EVALUATION OF THE THERMAL PERFORMANCE OF LOW-COST HOUSES UNDER TROPICAL CLIMATIC CONDITIONS

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ABSTRACT The construction of dwellings for people with low incomes in developing countries encompasses a broad range of issues starting from the choice of the building site, to the construction phase and finally to the evaluation of the building itself. For tropical climates, the thermal evaluation of low-cost dwellings should be primarily related to the optimisation of internal comfort conditions.

Nevertheless, from the financial point of view, the improvement of thermal comfort conditions in low-cost housing should not result in a substantial increase in the final building costs.

In the present research, the impact of low-cost strategies for the achievement of better thermal comfort conditions, such as improved ventilation techniques and appropriate building design was analysed for a typical project of a low-cost dwelling in Brazil. In this paper the methodology developed and the simulation results for summer climatic conditions of the city Florianópolis (27.5°S) are presented.

It was possible to evaluate in a detailed manner the impact of several natural ventilation strategies for a single-storey building with the AIOLOS software. Using the outputs in the form of airflow data as inputs for the TRNSYS simulation environment, the potential of design strategies was then observed, and several design improvements were proposed.

1 Introduction

As part of an effort to present efficient solutions to the considerable housing deficit of about 5 million housing units, a strong necessity to redefine new low cost housing policies has been noted throughout the last decade, with several research projects dealing with the evaluation of building systems for the low income sectors of the Brazilian population.

Indeed, in several publications and congresses on this matter, the evaluation of low cost housing programmes apart from technical and constructive considerations goes from such aspects as the improvement of quality standards (Qualharini 1993), the social and cultural factors of building for the poor (Santos 1995; Kruger 1998) and those related to the improvement of thermal comfort conditions within the built environment (Mascaro & Mascaro 1992; Barbosa 1997).

Usually low cost housing programmes are implemented throughout Brazil equally, with no concern to the climatic region where houses are to be built. In this way, the same building system is applied in cities with very distinct characteristics. To correct these distortions, projects such as the research project *Normalização em Comfort Ambiental* (Standards Development for Comfort in the Built Environment) UFSC/FINEP are being developed in Brazil, with the aim of: helping to develop standards which promote buildings that are adequate for the climate.

The following research has as its principal objective the improvement of internal comfort conditions of low cost houses. Taking the most frequently adopted building system in Brazil as a reference and as a model for thermal simulations, it was attempted to identify possible causes for thermal discomfort, presenting low cost solutions which could lead to a more appropriate building design.

2 Methodology

Climatic data in the form of test reference years (TRY) was first used for an initial prognosis of the building regarding its climatic needs. Focusing the research on summer conditions, it was possible, using the ANALYSIS software, developed at the *Laboratòrio de Eficiência Energética em Edificações* of the *Universidade Federal de Santa Catarina*, Brazil (*LabEEE/NPC/UFSC*), to have a summary of the basic strategies needed to achieve better thermal comfort conditions, such as information concerning the degree of thermal comfort for those climatic conditions. The ANALYSIS software plots hourly climatic data on the psycrometric chart and presents a list of basic strategies to help promote better thermal comfort conditions within a given environment.

The building considered was then modelled as a volume, and the characteristics of its openings defined, with the AIOLOS 1.1 software, developed at the University of Athens, Greece, by Mat Santamouris and Elena Dascalaki (Allard 1998). With this software, the simulation of natural ventilation strategies, including the proper positioning of the building in order to get the best possible airflow rates, was performed. The simulation results were then used as input data for the TRNSYS 14.2 thermal simulation environment (SEL 1996).

Finally, the TRNSYS results were processed using the ANALYSIS software. and the degree of thermal comfort was observed.

3 The model

The building which was used as a model for the simulations was a typical low cost house, extensively built in regions with different climatic characteristics in Brazil. This kind of construction is widely used throughout Brazil.

The building (Fig.1) consists of one living room, two bedrooms, kitchen and bathroom. The final built area is $34m^2$. External walls are made of standard red bricks (e=10cm), covered by 2cm of plaster. There is a ceiling between the rooms and the attic. The roof is covered by red clay tiles.

The openings have an average area of $1.2m^2$, where single glazing is used. No kind of sun shading was used either for the openings (basic case) or for the external walls.

4 The climatic region

Simulations were made for summer conditions (January) in Florianópolis (27.5°S) with DBT averaging between 18°C and 36°C and daily mean temperature amplitudes of about 7K.

Analysing the results of the ANALYSIS software for these climatic conditions (Fig.2, Table 1: ANALYSIS Results for Florianópolis), about 90% of the total hours of January present thermal discomfort, mostly due to excess heat. With regards to natural ventilation, its contribution in terms of promoting thermal comfort for summer conditions in Florianópolis is high and amounts to 76.5%. Thus, natural ventilation is the main strategy for the improvement of thermal comfort conditions.

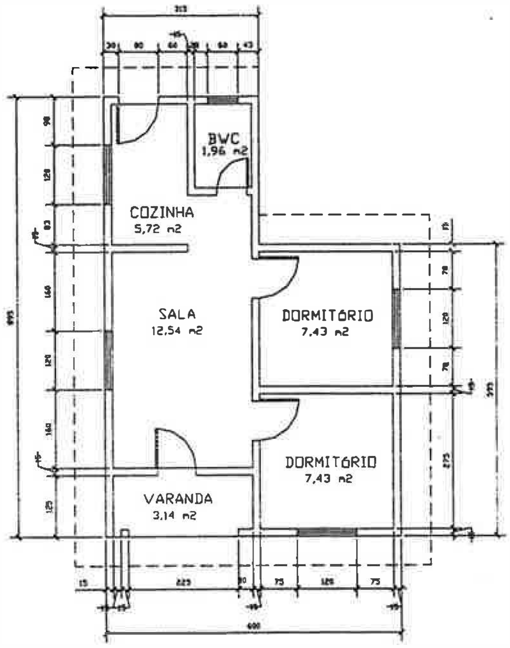

Fig.1 The model used

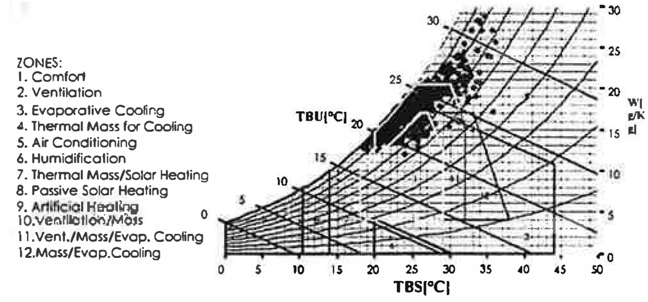

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Fig.2 ANALYSIS results for Florianópolis (January)

5 Simulation runs

Only those modifications to the basic model which would not mean substantial expenditures to the builder/user were considered, keeping the construction system. With this in mind, the following simulations were made:

1. ventilation during the day (6-18h) through slide windows (ventilation area = 50% of window area) and night ventilation through louvers
2. night ventilation (18-6h) through slide windows and during the day through louvers

3. ventilation during the day (6-18h) through whole windows (ventilation area = 100% of window area) and night ventilation through louvers
4. night ventilation (18-6h) through whole windows and during the day through louvers
5. ventilation during the day (6-18h) through whole windows and night ventilation through louvers with ventilated attic
6. night ventilation (18-6h) through whole windows and during the day through louvers with ventilated attic
7. ventilation during the day (6-18h) through whole windows and night ventilation through louvers with ventilated attic, roof painted white
8. night ventilation (18-6h) through whole windows and during the day through louvers with ventilated attic, roof painted white
9. ventilation during the day (6-18h) through whole windows and night ventilation through louvers with ventilated attic, roof painted white, ceiling with 2cm insulation material
10. night ventilation (18-6h) through whole windows and during the day through louvers with ventilated attic, roof painted white, ceiling with 2cm insulation material

Table 1 ANALYSIS Summary for January

GENERAL	HEAT	COLD	BIOCLIMATIC STRATEGIES
Comfort: 9.17% Discomfort: 90.8% Cold:3.19% Heat:87.6%	Ventilation: 76.5% Thermal Mass for Cooling: 0.833% Evap.: 0.694% Air Conditioning: 11.1%	Thermal Mass/ Solar Heating: 3.19% Passive Solar Heating: 0% Artificial Heating: 0% Humidification: 0%	Ventilation: 75.7% Ventilation/Mass: 0.139% Ventilation/Mass/Evaporative Cooling: 0.694% Thermal Mass for Cooling: 0% Mass/Evaporative Cooling: 0% Artificial Heating: 0% Comfort: 9.17% Thermal Mass/Solar Heating: 3.19% Passive Solar Heating: 0% Air Conditioning: 11.1% Evaporative Cooling: 0% Humidification: 0%

6 Results

With the simple improvements to the basic model it was possible to observe a reduction in terms of temperature of 6.2K, comparing the first with the last simulation case (Fig.3: temperature graph for the first and for the last simulation cases).

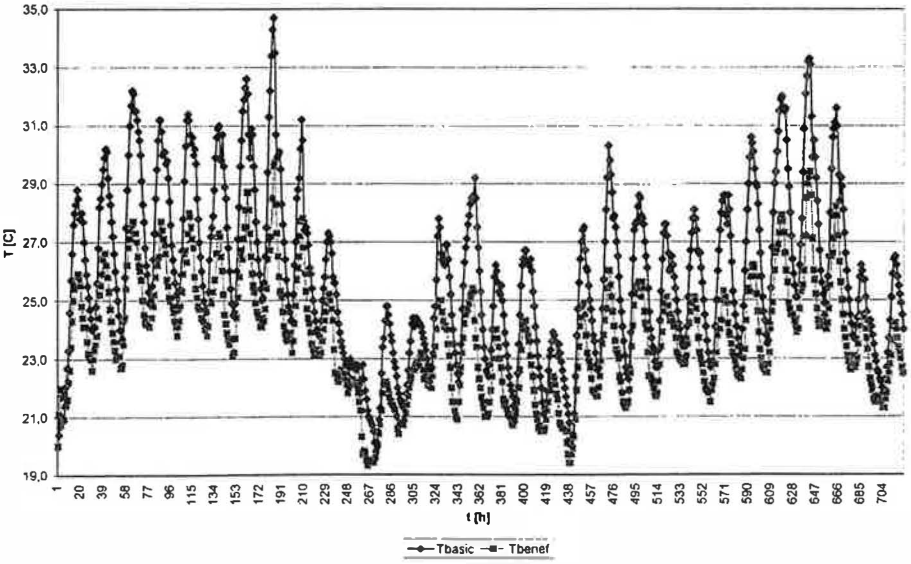

Fig.3 Basic model / optimised model

Examining each simulation separately, it was possible to draw the following conclusions (Table 2: Simulation Summaries):

Table 2 Simulation summaries

Simulation	Comfort Conditions	T_{max}	ΔT ($T_{max, outside} - T_{max, inside}$)
1	Comfort:6.95%; Discomfort:93%; Cold:0.139%; Heat:92.9%	34.7	1.2
2	Comfort:8.48%; Discomfort:91.5%; Cold:0%; Heat:91.5%	33.2	2.7
3	Comfort:7.37%; Discomfort:92.6%; Cold:0.417%; Heat:92.2%	35.0	0.9
4	Comfort:8.34%; Discomfort:91.7%; Cold:0.974%; Heat:90.7%	33.2	2.7
5	Comfort:9.46%; Discomfort:90.5%; Cold:0.695%; Heat:89.8%	34.6	1.3
6	Comfort:12.2%; Discomfort:87.8%; Cold:1.81%; Heat:86%	31.9	4.0
7	Comfort:11%; Discomfort:89%; Cold:1.25%; Heat:87.8%	33.9	2.0
8	Comfort:17.5%; Discomfort:82.5%; Cold:2.64%; Heat:79.8%	29.9	6.0
9	Comfort:10.7%; Discomfort:89.3%; Cold:1.53%; Heat:87.8%	33.9	2.0
10	Comfort:17.7%; Discomfort:82.3%; Cold:2.5%; Heat:79.8%	29.7	6.2

- more night ventilation and a reduction of the solar radiation directly transmitted through the openings to the interior (used shading factor of louvers =75%), contributed minimally to the improvement of thermal comfort inside the envelope. ANALYSIS summaries show that the period within the comfort zone rises, from 6.95% (50 from a total of 720 hours in January) to 8.48% (61h).
- the doubling of the window opening area (50-100%) was not relevant to the improvement of thermal comfort. As in the first simulation (slide windows), inside temperatures already show values close to the outside temperatures, increases in the airflow rates would not mean substantial temperature reductions. The comfort levels were 7.37% (53h) and 8.34% (60h), in comparison to 6.95% and 8.48%, for day and night ventilation, respectively.
- through the ventilation of the attic further reductions of the inside temperatures in relation to the first and the second simulation cases were 1.6K (day ventilation) and 1.9K (night ventilation). Comfort levels were 9.46% (68h) and 12.2% (88h) of the total simulated hours, respectively.
- a lower solar absorption of the roof material (white paint) was responsible for a reduction up to 3.8K (day ventilation) and 6K (night ventilation), compared to simulation 1 and 2. Comfort levels reached top values: 11% (79h) and 17.5% (126h).
- further reductions of inside temperatures and improvements of thermal comfort levels were not substantial for the simulations with the insulated attic. The removal of heat inside the attic with ventilation and the minimisation of solar gains with white paint proved to be sufficient to reduce the enormous heat load from the ceiling.

In conclusion, using low cost solutions which require only small changes to the building design, a substantial reduction in thermal discomfort inside a given building could be reached. Other improvements to thermal comfort conditions could be reached by using other building materials and by redefining the building design. However, the discussed solutions could help improving comfort levels for the summer period in many similar regions where the analysed construction system was applied.

7 References

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