Three green buildings from Venezuela: proposals for climate sensitive design

P. La Roche, F. Mustieles, M. Machado, I de Oteiza

Instituto de Investigaciones de la Facultad de Arquitectura, IFA, Universidad del Zulia. Maracaibo, Venezuela.

Abstract

Three green buildings designed to provide psychological, physical and social well being through improved comfort combined with lower energy consumption and less generation of wastes are explained.

The first case is the project "Habitar el Dispositivo" "T*o inhabit the device"* which was awarded a prize in an international competition in Tenerife in 1995 and in which the integration of bioclimatical and architectural concepts in a livable device is proposed; the second case is a bioclimatical house for Tamare, Venezuela, which incorporates design principles from traditional indigenous, colonial and oil company houses in the Maracaibo lake basin to generate a prototype adapted to contemporary urban Venezuelan problems; and the third case is a low cost variation of the second building.

Digital and analogical models of the first two prototypes have been built to analyze sunlight and shadow behavior and computer simulations permitted to predict thermal performance. Thermal satisfaction was 89.5% during typical summer and winter 24 hour periods for the Tenerife building; and in the Tamare house, assuming a higher comfort temperature, acceptable for summers in developing countries, we achieved 95% of satisfaction when the building is ventilated at night and closed during daytime. The third proposal has not been thermally evaluated yet.-

Some bioclimatic principles which are proposed for the summer of the Tenerife house and during the whole year of the Tamare house are: 1) minimization of radiation gains through windows and facades by solar protection, 2) minimization of conduction heat flow and thermal oscillations by-adequate positioning of insulation and mass and use of external light colors 3) control of air changes; and 4) bioclimatic landscaping. Some passive cooling techniques are: 1) comfort ventilation; 2) nocturnal convective cooling; and 3) direct evaporative cooling. During the winter of the Tenerife house, the summer principles will also perform adequately (insulation, mass, etc.) while protection from the cool winds and the passive heating technique, direct solar gain, is proposed.

Construction of the Tenerife and Tamare houses will begin in mid 1998 with financing from the Canarian and the European Economic Community for the Tenerife house, and PDV, the Venezuelan Oil Company, for the Tamare house. Financial assistance for the construction of the third prototype has not been secured yet. In all three cases thermal parameters and some indoor air quality parameters will be monitored after construction, to evaluate performance of these prototypes.

Keywords: Sustainable design, bioclimatical design, passive cooling and heating, housing

1 Introduction

Many bioclimatical buildings have been designed which seek to perform more efficiently. However, the performance of these is generally achieved by the addition of technological devices to a project, producing a work that is many times rejected by its dwellers, due to its high cost, complex appearance and even more complex utilization. In contrast to these proposals, we propose an integral relation between architecture and bioclimatism making these devices form part of man's space.

2 To inhabit the device: a bioclimatical house for Tenerife, Spain.

2.1 Architectural principles

As a base principle for the reencounter between architecture and bioclimatism, we proposed "to inhabit the bioclimatical devices", this is, to make them form part of man's space. Thus emerges, the inhabited triangular chimney, that directed towards the northeast, collects the wind and circulates it through indoor spaces.

As a second base principle, we proposed "to integrate the technological devices in an architecturized device". Thus appears the "Fortran" wall, called so because of its simple but operational technological devices which someway resemble old computer Fortran cards.

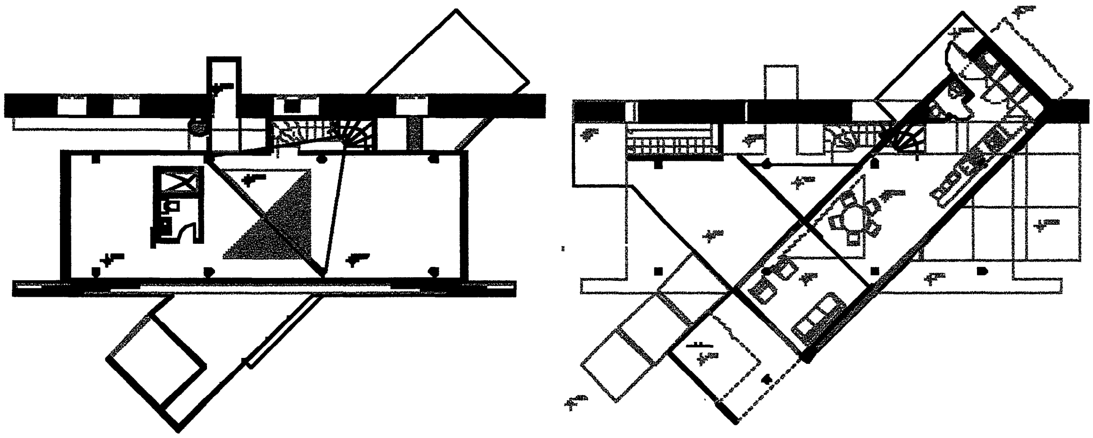


Fig 1 Plans of the Tenerife House

2.2 Bioclimatical techniques and passive systems

According to Givoni [1] bioclimatical techniques permit to reduce heat gains by conduction, radiation and convection through walls and windows in summer, and to reduce heat losses in winter. Passive cooling systems transfer incident energy to natural energetic deposits, or heat sinks, such as the air, the upper atmosphere, water and earth. Passive heating systems store and distribute solar energy without the need of complex controllers for its distribution.

Climate variables of southern Tenerife (Reina Sofia Airport) were analyzed using Fanger's and Givoni's method, in relation to the thermal comfort zone. Two situations were typified: winter, from November to May and summer, from June to September. In winter, night values are located in the passive warming zone, and towards noon, in the comfort zone. In summer, the values are located in the comfort zone during the night and in the comfort ventilation zone during most of the afternoon. Therefore, warming is required during the winter nights and cooling during the summer days; control of heat losses is also necessary in winter nights and control of heat gains in summer days. The building protects from the sun and opens to the fresh winds in summer, while in winter it opens to the sun and is closed to the cool winds.

2.2.1 Bioclimatical techniques

1. **Solar and eolic orientkion.** The direction of the building answers to the sun and to the wind. The top floor is oriented with its main shaft east-west, with openings to the south and protected in the other faces, answering to the solar direction. The ground floor is oriented 45 degrees in relation to the first floor answering to the dominant trade winds from the northeast. In the intersection of the two volumes and guided towards the northeast is located the triangular eolic chimney.
2. **Protection of openings** in **summer.** All the openings are adequately protected in summer. The transparent facade of the second floor has a rollable louvered mechanism permeable to the wind and impermeable to the light, that permits to regulate radiation to the dormitories, avoiding overheating.
3. **Mass and insulation as thermal regulators.** Indoor thermal mass and external insulation are used to store heat from the winter days and "cold" from the summer nights and to avoid heat gains in summer and losses in winter.
4. **Light external colors.** The external color of the facades is white, which reduces heat gain by conduction through walls and roofs, necessary in summer.
5. **Solar protection.** The overlapping of crossed volumes and the Fortran wall generate shaded areas, non-existent due to the lack of trees.
6. **Protection from cold winds.** The "Fortran" wall serves as thermal regulator of external conditions, protecting from the cold winds in winter but also has small windows that permit cross ventilation through spaces to generate comfort in the summer. The louvered windows can be also closed in the winter nights to protect the transparent facade and to reduce the coefficient of superficial conductance.

2.2.2 Passive cooling and heating systems

1. **Direct solar gain.** Energy gains in winter are by radiation through windows and then stored for night use.
2. **Convective night cooling.** Nocturnal ventilation cools internal mass of floors and walls during the night, reducing its surface temperature, helping to keep the building cool during daytime hours.
3. **Direct evaporative cooling.** The openings of the "Fortran" wall and of the eolic chimney have containers with water, to add moisture to incoming air and decrease air temperature.
4. **Comfort Ventilation.** High air speeds in the zone make it easy to introduce air into the house and extend the thermal comfort zone to the upper comfort values.

2.2.3 Renewable energy sources

Solar energy is proposed for water heating and photovoltaic cells to complement grid electricity and both located on the Fortran wall.

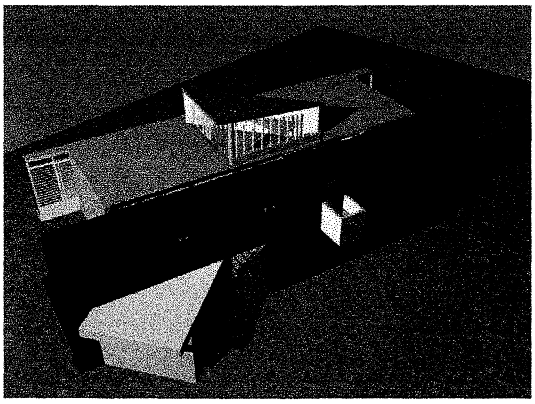


Fig 2 North and south views of the Tenerife House

2.3 Thermal evaluation of the proposal.

To determine the effectiveness of our proposal, the computer program for simulation of thermal behavior in dynamical regime CODYBA [2], was used. Data from the meteorological station was used to determine a typical summer day, July 15, and for a typical winter day, January 15. The percentage of satisfied with internal conditions was calculated with Fanger's Predicted Mean Vote method. A 75 kg male, with a height of 1,70 mts., and a moderate activity of 81 w/m^2 was used as reference. In winter, clothing was 1.2 CLO and air velocity 0.1 m/s. In summer clothing was 0.8 CLO and air velocity 1.5 m/s. ASICLIMA [3] was used to determine solar position during different days of the year, thermal transmitance values of envelopes and heat flows through the different plans of the facades.

During winter days the daytime average temperatures are 21.2 °C in the first floor and 21.6 °C in the ground floor, while the daytime external average is 19.6 °C. The average percentage of satisfied during the winter day are 87% and 86% respectively.

During the winter nights the average temperatures are 21.1 °C in the first floor and 20.7 °C in the ground floor, while the external average is 17.5 °C. The average percentage of satisfied during winter nights is 90% and 87% respectively.

During the summer days, daytime average temperatures are 24.9 °C in the first floor and 24.8°C in the ground floor and external average is 25.1 °C. The average percentage of satisfied during summer days is 91% and 89% respectively.

During the summer nights the daytime average temperatures are 24.1 °C in the first floor and 24.5 °C in the ground floor, while daytime external average is 22.8 °C. The average percentage of satisfied during the summer nights is 94% in either case.

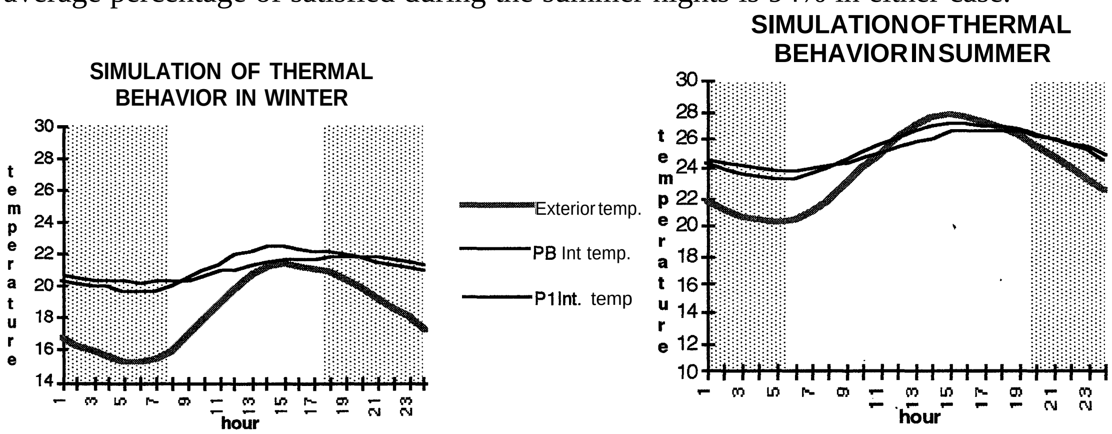


Fig 3 Temperature simulation results in the Tenerife house

3 A bioclimatical house for Tamare, Venezuela: the fourth house

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 region 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 climate adaptive concepts transmitted by individual generations, not architects. Three models of climate sensitive architecture in Maracaibo have existed: the palafitic paraujano building, the colonial-republican building, and the building imported by foreign oil companies. The teachings of these buildings have been forgotten due to the aesthetic popularity of imported styles and cheap energy.

As in the Tenerife building, we propose to integrate architecture with environmental techniques. with improvements on the previous architectural solutions and generating a house which is also adapted to the climatic, social, urban and economic environment of our contemporary cities.

Special importance was given to availability of materials in the eastern coast of the lake of Maracaibo, where Tamare is located, and their environmental characteristics. A steel structure is proposed since steel is used extensively in the oil industry that prevails in this region and much specialized labor is available. Insulating materials are available from the petrochemical industry but do not have a very clean production process.

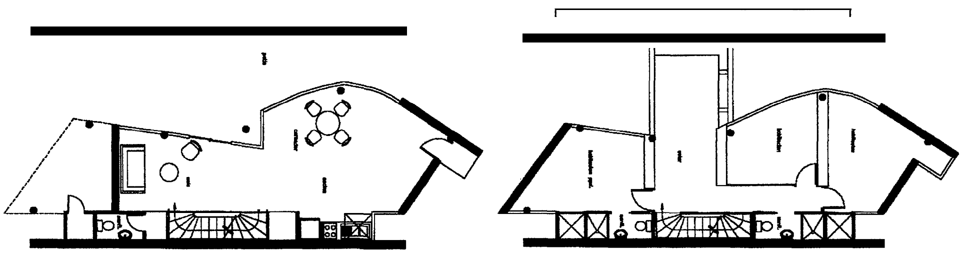


Fig 4 Ground floor and first floor plans of the Tamare House

3.1 Architectural principles

3.1.1 Detached Row Housing

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.

3.1.2 Horizontal organization of functions in bands

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.

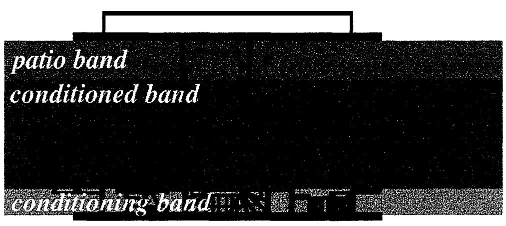


Figure 5 organization in bands

3.2 Bioclimatical techniques and passive systems

Our building increases energy conservation and thermal comfort and uses clean and renewable energy sources to decrease non renewable energy consumption.

In Maracaibo, which has a similar climate data as Tamare, avg. min. Dry Bulb Temperature is 24.7°C, avg. is 27.7°C, avg. max. is 32.9°C, avg. variation 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.

Due to extreme climate conditions in the Zulia lake basin, which are even worse in its cities, (thermal islands) our proposal was to design a passive building using natural techniques, mechanical cooling, or both, to reduce energy consumption and approach comfort values. Simulation results show improvements in energy consumption and thermal comfort in all three cases.

3.2.1 Bioclimatical techniques

1. **Shade.** Organization in row houses permits the walls between buildings to be used as shade elements over the facades.
2. **Landscaping** with organic ground cover, and trees, provide lower temperatures around buildings. This cooling effect is not taken into account in thermal simulations, so indoor values could be lower than results indicate.
3. **Precise design of window systems.** Window panes parallel to, the exterior walls are transparent and designed as a window system, which we have called a Matricial Bioclimatic Window, MBW, divided in bands, lines and points, assuming different responsibilities: ventilation, solar protection, natural illumination, visual relations and privacy.
5. **Air movement** is promoted through chimneys, which transfer this air through the living spaces and out to the patio through the MBW. This movement is useful to evacuate hot indoor air, introduce cool air, or achieve comfort by air movement.
6. **Open, shaded, and ventilated indoor floor plans** are proposed, using opaque partitions perpendicular to the servant band and permeable interior partitions perpendicular to these for maximum flow of air.
7. **External finishes in walls and roofs are white.**
8. **Thermal mass** is positioned on the inside of building to reduce thermal oscillations and to work with night cooling. Air cavities for insulation is used in walls, floors and roofs to diminish heat flow by conduction.

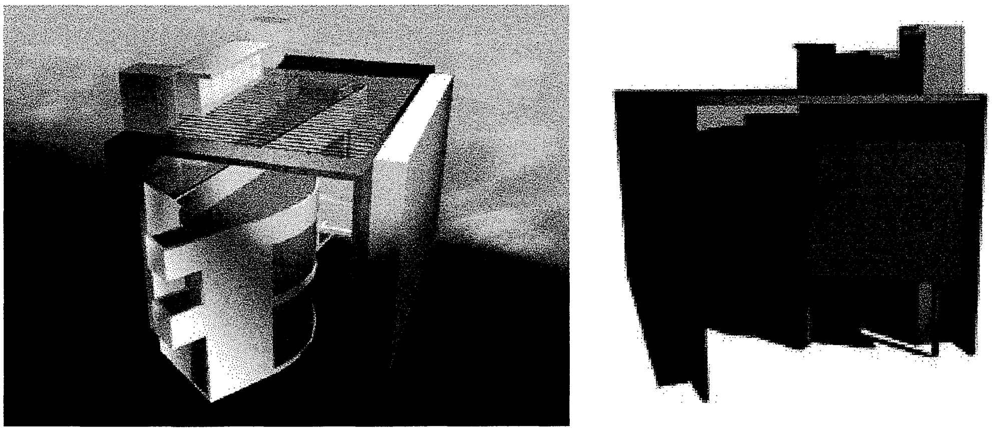


Fig 6 Back and front views of the Tamare House

3.2.2 Passive cooling systems.

1. **Comfort ventilation** by the chimney to the patio, is used to provide direct human comfort by transversal air movement from the chimneys to the patio.
2. **Nocturnal ventilative cooling.** The mass of the building interior is cooled during

the night and then the building is closed during daytime to keep cool air in. When the building is closed electrical fans are used.

3.2.3 Mechanical cooling systems

Air conditioning is proposed as occasionally necessary and useful to cool the building when outdoor conditions are out of the range of passive cooling systems. It can also be used to improve performance of passive bioclimatical systems such as night cooling, which would in this case be mechanical night cooling.

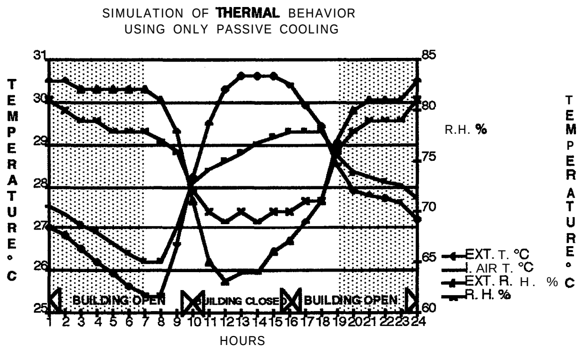
3.2.4 Renewable energy sources

Solar energy is proposed to generate electricity for the electrical fans in the chimney and to heat water for domestic use.

3.3 Thermal simulations

Meteorological data from the urban and airport weather station in Maracaibo was used to analyze thermal performance. Simulations for the worse (May) and best conditions (January) in Maracaibo were carried out. In each case several simulations were done assuming different forms of operating the building which were a combination of opening windows and chimneys to permit flow of air, closing openings to maintain cool air inside combined with fans to achieve comfort and using air conditioning to cool air mechanically.

Two options are shown, the first is opening the building to ventilate from 19:00 to 10:00 hrs and closing it from 10:00 to 16:00 hrs. 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 the 30 °C value recommended by Givoni as the upper limit with which we can achieve comfort with air movement of 2 m/s in developing countries [1]. In May, maximum indoor values reached 33°C but were still lower than the maximum outdoor.



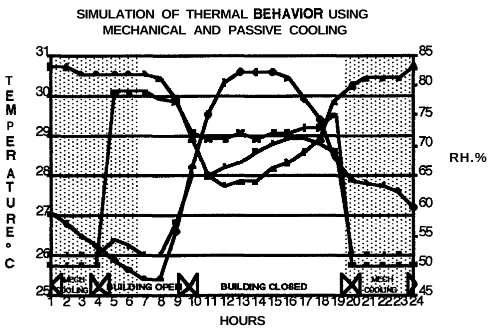


Fig 7 Thermal simulations in the Tamare House

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, opened from 4:00 to 10:00 Hrs. and closed from 10:00 to 20:O0. In this simulation indoor temperatures are even lower, never reaching 29 °C in January, but reaching 32 °C in May. These cases have the disadvantage of high relative humidities (70%) when the building is closed which decreases effectiveness of comfort ventilation.

Other options that have been analyzed are continuos 24 hour cooling, 24 hour natural ventilation and other combinations of closing and air conditioning. All cases provided acceptable results.

Natural illumination values have also been calculated and the averages are between 320 and 210 luxes which are very high compared to necessary standards (100 luxes). There is an adequate distribution of illumination in the spaces, because there isn't a large difference in obtained illumination levels. Uniformity factor is 0.65 which is higher than 0.3 which is the common established limit .

4 House for low income groups in Maracaibo, Venezuela.

This proposal adapts the architectural concepts of the Tamare house, to a proposal for lower income groups. Emphasis is in economy, progressive growth, use of materials found in the site, manufacturing of construction materials by its own dwellers or neighbors, increase of thermal comfort by the use of bioclimatic techniques, and passive cooling systems, and use of materials with low embodied energy. To achieve these objectives manufacturing of soil bricks with a cement content of only 10%, and an artisan elaboration process are proposed. This, together with reduced transportation distances (materials will come from the site) assures an adequate thermal behavior and will reduce environmental pollution. On the other hand, local economy will be improved since brick producers will be members of the community.

5 Conclusion

We think that these two examples demonstrate that it is possible to apply bioclimatical design concepts to an architectural project, avoiding its appearance as an assembly of technological devices. This will increase the possibilities to incorporate bioclimatical devices in new architectural proposals, which will thus have a greater degree of acceptance from its users.

The buildings are expected to be flexible in the management of the sun and the wind, permitting their independent regulation according to comfort requirements and daytime and seasonal variations. The results of simulations demonstrate an adequate application of different bioclimatical techniques and passive cooling systems, for two different climates. However the monitoring of the thermal conditions within the houses, will permit to evaluate with greater precision the behavior of the proposals and the degree of satisfaction of the users with the proposal will be the definitive evaluation of the effectiveness of our proposals.

6 Acknowledgments

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