Thermal Performance Evaluation of Low Cost Housing in Santa Maria - Brazil

GIANE DE CAMPOS GRIGOLETTI [1], RENATA ROTTA [1], SÂMILA MÜLLER[1]

Centro de Tecnologia, Universidade Federal de Santa Maria, Santa Maria, Brazil[1]

ABSTRACT: The lack of thermal comfort of low cost housing in Brazil has been object of recurring research and efforts have been directed towards improving the thermal performance of housing. Developing local standards is important for thermal comfort evaluation. This paper presents the results obtained for evaluation of low cost single-family one-floor housing solution in the Santa Maria city, in the south of Brazil. Three methods are considered: simulation, survey and in situ measurement. Simulation (with software Transmitância) was based on Brazilian standards for thermal transmittance and time delay of walls and roofs. Survey was applied to thirty families that live in a same housing project. The used tool is a questionnaire about habits and domestic equipments such as stove, fan, heating, among others. In situ measurements were carried with HOBO © sensors during fourteen days. Outdoor and indoor air temperatures were measured for three different tipologies. The results feed an all-embracing research where simulation, survey and in situ measurement will be take for a larger number of houses in a larger period of time. The simulation, the survey and the in situ measurement result in the same undesirable thermal behaviour for the three houses analysed.
Keywords: performance evaluation; low cost housing.

INTRODUCTION

In Brazil the housing presents historically problems of thermal comfort and energy efficiency. This is mainly verified for low cost housing and its low performance has been subject of broad researches. The evaluation founds on the user's perception or computational simulations and measurements in situ. Studies have been developed with the intention of configuring guidelines for the project of low cost housing and define methods for evaluation for the Brazilian context. In 1993 thermal performance evaluation was proposed for single storey housing for low income families [1]. The method is based on consulting tables contend thermal parameters resistance and capacity for walls and roofs. The standards are defined according to eight bioclimatic zones not considered sufficient to arrange territorial dimension of Brazil. Three methodologies were studied by [2] (including the previous presented method). The methodologies were applied to five constructive systems housing in Londrina (city of Brazilian south region). The authors demonstrated that the previous approach cannot be applied to social and cultural conditions of the Londrina. Additionally the authors suggested thermal parameters such as thermal transmittance, time delay and solar factor and they demonstrated that these parameters can be applied to all house considered in the research. These studies contributed to define Brazilian standards for low cost housing. Simulations with softwares have been used and they are a important tool for testing alternative to low cost housing. Softwares such as Analysis, Thedes, Arquitrop, developed by a Brazilian research centers, Aiolos, developed by a Greek institution, among others, have been used to analyse the thermal behaviour of low cost housing and to propose improvements for housing configurations [3][4][5]. However thermal simulation with softwares requires its adjusting with field data with the aim of defining local references [4]. Several researchers have carried additional in situ measurements. Measurements of air temperature and relative humidity as well simulations were conducted by [5][6][7] and specific climatic conditions as well factors that influence the thermal comfort are considered.

All studies previously presented demonstrate the lack of thermal quality of low cost housing in Brazil and the need of defining local standards according to economic, cultural and social conditions. Therefore these studies demonstrate the importance of adopting approaches that allow considering local specificities.

Recently several studies have been developing with the purpose of measuring thermal behaviour of low cost housing in south of Brazil. A low cost housing prototype has been submitted to measurements and computational simulation [8][9]. The measurements consider indoor, outdoor air temperatures and relative humidity. Additionally efforts have been aimed to define minimum and satisfactory standards in accordance with

government resources [10], starting from local practice to define levels of acceptable performance.
This paper presents the results obtained for partial evaluation of three typologies of low cost housing built in Santa Maria, city in south of Brazil. The research intends to define thermal performance for local housing for the poor, initially considering two possible categories of solutions: appropriate to the local standard and no appropriate. In the future, other housing will be submitted to the same methodology in order to enlarge the categories according to several levels of performance. Additionally a broad in situ measurement will be carried for the present housing and others.

METHOD

The three houses were selected starting from the indication of local government responsible by the project and construction of low cost housing. The government indicated a settlement as a solution no advisable because the houses, along the time, presented problems of thermal comfort, according to the occupants' perception. The houses were selected starting from three typologies: one, two and three bedrooms and all of them have the same construction system (walls, roofs, fenestration) (see table 2).

The houses were submitted to measurements in situ for 14 days. Outdoor and indoor air temperatures were registered on an hourly basis. Two sensors were installed in each house and they were located on west and south sides of the living room close to the wall at approximately 2m above the floor. For house 2, an external sensor was fixed under the roof (on the edge) of the porch located in the south with the aim of measuring the outdoor air temperatures. Measurements extended from October 18th to October 31st (2008). The used equipment was a HOBO Temperature, Rh © Onset 1996. The comfort zone for developing countries according to [11] is used to analyze the thermal behavior of housing.

Additionally thirty occupants of thirty different houses (6 with one bedroom, 14 with two bedroom and 10 with three bedroom) answered to a questionnaire that intended to verify the occupants' satisfaction in relation to the thermal comfort, sources of heat inside the housing and habits in the use of the houses among others topics. Besides the measurements and survey, the construction was analyzed according to Brazilian standards for low cost housing [12] using the software Transmitância developed by LABEEE/UFSC. The Transmitância software allows calculated the thermal transmittance, time delay and solar factor for walls and roofs starting from a database with material thermal and physical parameters.

ANALYSED HOUSES

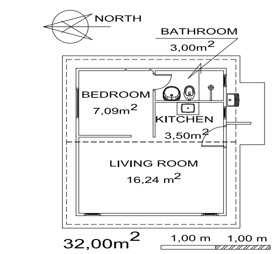
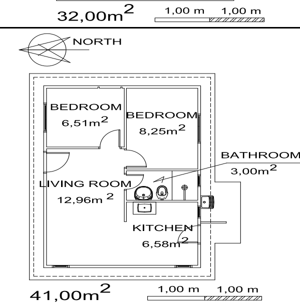
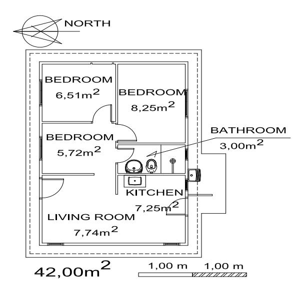
The three selected houses are located in an urban zone of the city in a low cost district. This zone is characterized by medium density (one-family houses in individuals plots) with 2,608 houses. The houses are made of concrete bricks fixed and plastered with mortar and the roofs are composed of asbestos cement and an internal layer of wood (see table 1). The three houses have porches placed at the south side.

Table 1: Building materials of analyzed houses

	Layer	External	Medium	Internal
Wall (light color)	Material	Cement plaster	Cement brick	Cement plaster
	Thickness	0,015m	0,07m	0,015
Roof (grey color)	Material	Asbestos cement	Air-camera not-ventilated	Light wood
	Thickness	0,006m	> 0,05m	0,008m

Table 2 illustrates the plan floor of the 1, 2 and 3 houses that have one, two and three bedrooms respectively.

Table 2: Floor plan of houses with 1, 2 and 3 bedrooms

House/bedroom	Floor plan
1 / one bedroom	
2 / two bedroom	
3 / three bedroom	

CLIMATE OF SANTA MARIA

Santa Maria is a medium city (250,000 inhabitants) located in the south of Brazil, in a region with subtropical climate. In the winter (June to September) mean minimum temperature varies between 9°C to 10°C. During summer (December to March) mean maximum temperature is between 28°C to 30°C. Minimum and maximum air temperatures registered for winter and summer between 1961 and 1990 were -2,8°C and 40,2°C respectively [13]. The regional climatic characteristics suggest the importance of bioclimatic strategies and the adequate choice of thermal parameters of walls and roofs since there are frequent hot spells with elevate relative humidity in winter. The summer is characterized by lower relative humidity presenting frequently daily swings higher than 10K.

FINDINGS

Simulation Simulations take into account the recommendations of Brazilian standards [11] that establish the lowest performance for low cost housing for different Brazilian bioclimatic zones. Santa Maria belongs to Bioclimatic Zone 2 that prescribes light walls and roofs. The simulation was carried with the software Transmitância developed by LABEEE/ UFSC. Table 3 illustrates the results for the three analyzed houses.

Table 3: Simulations for the three houses

	BioZone 2	**Simulation**	
Walls thermal transmittance ($W/m^2.K$)	≤ 3,0	4,24 $W/m^2.K$	
Wall thermal delay (hour)	≤ 4,3	2,4	
	BioZone 2	**Simulation**	
		summer	**winter**
Roof thermal transmittance ($W/m^2.K$)	≤ 2,0	2,2	2,6
Roof thermal delay (hour)	≤ 3,3	3,4	2,87

According to results both wall and roof do not satisfy the criteria of Brazilian standards. Thermal transmittance of the walls is very high (nearly 50%). Thermal transmittance of the roofs is also high for summer and winter.

In agreement with Brazilian standards, time delay could be lower. But the climate conditions of Santa Maria suggest that time delay could be larger, since associated to night ventilation of building and a appropriate thermal capacity of walls and roofs. Unfortunately the houses analyzed do not have windows with size sufficient to permit natural ventilation. The insufficient size of fenestration is a recurrent problem in Brazilian low cost housing due to cost involved in this subsystem of construction.

Survey Survey aims to verify occupants' satisfaction with the thermal comfort promoted by houses. Topics included in the survey were occupants' age and how long they have been living in the residence; how long daily they stay at home; if occupants consider the house hot in the summer; if they use fans or other cooling equipment and the period of time they use it; what is the hottest room; what room is more comfortable in the summer; if occupants consider the house cold in the winter; if they use artificial heating and the period of time they use it; what is the coldest room; what room is more comfortable in the winter; if the house is humid.

Interviewed occupants live more than five years in the houses (the oldest lives 24 years). They are thirty years old or more. The houses are occupied during all day or in the part of the day. All occupants consider their houses hot in the summer and all of them use fans at night and some of them in the afternoon. Nobody has air-conditioning equipments (according to their income level). The whole house is considered hot but mainly the west-facing living room. During the day occupants stay at backyard but at night they prefer stay at the living room (probably due to habit of watching TV in this period). In the winter, 67% of the occupants consider the house cold. Only 1,7% uses artificial heating occasionally (electric heater, firewood stove or air-conditioning equipment). The bedroom is considered the coldest room by 43% of the occupants. The living room is considered the coldest room by 30% of the occupants. In the winter, occupants prefer staying at the living room. The house is considered humid by 73% of the occupants.

Starting from the results presented above, the houses have unfavorable thermal conditions for both the summer as the winter but the thermal discomfort due to the hot (summer) is unanimous. This situation is associated to deficient ventilation system (windows do not promote sufficient ventilation and some of them do not have shadow devices). Additionally, building envelope with insufficient thermal transmittance contributes for the low performance.

In situ measurements The sequence of consecutive days is characterized as summer condition (maximum air temperatures above 29°C). Figure 1 illustrates indoor and outdoor air temperatures for the houses with one, two and three bedrooms respectively. The houses were occupied during measurements.

The results demonstrate that indoors air temperature, for the three houses, are very near to outdoors air temperature mainly for maximum air temperatures. This behavior can be associated to low thermal inertia of the houses, which causes their fast response to external changes of temperature. Indoor air temperatures are above the highest limit of comfort zone for developing countries (equal to 29°C) [11]. For house 2 indoor air temperatures are above outdoor air temperatures for

October 27th, 28th and 30th. Indoor air temperature reaches 30°C (October 28th) while outdoor air temperature reaches only 28°C. The same is verified for house 3. Also for house 3, indoor air temperature reaches 35°C (October 21st) while outdoors air temperature reaches 27°C).

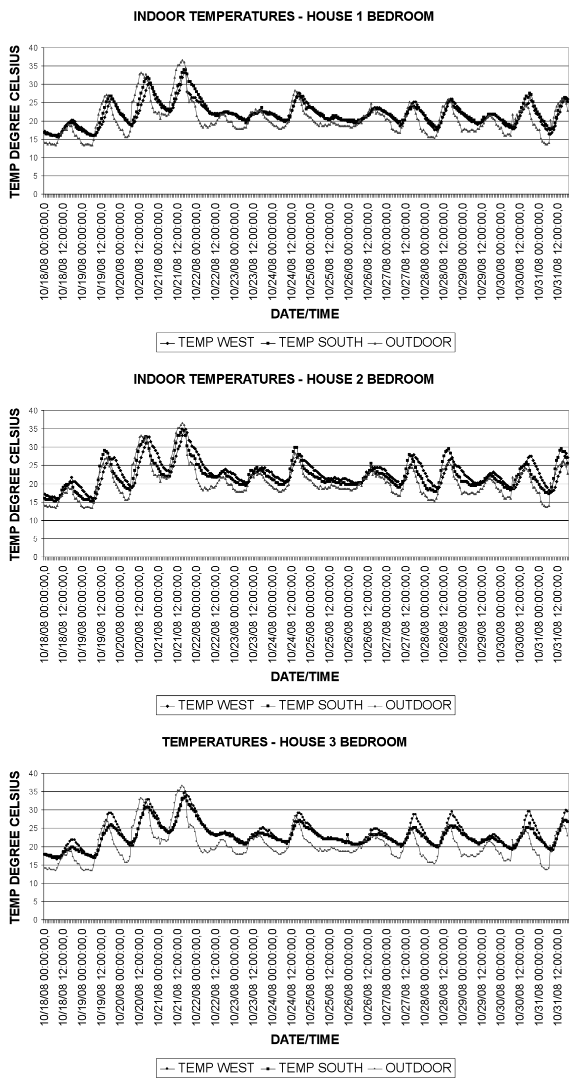


Figure 1: Indoors and outdoors air temperature for one, two and three bedrooms respectively

CONCLUSIONS

The three different methods used indicate the same result, that is, the housing standard analysed is not appropriate solution. For the two rooms analysed of house 1, there was no significant difference between indoor air temperatures. In other words, for small houses, solar orientation of rooms seems irrelevant for its thermal behaviour. However specific studies must be carried to support this hypothesis.

Starting from occupants' perception, summer conditions are more uncomfortable than winter conditions. This result indicates the importance of bioclimatic strategies that improve housing performance for high temperatures such as cross-ventilation, roofs with large edges, light colours of walls among others.

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REFERENCES

1.AKUTSO, M. et al. Método expedito para avaliação do desempenho térmico de habitações. Encontro Nacional de Tecnologia do Ambiente Construído. 3. 1995. Gramado.

2. LEMOS, P.; BARBOSA, M. Desempenho térmico em habitação popular: adequação de métodos de avaliação. Encontro Nacional de Tecnologia do Ambiente Construído. 5. 1999. Fortaleza.

3. KRÜGER, Eduardo; LAMBERTS, Roberto. Avaliação do desempenho térmico de casas populares. Encontro Nacional de Tecnologia do Ambiente Construído. 8. 2000. Salvador.

4. BARBOSA, M.; LAMBERTS, R. Uma metodologia para especificar e avaliar o desempenho térmico de edificações residenciais unifamiliares, aplicada a Londrina-PR. Ambiente Construído. 2 (2002) 15-28

5. MARROQUIM, F.; BARBIRATO, G. Avaliação do desempenho térmico e condições de conforto de um conjunto habitacional horizontal na cidade de Maceió – AL. Encontro Nacional de Conforto no Ambiente Construído. 7 2003. Curitiba.

6. BECKER, Maria de Fátima Monteiro. Análise do desempenho térmico de uma habitação unifamiliar térrea. 1992. Dissertação de Mestrado. UFRGS. Porto Alegre

7. KRÜGER, E.; GIVONI, B. Predicting thermal performance in occupied dwellings. Energy and Buildings 36 (2004) 301-307

8. SATTLER, M.; MORELLO, A. The monitoring of a low cost, more sustainable house. Conference on Passive and Low Energy Architecture. 22nd. 2005. Beirut.

9. GRIGOLETTI, G.; SATTLER, M. A.; MORELLO, A. Analysis of thermal behaviour of a low cost, single-family, more sustainable house in Porto Alegre, Brazil. Energy and Buildings 40 (2008) 1961-1971

10. GRIGOLETTI, G.; SATTLER, M. Thermal performance evaluation method for low cost single-family one-floor housing for Porto Alegre – Brazil. Conference on Passive and Low Energy Architecture. 25., 2008, Dublin

11. GIVONI, Baruch. Comfort, climate analysis and building design guidelines. Energy and Buildings 18 (1992) 11-23

12. ABNT – Associação Brasileira de Normas Técnicas – NBR 15220-1/2/3. Desempenho térmico de edificações. Rio de Janeiro: ABNT, 2005

13. INMET - Instituto Nacional de Meteorologia. <http://www.inmet.gov.br>. 2007