

[5] INMET. 2011. *Rede de Estações. Superfície Automática.* [online] Available at: <http://www.inmet.gov.br/sonabra/maps/pg_automaticas.php> [Accessed January-December 2011]

[6] Fernandes, A. M. C. P.. 2006. *Clima, homem e arquitetura.* Goiânia: Trilhas Urbanas.

[7] ABNT. ABNT NBR 15220-3:2005. 2005. *Thermal performance in buildings. Part 3: Brazilian bioclimatic zones and building guidelines for low-cost houses*. Rio de Janeiro: Associação Brasileira de Normas Técnicas.