

Simulation assessment of bioclimatic strategies to improve thermal behaviour of a lightweight building prototype

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ABSTRACT: In Uruguay, get more often the use of lightweight building system with low thermal inertia to build dwelling for low resources people, for that reason it is essential to rationalize costs. The studies made, the users opinion and technical information available showed that it is necessary to investigate about lightweight building system so as to improve its thermal behaviour.

The aim of the task was to identify the influence of some passive design strategies in the interior temperature fluctuation and energy consume of a lightweight prototype located in Montevideo, Uruguay. The prototype is made with polystyrene panels finished with metallic sheet. Methodology: Temperatures and humidity have been being collected during the application of different strategies: solar protection, thermal mass and solar protection plus thermal mass. Ventilation strategy was use as a control variable. The same strategies were analysed to asses its thermal performance by running the simulation programs. First of all it was determinated which of the programs faithfully represented the thermal performance of the prototype, choosing: Simedif program. Results: The evaluation by predicted performance shows that the most energy efficient strategy is the one which associate solar protection and thermal mass.

Keywords: simulation, bioclimatic strategies, energy and comfort

NOMENCLATURE

Text	Exterior temperature [°C]
Tn	Minimum absolute temperature [°C]
Tx	Maximum absolute temperature [°C]
<i>U-value</i>	Thermal transmittance [W/m ² K]
CTm	Mean thermal storage [kJ/m ² K]

1. INTRODUCTION

In recent years, the use of light weight building system with low thermal inertia in Uruguay got more often to build dwelling for low resources people. The knowledge of their thermal behaviour is essential in sub

developed countries, where most of the people do not have enough money to afford comfort conditions with additional economical costs.

This paper summarizes part of the results obtained of an extensive investigation which initial aim was to improve knowledge of light weight thermal and energy behaviour

and to give guidelines design to adapt this building system to our climate.

It is focused on the simulation analysis of: a- Thermal assessment of a light prototype made with an available technology; b- Thermal and energy assessment of passive strategies behaviour c- Thermal and energy behaviour comparison between both the light weight and heavy weight prototype.

The thermal monitoring started on December 19, 2005 and ended in December 31, 2006.

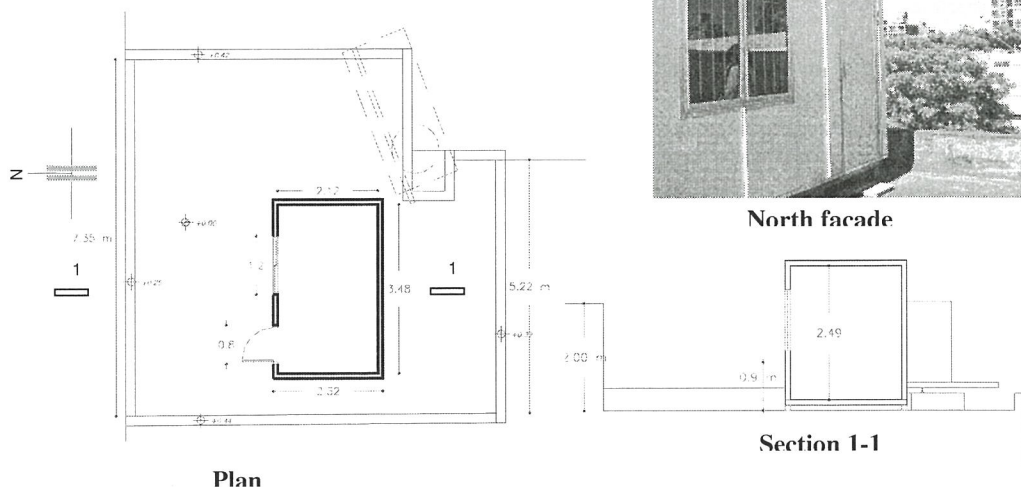


Figure 1: Light weight prototype, plan and section

The prototype is made with polystyrene panels finished with metallic sheet. The nuclear of polystyrene has a density between 16 and 20kg/m³, $U\text{-value}=0.33 \text{ W/m}^2\text{K}$. The weight is approximate 680 kg, is to say 17 kg/m² low-inertia. The exterior dimensions are 3.68m x 2.33m x 2.59m high. It has only one room, the thickness of the wall is 0.1m, in the north wall has a window of 1.20m x 1.20m, without solar protection, and a door of 0.9m x 2.10m made with alike panels.

The building was located in the roof of Faculty of Architecture in Montevideo (34° 58' south latitude and longitude 56° West), (see fig 1).

Montevideo has a template climate with maritime influence, the mean temperature arises in January (hottest month) 22.5° and 10.5° in July (coldest month). The hot period is shorter than the cold one, and winter temperatures are more rigorous.

The amplitude of external temperature reaches 10°C. Montevideo bioclimatic chart shows the thermal inertia and solar protection are suitable design strategies for our weather conditions. For that reason we try to confirm their suitability.

The interior prototype thermal climate was monitored and simulated.

The aim of this paper is to assess bioclimatic strategies to improve thermal behaviour of a lightweight building prototype through a detailed simulation program. It was a priority to improve comfort conditions for users and minimize the additional cost of energy.

2. METHODOLOGY

Simulation programs are excellent tools to pre-design stage, investigate, and to rapidly visualize thermal and energy behaviour of a building. They allow to assess different design strategies applied to a building in a certain environment. Changes could be made more easily and better manager than experimental method, and verification become simpler. Furthermore, the user has the freedom to introduce global or local changes, focus on a single room, propose solution and show rapidly how its thermal behaviour can affect the system [1].

The simulation process was developed with Simedif computational program.

Simedif had a good correlation [2,3] with experimental data (see fig. 2).

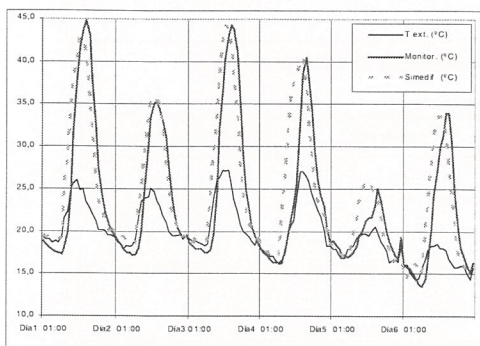


Figure 2: Monitored and simulated interior air temperature with free floating

. The simplified simulation programs do not adjust predictions with the thermal light prototype behavior situated in Montevideo. The correlation between strategies simulation showed adjust problems with minimum temperatures monitored in Energy Plus.

2.1. Strategies simulation

We compare free floating (prototype without any modified) with some passive strategies. in order to assess the thermal and energy behavior of the prototype using a simulation program.

2.1.1. Summer season strategies

To simulate each strategy we define a typical summer week, from 27-12-05 to 02-01-06, with similar weather conditions days. The input external air temperature data was recorded in our weather station near the prototype. The solar radiation was calculated from cloudiness registered. The strategies simulated were:

Strategy 1: Thermal mass

We added 102 bricks, 0.25 x 0.25 x 0.12 m, density 1900 Kg/m³, U -value mean= 3.85 W/m²K, CTm=111 kJ/m²K (see fig 3) on the insulated floor.

Strategy 2: Solar protection

We put a solar protection in the north window, which shadow factor =0.70 (see fig 3). U -value= 6 W/m²K.

Strategy 3: thermal mass and solar protection.

We applied at the same time thermal mass and solar protection (see fig 3).

2.1.2. Winter season strategies

As we did in summer we define a typical week of winter, from 14-08-06 to 20-08-06, with similar weather conditions days. In winter we repeat some of summer strategies. Strategy 1: Thermal mass (see fig. 4) the same as summer.

Strategy 2: Thermal mass and solar protection (see fig. 4) the same as summer.

2.2. Comparison light weight vs heavy weight building prototype

Finally we compare thermal behavior and energy consume of light weight prototype and the other one heavy weight. This heavy weight building simulate has the same volume of the prototype and only one room. The insulated wall are made of double bricks, U -value= 0.82 W/m²K. The roof was concrete and had expanded polystyrene (thickness 0.04 m), U -value=0.72 W/m²K, thermal mass= 298 kg/m².

3. RESULTS

3.1. Summer season strategies

The strategy of thermal mass and solar protection was the best thermal performance for this period of time.

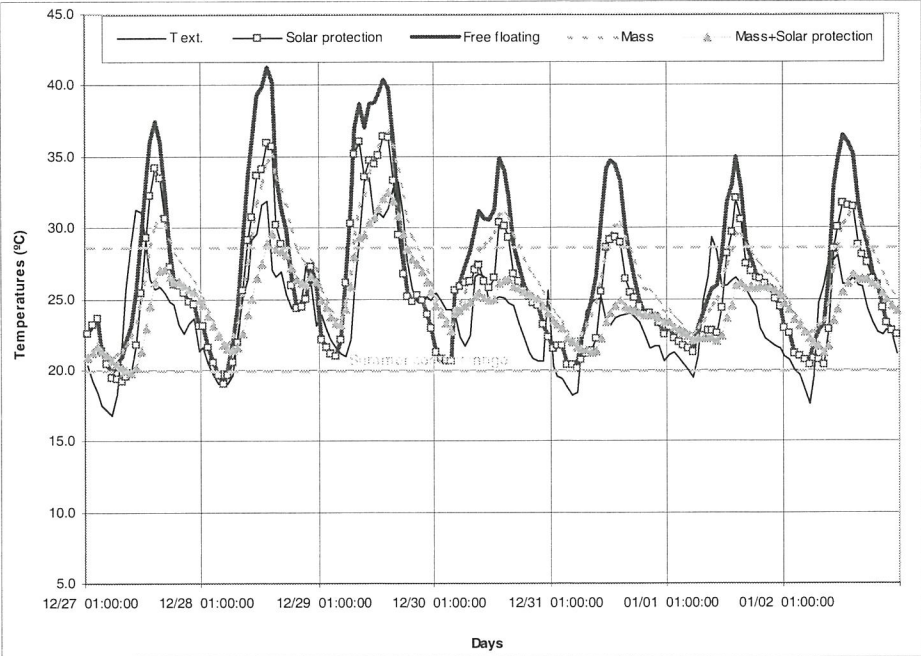


Figure 3: Simulated strategies for one week in summer season

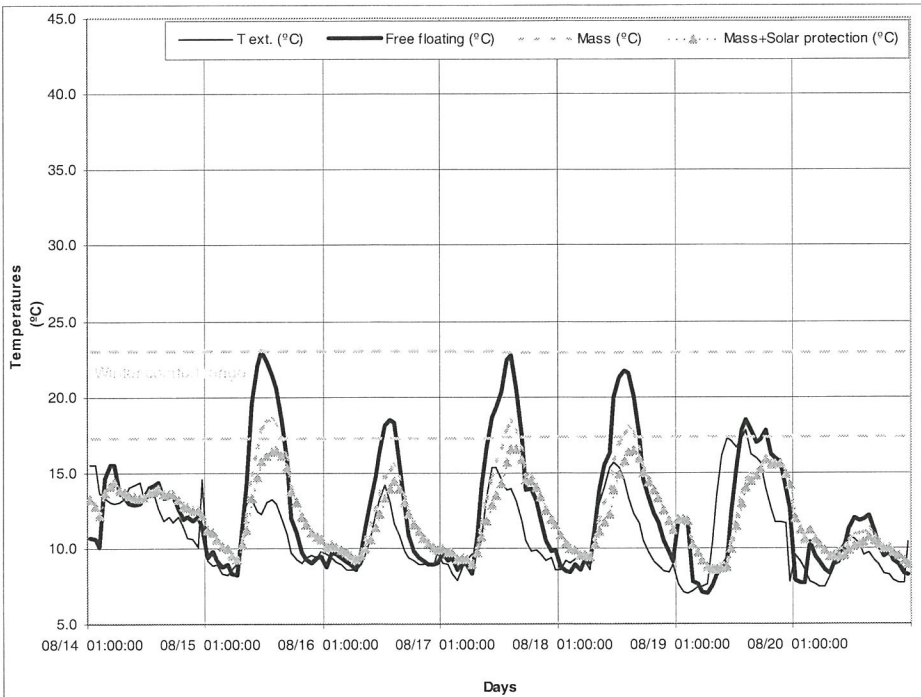


Figure 4: Simulated strategies for one week in winter season

The lightweight prototype in free fluctuation showed a great air temperature oscillation (more than 10°C) because of overheating. For that reason interior air temperature were far from comfort range. While the exterior air temperature was 33,5°C the interior one was 41,3°C. There was not delay between interior and exterior air temperature. In sunny days occurred the maximum temperature peaks, because the prototype easily gained solar energy (see fig 3).

When we introduce changes to the prototype we observed that most of the interior air temperatures strategies simulated were in the summer comfort range. Although we noticed temperatures out of this range happened during midday hours (see fig 3).

The thermal mass and solar protection strategy showed the less value of maximum interior temperature, more over obtained 80% of comfort hours against 60 % of hour for free floating. In low interior temperatures, there were not significant differences between strategies.

While the solar protection strategy delayed one hour the swinging of the prototype temperature in free floating, mass and mass plus solar protection delayed two hour the response. The protection strategies were the best design decision for extreme temperature values. In relation with energy consume mass with protection need eight times less for refrigeration than free floating., four times less than protection and four and a half than mass.

3.2. Winter season strategies

As we say in the begging none strategies could present a good thermal performance in winter season. The exterior temperature are far from comfort range temperature (18°C-24°C) in winter.

The mass with solar protection strategy reached lowest temperatures. The maximum

absolute interior temperature was 16°C, for that reason we have to design properly solar protection because it would influence the solar gains (see fig 4).

Free floating presented the highest interior temperature (23°C), while exterior temperature was 14°C, although there were almost 100% of discomfort hours.

3.3 Energy consumption: Comparison light weight vs heavy weight building prototype

In comparison the light prototype always needed more supplied energy than the traditional prototype (see table 1).

Table I: Energy consumption

	Light prototype		Traditional prototype	
	Winter season	Summer season	Winter season	Summer season
	Heating (KW)	Cooling (KW)	Heating (KW)	Cooling (KW)
Free fluctuations	755	544	146	120
Solar protection	911	132	150	87

If we consider summer and winter season energy consumption to maintain comfort conditions the light prototype needed five times more than the traditional one.

Additional to the mass in summer it was an excellent strategy set a solar protection, because reduce significantly refrigeration energy required. In all cases heating energy needed was more than cooling one.

4. CONCLUTIONS

The light prototype thermal assess showed that there was an extremely high oscillation in interior air temperature, and this oscillation was higher than the exterior one. This is not desirably situation, it is exactly the opposite one.

The higher interior amplitude was a consequence of increase temperature, once the prototype heated by solar gains or heat

fluxes because it had low capacity to control heat fluxes in a period of time (storage and transfer energy to the environment) and a low dissipate heat because of its low transmittance.

For this reason in summer season interior air temperature surpasses the higher value of thermal comfort range in many hours. In winter the problems is the minimum temperatures, they could not reach comfort values in 99% of hours. To increase comfort hours we need to introduce passive strategies to save energy.

In summer if we associate mass and solar protection to the initial situation (free floating), the results showed: lower peaks and oscillation interior air temperature and lower energy consumption in comparison with light prototype. What is more, interior comfort hour increases but energy consumption is more than the heavy weight prototype.

In summer season the design strategies to apply in a light weight system building (low inertia) are complex and integrate [4].

In winter season the light weight prototype reached a similar thermal behaviour and energy consumption to the strategy with mass. For that reason the added thermal mass did not modified its behaviour in winter season, as we could see in summer. The overheating in a punctual problem, could be controlled with solar protection

The evaluation by predicted performance shows that the associate strategy 'solar protection and thermal mass' is the most energy thermal efficient for a whole year. This result needs to be contrasted and adjusted so as to obtain better result in air interior temperature and energy save. We notice that we have to improve the knowledge about added thermal mass position and its quantification.

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