A LOW ENERGY HOUSE IN WARM HUMID REGION OF BRAZIL

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ABSTRACT. The paper presents an environmental analysis of a single storey house located in Maceio', Brazil. It comments on the house design and environmental performance, based on measurements done on site and on computer simulations. The interest of the study lies on the fact that the building has been used for four years with the inhabitants making no use of mechanical equipments for cooling (heating is not used at all in the region). The aim of this case study is to show that there is scope to design adequate buildings, in warm and humid areas, where the use of air conditioning would be drastically reduced, and even eliminated for many of the buildings purposes.

1. Introduction

The paper refers to a house designed to reach comfortable spaces in a warm humid region. This section gives a rough idea of the area's climatic characteristics. Section 2 describes the building design principles and its components and analyses its environmental performance. Section 3 presents the simulations and measurement results obtained for a summer period while section 4 suggests some steps to improve the building performance.

The town of Maceio' is located at latitude 10deg South in the Brazilian coastal area. It has a warm and humid weather almost all year round. The annual mean temperature is 25 degC. The maximum mean DBT is 29 degC and the minimum mean is 21 degC, which gives an annual amplitude of about 8 degC. In the summer the mean air temperature is 27 degC while in the so called 'winter' is about 24 degC (1).

The mean relative humidity of the air is 81%. In summer it reaches 70% as average and in 'winter' it may go up to 99% during some nights.

Sky nebulosity varies from 6.9 (1/10) in June to 4.5 (1/10) in November. Solar radiation is strong and varies from 12 MJ/day on winter, to 27 MJ/day on summer (1).

There is a constant breeze coming from the ocean and predominant wind directions are placed within the East quadrant. In the wintertime the mean wind speed is around 2 m/s while in the summertime time the mean wind speed goes up to 4 m/s. The calm periods represent 8.2% of the day duration as an average, and occur mainly between 2:00 and 6:00 h (2).

It is also important to state that local population always wear light clothes and that there is no heating appliances at all. Cooling is the target.

S. Alvarez et al. (eds.), Architecture and Urban Space, 399–404.

2. The Building Design Principle and Environmental Performance

The house is located on an urban plot measuring 12.00 m on the frontage and 23.00 m depth. It is located some 200.00 m from the ocean in a low density area where most of the buildings are single storey constructions.

The design strategy was to divide the plot into three zones (service, social and private/study) in order to assure that every zone has an inlet facing the predominant winds, and to reach an integration between inside and outside spaces. To guarantee an adequate air speed, the building was located back in the plot, where it could also benefit from the large tree's shading. See Figure 1 and 2.

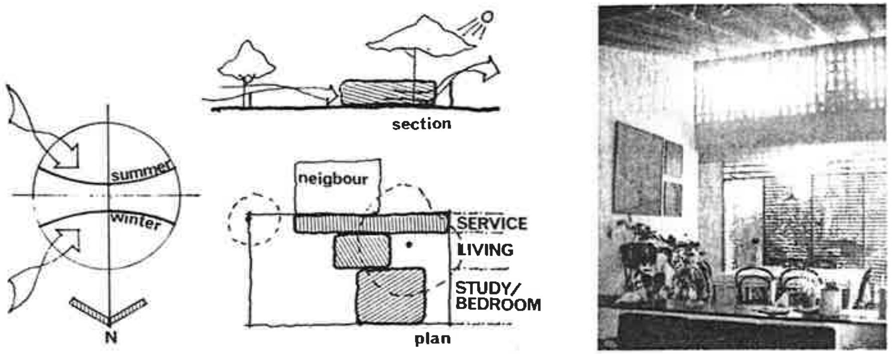

Figure 1. Site Layout (left) and interior view looking from the living room toward the courtyard (right).

KEY:
1- verandah
2- living/dining room
3- bedroom
4- studio
5- bathroom
6- gardening dep.
7- deposit
8- kitchen
9- washing area
10- car port
11- courtyard
12- roof garden
13- water tank

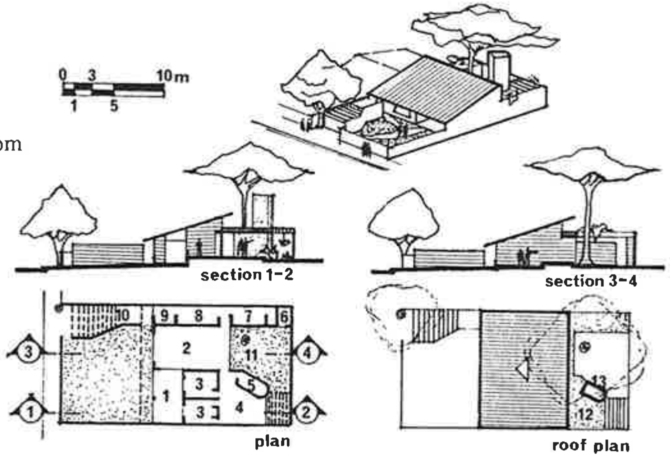

Figure 2. Plans, sections and isometric view.

The building design shows some problems related to the internal layout. The bedrooms, for example, may present some discomfort during hot days peak hours (13:00 to 16:00 h), due to the roof bad insulation. Here, daylighting appears to be insufficient during in cloudy days.

The studio does not present the ventilation rate expected by the architect. Part of the airstream, coming through the bedrooms' windows, goes out through the perforated block located between the roof-garden and the pitched roof. Daylight is insufficient in the back of the room and artificial light is necessary most of the time as shown in Figure 3.

In the living room and kitchen the roof radiation effect is reduced because of the much larger openings (See photo in Figure 1) and also because they are partially protected, by the existing tree, from solar radiation.

Though the kitchen performs well in thermal aspects, it needs artificial lights to be turned on especially in cloudy days. The other rooms present no environmental problems.

The verandah plays an important role to the living and bedrooms comfort, especially during raining days, when it allows the louvres of these two rooms to remain open. It also protect part of walls and openings from the East insolation, though reducing daylighting inside bedrooms. The verandah is located leeward working as a windcachter, improving ventilation in living and bedrooms due to Venturi effect.

Some components design and location play important roles in the house performance, namely roof, windows, perforated blocks and pergolas.

There are two kinds of roofs. The pitched one and the roof-garden. The first consist of blue tiles over a wooden ceiling. Due to its colour it absorbs a lot of solar radiation (68%). The later, consisting of a flat concrete slab and 0.30 m of earth, covers the studio and service area.

Figure 3. View from the studio, showing the lights on.

The gap between the two roofs are filled with perforated blocks.(See Figure 4). The time-lag produced by the roof-garden has a buffer effect during peak hours but it rises internal temperature during summer nights. Figure 5 shows the time-lag and decrement in external air temperature produced by the roof-garden.

Due to its movable louvres, the windows allow a good solar control and permanent air flow. The sill height (0.50 m) brings ventilation to pass along occupants body. Since the fanlight is open, there is always air movement close to the ceiling. See Figure 4.

The perforated blocks forming a screen wall are located between the pitched roof and the flat one, along the whole building width, facing West. It is made of precast concrete and is coloured grey, absorbing part of the afternoon solar radiation. Due to its shape it doesn't obstruct the sun beans after 16:00 h. The daylight it could provide is reduced by its dark grey colour.

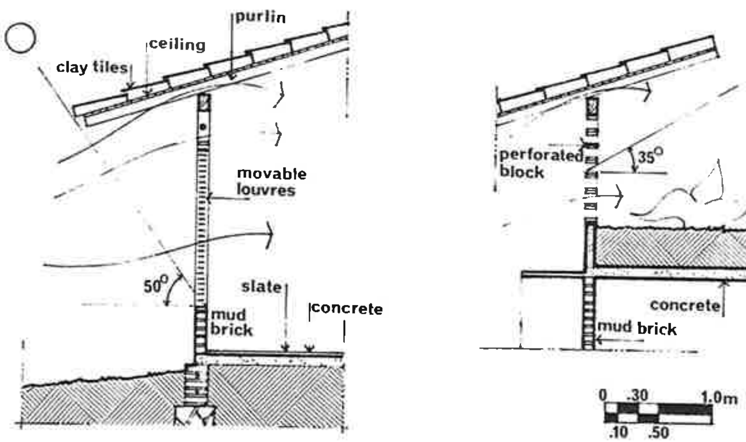

Figure 4. Detail of movable louvres, perforated blocks and roofs.

The pergolas covering the studio's internal garden works as ventilation outlet and avoids completely the sun penetration. However, it turns the room illuminance level lower than the necessary for its function.

3. Simulations and Measurements

Simulations have clarified how effective is the shading produced by the large tree and the consequent reduction on the radiation received by the roofs. Figure 5 introduce the results of software modelling of the house showing shading produced by the trees in summer and winter solstice, considering clear sky. It has shown that considering the tree opaque it would reduce the insolation by 67% and 89% for the tilted roof and the roof-garden, respectively, in the summer solstice. In winter solstice these figures change to 47% and 46% respectively. Internal and external air temperature near the two kinds of roofs above referred, were measured for summer typical days during 1991 summer. Results are presented in Figure 6 below.

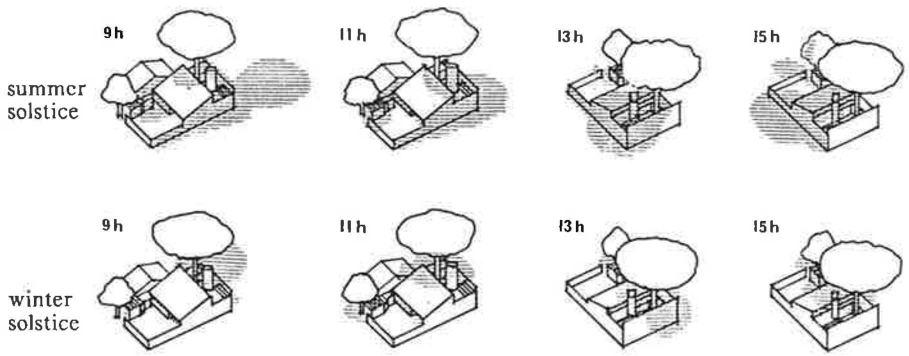

Figure 5. Shading produced by the tree.

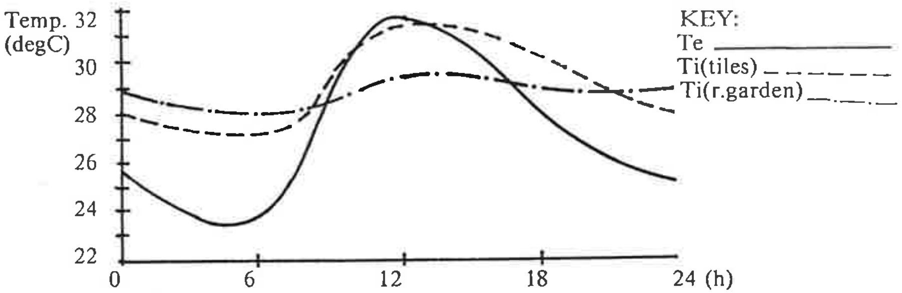

Figure 6. Internal and external air temperature for typical summer days.

Daylight levels were measured for typical summer sky at 9:00 h, 12:00 h and 15:00 h in all rooms having perforated blocks (Figure 4) on it, in the center of each room at 0.80 m height. First considering its concrete grey colour. Then the blocks were painted white and new measurements were carried on in order to examine the effect of this very simple step. Results are presented in Table 1, where room number are the same as in Figure 2. One can note though significant improvements may occur, daylight levels are below those required for these rooms' functions, introducing daylight is the main environmental problem encountered.

The same procedure was performed with the pergolas, where was found an increment in daylight levels of the order of 155% in the center of the studio and 105% in the back of it. Even so, illuminance levels encountered were not enough for reading and drawing tasks.

TABLE 1. Influence of block colour on illuminance levels (lux)

	concrete grey			white paint			increment (%)		
time	9:00	12:00	15:00	9:00	12:00	15:00	9:00	12:00	15:00
room									
2	47	70	41	68	99	59	45%	41%	44%
3	21	23	17	41	33	33	95%	43%	94%
8	26	19	31	41	30	33	58%	58%	6%

4. Conclusions

From the data presented one may conclude that though the building is not using any cooling device, it can perform in a better way if some improvements were to be introduced.

a) The roof tiles can be given a higher reflectance in order to avoid the strong solar radiation. If the ceiling is placed below the purlins with an aluminium foil above it, part of the heat transmitted by the tiles will be reflected and an air gap between the tiles and the ceiling will be created.

b) The bedrooms windows can be better located, in order to propitiate a better ventilation distribution, and maybe a bigger size to improve the air speed (reduced by the necessary use of mosquito screens). The present position do not allow air flow to reach the corners of the rooms where the beds are located.

c) The implementation of white painted perforated blocks and pergolas shows significant improvements. However, the introduction of other perforated block types would reach the required illuminance levels without compromising thermal performance. Also, if the louvres colour (now dark brown) is changed to lighter colours one certainly will obtain much better results regarding daylighting.

Part of the modifications above suggested would change some of the house aesthetical characteristics, especially the roof colour. But most of them would neither affect the architectural composition nor the construction budget and would save on mechanical equipments and future electricity bills.

References

(1) Lima, B. et Bittencourt, L. (1983) 'Analise do Clima de Maceio', Report for Departamento de Arquitetura da UFAL, Caderno de Arquitetura e Urbanismo no.1.

(2) Carneiro, C. et al. (1986) Sistematizacao de Dados Climatologicos do Recife, SUDENE/UFPE, Recife.