ENVIRONMENTALLY FRIENDLY CITIES, Proceedings of PLEA'98, Lisbon, Portugal, June 1998
Pages 253-256

An environmentally conscious house for Tamare, Venezuela.

An architectural proposal for warm humid climates

PABLO LA ROCHE, FRANCISCO MUSTIELES, MARIA V. MACHADO, IGNACIO OTEIZA AND ELIZABETH SAEZ

Instituto de Investigaciones de la Facultad de Arquitectura, Universidad del Zulia,
Apartado Postal 15399, Maracaibo, Venezuela
plaroche@luz.ve

Abstract

A bioclimatic house for Tamare, Venezuela, designed to provide psychological, physical and social well being through improved comfort and less energy consumption is explained. Digital and analog models were built to analyze sunlight and shadow behavior and computer simulations to predict thermal performance. Assuming a maximum comfort temperature of 30° C we achieved 95% of satisfaction when we ventilated at night and closed the building during daytime. Some bioclimatic principles integrated in the design are: 1) minimization of solar radiation gains through windows, using solar protection and exterior building facades to generate shadows 2) minimization of conduction heat flow and thermal amplitude by adequate positioning of mass and insulation 3) control of airflow through windows, and 4) use of vegetation to diminish surrounding air temperature. Some passive cooling techniques are: 1) comfort ventilation and 2) nocturnal convective cooling. Mechanical cooling can also be used in combination with passive cooling principles. Construction of the Tamare house will begin in mid 1998 with funding from PDV, the national oil company. Indoor thermal and air quality parameters will be monitored after construction to evaluate its performance.

INTRODUCTION

Venezuela is the country with the greatest annual per capita electrical consumption in Latin America. In the Maracaibo lake basin, 40% of electrical consumption is accountable to the commercial and residential sector, and in buildings with air conditioning, about 75% of energy consumption is used to provide mechanical cooling, making this one of the regions with the greatest per capita energy consumption in America.

The bioclimatic conception, many times perceived as a novelty, is no more than the prolongation of concepts transmitted by individual generations, not architects, based on an intuitive knowledge of the environment and the climate. It is possible to learn much from vernacular architecture especially the concepts of respect towards the site and construction systems of the buildings. Three models of climate sensitive architecture have existed in Maracaibo: (i) the palafitic paraujano building, permeable to the wind, and filter building, with little thermal mass; (ii) the colonial-republican building, which permitted the movement of air and used mass to regulate thermal conditions and (iii) the building imported by foreign oil companies which had a more technological nature. The teachings of these buildings have been forgotten largely due to the aesthetic popularity of foreign or imported styles and the availability of cheap energy. We propose application of proven principles but in an architectural proposal adapted to contemporary cities.

ARCHITECTURAL PRINCIPLES

Our proposal for middle income users, in an oil field context near the Lake of Maracaibo, has led us to propose narrow, but rather high, single family units to reduce urban soil consumption and urbanization costs, while at the same time permitting us to perceive the lake horizon. In this situation, where we needed the high density of traditional urban centers in a suburban context, but in an oil culture used to the isolated building, we had to produce a different typology, which could satisfy these apparently contradictory urban and social requirements.

In our proposal, the spaces which characterize an isolated building have been occluded: the backyard and the front garden have been absorbed by the house: the outside has been folded towards the inside. At the same time, the building has been directed upwards and coexists with the exterior, now inside; a channel of light on the side of the property helps to isolate a building that was conceived in a row; thus a typology extracted from the site is born: the detached row house. Thus, the building does not look out onto the street, but rather develops its facade along the band of the patio, contributing, by its curved volumes, to reinforce the feeling of external space.

Three bands are organized horizontally: the conditioning band, the conditioned band, and the patio. All the services of the building (kitchen, baths) and the active and passive conditioning systems are located in the conditioning band. The function of this band is to serve the main spaces of the dwelling: bedrooms, family room, dining room, the conditioned band. The patio, is an inner exterior, lodging vegetation, light and wind. The patio, together with the servant band are responsible for the bioclimatic conditioning of the building. This patio band constitutes another step towards the enrichment of the historical evolution of local patios.

SUSTAINABLE DESIGN PRINCIPLES

Sustainable design must address social, cultural and economic issues at many scales, from a regional scale to an architectural scale. In this paper, we will explain some architectural design principles that exist in local traditional architecture and have been included in our. Most of these are energy reducing and passive cooling principles which are the traditional scope of bioclimatic or solar architecture.

Energy Reducing Principles.

Buildings should save energy and use renewable energy sources, because the process of extracting, refining and transporting fossil fuels is a great source of pollution in the world.

BIOCLIMATIC STRATEGIES FOR SITE DESIGN

1.- We propose a building that is simultaneously a row building and an isolated building. Isolation promotes flow of air through the lateral patio and row organization permits neighboring buildings to be used as shading elements over lateral facades and large portions of the main and back facades (see Figure 1). Heliodon analysis was done for five periods of the day and three dates of the year for Latitude 10° N, to analyze shadow behavior in plans and facades (see Figure 2). Solar protection was achieved during more than 95% of the time during critical hours.

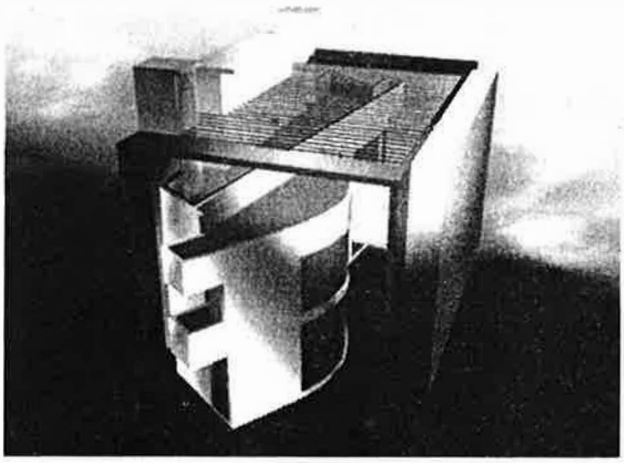


Figure 1. Proposal of isolated and row building

2.- Landscaping helps keep air cool around buildings. A vertical patio is proposed which permits cross ventilation and views from all spaces towards the patio. Trees increase shaded areas and act as natural air conditioners and organic ground cover absorbs and transforms solar energy. This cooling effect is not taken into account in simulations, so indoor temperatures might be lower than results indicate.

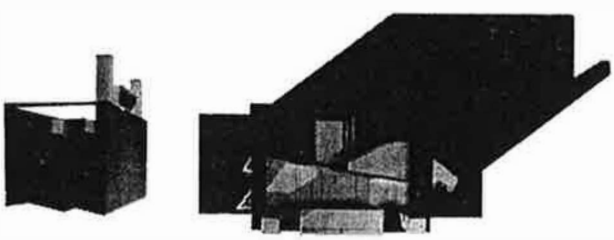


Figure 2. Images from heliodon analysis

3.- Building is oriented so that chimneys, which have openings in two directions, will catch the maximum of prevailing trade winds from northeast, and even from other nondominant directions (see figure 3).

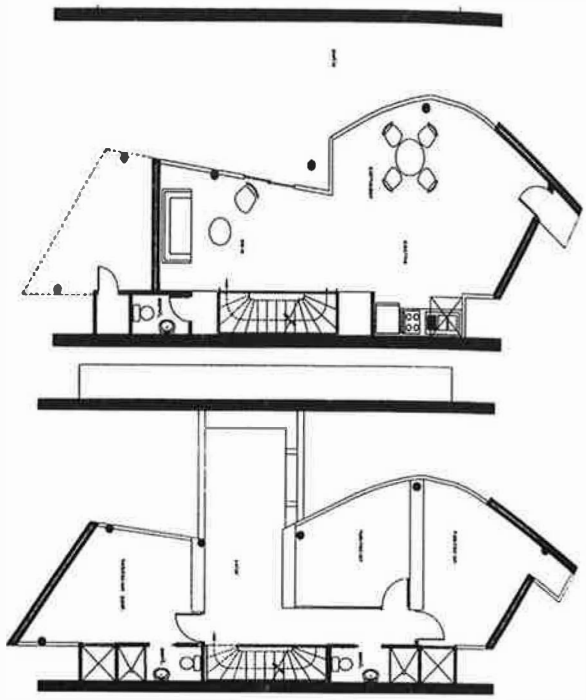


Figure 3. House Plans

BIOCLIMATIC STRATEGIES FOR ARCHITECTURAL DESIGN

4.- Volumetric organization of the building maximizes flow of air, starting from the top, at the chimneys, and through indoor spaces out to the patio. This ventilation is useful to achieve thermal comfort with higher temperatures and to evacuate hot air.

5.- Window panes parallel to the patio walls are transparent and designed as a window system, which we have called a Matricial Bioclimatic Window, MBW, whose surface has been divided in bands and lines assuming different responsibilities: ventilation, solar protection, natural illumination, visual relations and privacy.

6.- Open floor plans are proposed, which are shaded, insulated, and well ventilated, using opaque walls in one direction and permeable interior partitions in the other.

7.- Heat and humidity generating functions, such as kitchen, laundry and bathrooms, are in the same band and do not disturb rest spaces and living spaces.

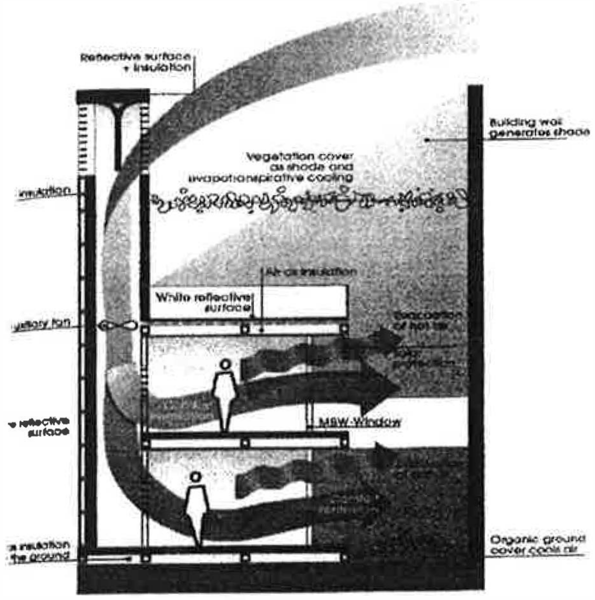
8.- Roofs and walls are insulated by small air chambers incorporated in construction system.

9.- External roof finish is made of white tiles or gravel (low absorptivity) and exterior walls are painted white.

10.- Indoor spaces have openings towards the patio and the eolic chimney to promote cross ventilation.

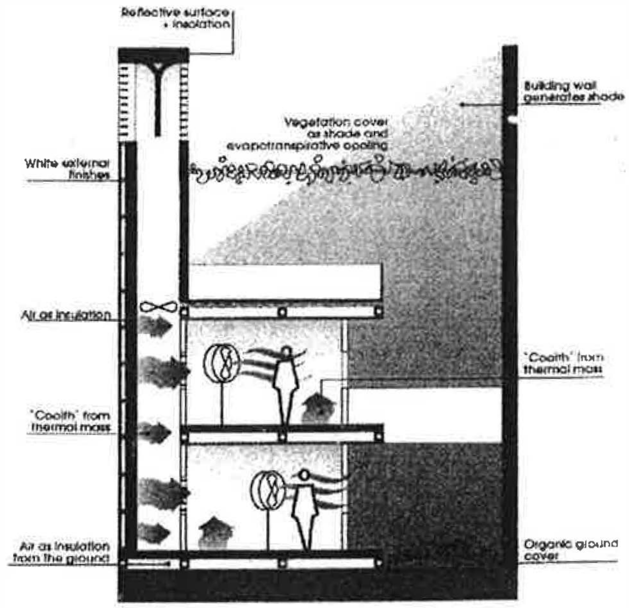
11.- Thermal mass in floors and the main lateral wall under the eolic chimney is used to reduce thermal amplitude and can also be used with mechanical air conditioning or nocturnal ventilative cooling to "store night coolth" for daytime use (see Figures 5, 6 and 7).

12.- Ground floor slab is insulated from the ground by an air chamber, preventing heat conduction from the ground, which is important because avg. temperature one meter under the ground in Maracaibo is around 30°C, which would account for larger heat gains towards the building, especially at night.



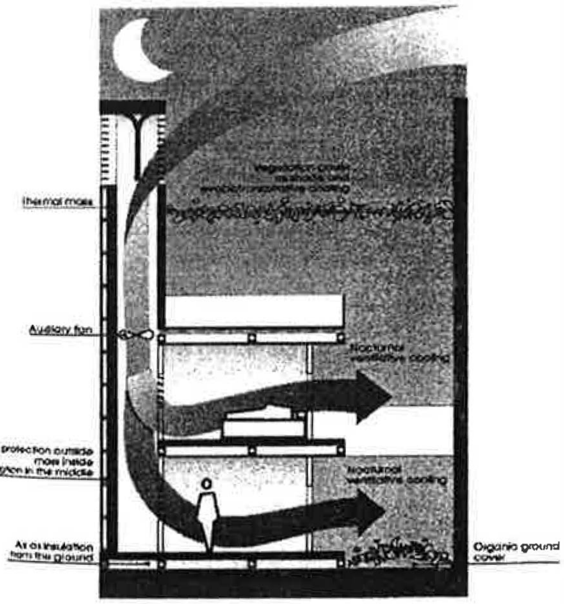
Building open during the day

ure 4. Daytime thermal behavior of open building using ssive systems



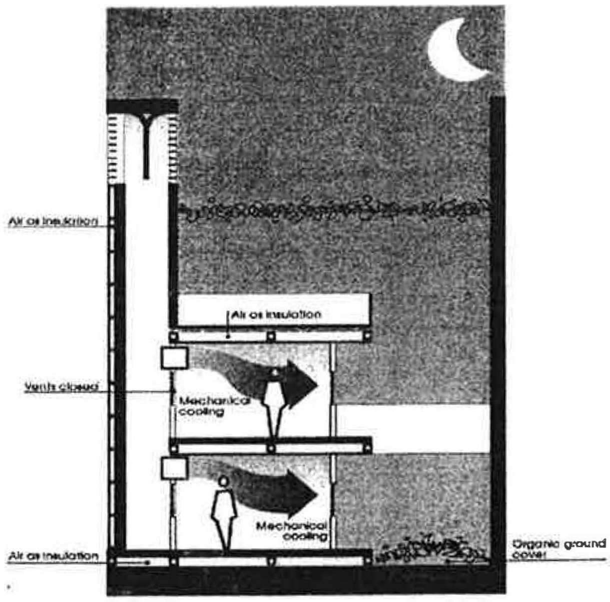
Building closed during the day

Figure 6. Daytime thermal behavior of closed building using passive systems.



Building open during the night

Figure 5. Nighttime thermal behavior of open building using passive systems.



Building closed during the night

Figure 7. Night behavior of closed building with mechanical cooling.

PASSIVE COOLING PRINCIPLES

14.- Comfort ventilation is used to provide direct human comfort by transversal air movement or with the help of electrical equipment (see Figure 4).

15.- Nocturnal ventilative cooling is proposed in combination with the mass inside the building so as to keep the building cool during the day for a longer period (see figures 5 and 6).

USE OF RENEWABLE ENERGY SOURCES.

16.-Photovoltaic cells can be placed in the roofs for generation of solar energy. These can be used to provide part of electrical needs of the house.

Construction Materials and Processes

17.- Energy consuming and polluting elements such as cement based materials have been reduced to an absolute minimum, by precise positioning of mass, and use of steel.

18.- Toxic materials which contribute to the sick building syndrome are not used.

19.- Building can be recycled and its space adapted for other uses, such as offices.

20.- Some materials, such as wood, are obtained from renewable sources.

Environmental factors: Exploitation and protection of our natural resources

21.- Rational use and placement of materials is promoted for economy.

22.- Most construction elements used in the building can be recycled (steel, glass and wood).

Economical factors

23.- The cost of the building should not provoke excessive economic pressures on the family because it can be built in two stages. Standardization and organization of construction elements guarantees economy.

THERMAL SIMULATION

Meteorological data from the urban and airport weather station in Maracaibo, with a hot humid climate similar to that of Tamare, most of the Maracaibo lake basin, and large portions of Venezuela, was used to analyze thermal performance. Avg. min. Dry Bulb Temperature is 24.7°C, avg. is 27.7°C, avg. max. is 32.9°C, avg. amplitude is 8°C; avg. Air Velocity is 4.5 m/s, main direction is NE; Avg. max. Relative Humidity is 92%, avg. is 76%, avg. min. is 54%; and avg. yearly precipitation is 490 mm. Simulations for one of the worse (May) and one of the best months (January) in Maracaibo were carried out using CODYBA [1]. Options such as continuos 24 hour cooling, 24 hour natural ventilation, and different combinations of opening and closing windows or using air conditioning were studied. All cases generated acceptable results.

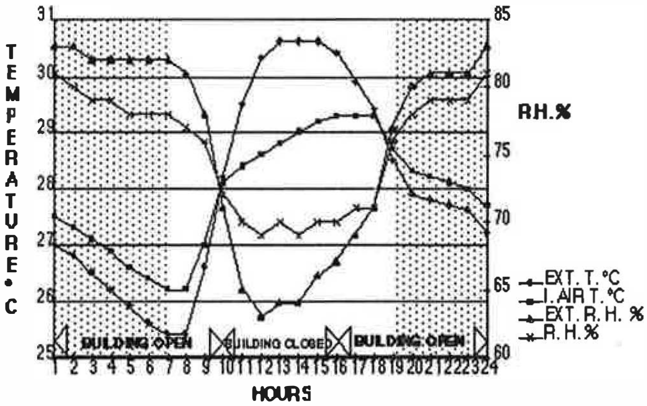


Figure 8. Simulation using only passive cooling.

Only the results of the analysis of two options are shown, and for January. The first is using only passive systems ; opening the building to ventilate from 19:00 to 10:00 hrs (see Figure 5) and closing it from 10:00 to 16:00 hrs. (see Figure 6). In this case no mechanical cooling is used, but fans are used to generate air movement for comfort. In January, maximum temperatures were generally lower than outdoor values during daytime and significantly lower than 30 °C. Maximum indoor values reached 33°C, which is higher than the 30 °C value recommended by Givoni, as the upper limit with which we can achieve comfort with an air movement of 2 m/s in developing countries [2], but were still lower than the maximum outdoor values (see Figure 8).

The second option is combining mechanical cooling with passive systems. In this case the building is air conditioned from 20:00 to 4:00 hrs (see Figure 7), opened from 4:00 to 10:00 Hrs (see Figure 4). and closed from 10:00 to 20:00 (see Figure 6). In this case indoor temperatures are even lower, reaching 32 °C in May, but never reaching 29 °C in January (see Figure 9). This option has the disadvantage of high indoor relative humidities (70%) when the building is closed for a long period, which decreases effectiveness of comfort ventilation and increases latent cooling loads when the air conditioning system is activated.

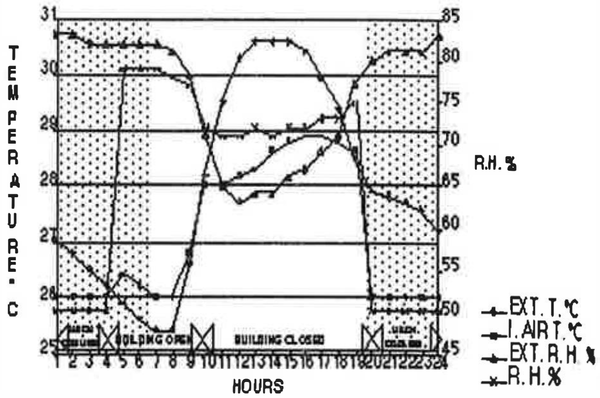


Figure 9. Simulation combining mechanical and passive cooling

Natural illumination values have also been calculated and averages are between 210 and 320 lux, which are higher than local standards (100 lux), with an adequate distribution of illumination: uniformity factor is 0.65, which is higher than 0.3, the common established lower limit in Venezuela

CONCLUSION

It is possible to apply bioclimatic concepts to an architectural project, avoiding its appearance as an assembly of technological devices, and increasing the possibilities of user acceptance. The results of simulations demonstrate an adequate application of these techniques. However, the monitoring of indoor thermal conditions will permit to evaluate with greater precision the behavior of the proposals, and the degree of satisfaction of its dwellers will provide the definitive evaluation of the effectiveness.

ACKNOWLEDGMENTS

We are grateful to Consejo de Desarrollo Científico y Humanístico CONDES of the University of Zulia and the Venezuelan National Oil Company, PDV, for their grants that have permitted us to develop these research projects and attend this congress. Also to our research assistants I. Rodríguez, M. Morán, N. Soles, R. Fernández, E. Abreu.

REFERENCES

1. Brau, J, Roux, J.J., Depecker, P. '*Micro-informatique et comportement thermique des bâtiments en régime dynamique: CODYBA*' Génie Climatique, 11, 15-23. (France : 1987)

2. Givoni. B. '*Passive and Low Energy Cooling of Buildings*' Van Nostrand Reinhold. (New York : 1994).