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Bioclimatic Architecture Potential in Buildings Durability and in their Thermal and Environmental Performance

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ABSTRACT

Bioclimatic architecture increases the comfort of a building in any season while reducing the need for heating, cooling, lighting and ventilation, which in turn leads to an accentuated decrease in energy costs. The implementation of these assumptions in a building does not involve increased investment in construction nor the installation of specific domotic systems.

The Regulation of the Characteristics of Thermal Performance of Buildings (RCCTE) was reviewed and the National Energy Certification Buildings was created in an attempt to overcome environmental and energy problems. They establish new rules and methods for improving the indoor comfort and health conditions of buildings and for changing the philosophy of current building to a more sustainable level. Dissemination of knowledge of and the capital gains from bioclimatic architecture combined with sustainable building is now an urgent matter, so that these new approaches can be implemented effectively.

Buildings designed based on bioclimatic architecture are more sustainable have a healthier indoor environment, are more comfortable and have improved energy efficiency, which ultimately leads to lower energy costs.

One of the issues this study will examine is the historical evolution of buildings on an energy and environmental level and explain the methods and strategies used in bioclimatic architecture. Their effects and results will be analysed carefully and several examples and a practical case study will be given.

KEYWORDS

Bioclimatic architecture, Thermal performance, Durability, Sustainability, Comfort.

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1 INTRODUCTION

1.1 Vernacular Buildings

Vernacular buildings have come from a history of good construction practices and traditional social and technological knowledge developments acquired from experience over time. Vernacular architecture (which is undoubtedly bioclimatic) originated in empiricism, dictated by our forebears' rules of good building. It arose at a time when there was no technology to answer the needs of HVAC and lighting, and this led to efficient construction optimized for the the building's location within the surrounding environment, using local materials. Vernacular buildings use simple techniques to provide comfort both in winter and summer:

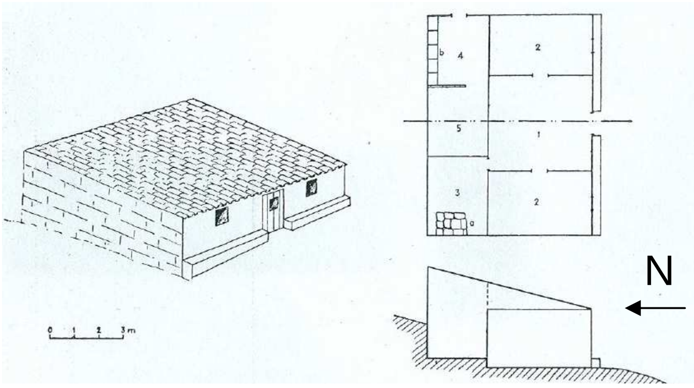

Figure 1. Isolated house in the hills of Monchique, mud: Perspective, cutting and elevation (according to a note by Ivo Castro Pereira).

In the Alentejo (Portugal) buildings used to be built in rows along narrow streets to provide more shade. Thick, white-painted walls were used to increase the thermal inertia and to reduce the absorption of solar radiation.

In northern countries houses have steep-sloped roofs so that snow does not stay on them for a long time. These are examples where the thermal comfort in both winter and summer can be improved with very simple steps. However, with the fascination for technical innovations, aid from industry, and belief in inexhaustible natural resources, the "best practices" evident in ancient and vernacular buildings were gradually abandoned and forgotten, because it was thought (and sometimes still is) that technology has magical solutions for everything.

2 BIOCLIMATIC ARCHITECTURE

Bioclimatic architecture is an integrated architecture, adapted to its physical, socio-economic and cultural environment. It is the kind of architecture that takes into account the analysis of the climate and environmental characteristics where the building is situated, promoting improved comfort and a reduction in energy consumption.

Its aim is to maximize interior environmental comfort, (thermal comfort, light, sound, etc..) using only the design elements and architectural forms available.

General Characteristics:

- It has very primitive roots in traditional or vernacular architecture, which are based on empiricism and the subsequent ancestral building arts;
- It seeks to give a practical response to the measures identified to achieve sustainability in construction;

- Its quest is to achieve conceptual and constructive integration with the environmental, thermal, climatic and biological context;
- It allows a "healthy balance" to be maintained in the building, rationalizing both the resources and waste.

Bioclimatic architecture is inseparable from passive solar design (which deals only with energy gained from sunlight), active building (which studies the mechanical low-energy means, usually associated with the use of renewable energy, eg solar panels, etc) and sustainable building (which deals with the environmental impact of all processes involved in building) since these concepts all work toward similar objectives and concerns.

2.1 Bioclimatic Building Techniques

The adoption of strategies in the design of a bioclimatic building significantly influence its performance in terms of thermal comfort and also leads to a reduction in energy consumption. During the project and building deployment, several aspects should be taken into account, such as:

- The local climate characteristics;
- The location that best fits its effective use in terms of human comfort;
- Technical factors associated with aspects like building orientation, the orientation of glazed façades, the building's shape, ventilation and air movements, the environment (heat gains and losses) and the internal and external temperatures;
- The effects of surrounding buildings in terms of sunlight and wind exposure;
- The solar radiation exposure during the year.

2.2 Passive Solar Architecture

Passive solar design refers to devices embedded in a building’s construction with the purpose of contributing to its natural heating or cooling.
During the cold season (heating), these systems aim to maximize the winter sun captured, through well-targeted and well-scaled glazing, which can be associated with mass elements, allowing the storage of solar energy and its use later on. In hot weather (cooling), one aim is to take advantage of sources of cold such as the soil or the outside air, which at certain periods of day will help cool the building.

2.2.1 Passive Heating Systems (Cold Season)

In passive heating systems, the glazed area to the south or southeast-southwest quadrant should be taken into account, in order to capture solar radiation and thermal mass for heat absorption, storage and distribution.

2.2.1.1 Direct Gain Systems – Glazing

Direct solar gain is the simplest way to take advantage of passive solar energy. It simply consists of opening oriented glazing in order to maximize the impact of radiation (S, SE, SO) and storing it in the surrounding thermal masses, thereby achieving substantial solar gain in winter.

2.2.1.2 Indirect or Lagged Gain Systems

In indirect gain systems, the system’s thermal mass is installed between the gain surface and the space to be heated. The thermal mass absorbs the incident solar energy, transferring it into the space later. The most popular systems are Trombe walls, storage walls and water walls and columns. Indirect gain systems must include mobile shading devices to turn them off during the summer, thus avoiding overheating conditions.

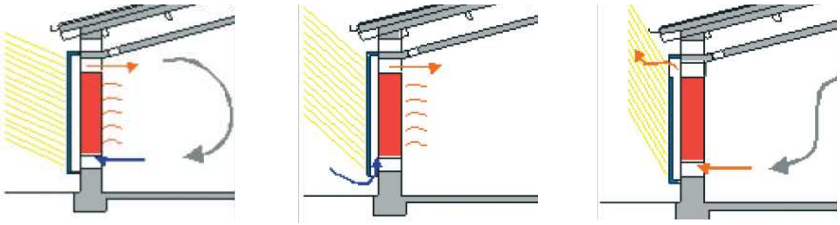

Figure 2. Trombe wall operation diagram.

A. Immediately transfers the incident energy into the space to be heated through natural ventilation via the existing holes. In this case, the space will be heated by a stream of natural convection between the interior space and the "greenhouse" space;
B. Preheats the outside air in mid-season (spring or autumn), requiring a hole between the outer and the "greenhouse" space.
C. Does not have natural ventilation between the wall and the glass, allowing the incident "energy" to gradually accumulate in the wall and be transferred (by conduction) to the interior of the space to be heated up. The amount of time this takes depends on the thickness of the wall - Storage Wall.

2.2.1.3 Isolated Gain Systems - Greenhouses
Greenhouse spaces can combine the effects of direct and indirect gain. Solar energy is transmitted to the adjacent greenhouse space by conduction through the separating storage wall and also by convection, when there are holes allowing air circulation.

This system should also provide a way of shading during summer.

2.2.2 Passive Cooling Systems (Hot Season)
These systems aim to considerably reduce the cooling requirements and improve thermal comfort without resorting to a conventional air conditioning system. Some of the strategies to take into account for passive cooling systems are:

• Solutions for preventing and mitigating heat gain, to reduce the uptake of solar radiation through shading, insulation and thermal mass;
• Solutions using the existing sources of cold in order to reduce the temperature inside the buildings;

The strategy of prevention or protection from solar gains can be considered in all buildings through different architectural options. We must bear in mind the following aspects:

• The choice of low-emissivity glass to reduce solar gains;
• The shading of glazing to reduce radiation entering the buildings;
• The insulation of the building surroundings (preferably on the outside) to restrict the gains by conduction;
• The increase in the thermal mass of the building to increase its capacity to store heat and reduce the peak cooling loads;
• The implementation of strategies for heat dissipation (passive or natural cooling), by providing environments acting as sources of cold, which allow significant processes of heat transfer, such as soil, exterior air during the night and morning or water.

3 EXAMPLES OF BIOCLIMATIC SOLUTIONS

3.1 Example 1 – Implementation of a Shading System in an Historical Building

In this example a shading system was implemented to prevent and mitigate heat gains in an old building. This is a solution that fits into the building without the neutering or amending its image instead of installing a solution on the 1st floor, which distorts building's lines and the reading one gets of it. The shading system adopted on the ground floor is very versatile (Figure 3). During the cooling season, it prevents the sun's rays from hitting the glass by lowering the screens, and in the heating season it allows the sunlight to enter through the glazing, by raising the screens.

3.2 Example 2 – Example 2 – Thermal Rehabilitation of Old Buildings (Altering Frames)

In this building, instead of replacing the existing window frames, which always looks out of place on the existing façade, a system of double frames was implemented by reshaping the existing portals and installing plain glass. A second portal was implemented to improve the frame's thermal/acoustic performance (Figure 4).

This measure preserves the overall image and the building's exterior lines and is therefore one of the most appropriate methodologies for these cases. This is an example of success that is recommended as it greatly increases a building's comfort and endows it with better thermal / acoustic properties.

Figure 3. View of shading system.

Figure 4. Double frame system.

3.3 Example 3 – Placement of Passive Solar System

This is a bad example of the implementation of photovoltaic and solar panels with disproportionate impact, without any care or rationale, which should never occur. The implementation of these systems should always done in a way that integrates them into the building and its surroundings. It is up to the municipalities to coordinate, regulate and monitor the implementation of these technologies through their municipal regulations. However, companies that sell these systems also have an added responsibility in that the solutions they provide to their customers must include studies performed by trained technicians about how to integrate the systems.

Figure 5. Wrong implementation of solar systems.

3.4 Example 4 – Solar Control using Glazing / Shades

In this example a shading system was implemented in a hospital, to prevent and mitigate heat gains during the cooling season. The results were satisfactory since it is an effective shading system that does not compromise the gains required during the heating season. In the cooling season this system also has the advantage of allowing you to enjoy the natural lighting and the views during the period in which the solar rays are strongest as it occludes the system without the need to occlude the openings.

Figure 6. Glazoing / Shades Solar Control.

4 CASE STUDY

The case study is about the group of houses that won the DGE 2003 Prize. The choice was made because this was a success case that can contribute to the dissemination of this type of architecture.

4.1 Case Study 1 - DGE 2003 Prize "Energy Efficiency in Buildings" - Winner in the "Residential Building" category, houses in Janas (Sintra - Portugal)

The houses in Janas, in the countryside around Sintra, consist of three detached row-houses. The location is slightly inclined with a southern-facing slope that facilitated the integration of the concept of harnessing solar energy.

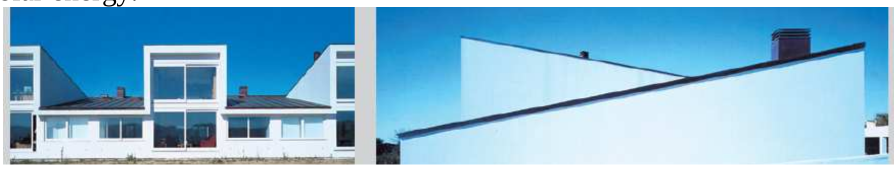

Figure 7. Photos from the South and West facade.

Project Strategy

The strategy of the project took into account the fact that the buildings have an east-west axis and took advantage of the excellent solar orientation of the southern façade. The building is also protected from the prevailing winds from the northwest quadrant, through the placement of vegetation at the north and west of the land. The complex is rectangular in shape (30x11 m), with two floors in the main body of each villa. The north façade is nearly opaque and has a small window and the entrance door, while the east and west façades are completely opaque. The service areas (kitchen and toilet facilities) are located in the northern part of the building, serving as a thermal buffer for the residential areas located in the south area. Thus each dwelling unit is organized from the nuclear space of each family's living room from which you access the other areas in the house. A mezzanine in the room will give the shape of the building its alternative profile of pitched roofs.

On the south façade we have extensive glazing to capture solar radiation (25 m2 of glazing for a total floor area of 110 m2). These openings are the fundamental elements of this project's strategy of passive use, together with the inertial mass of the building. The building features natural cross ventilation, which is an important element in controlling the temperature inside.

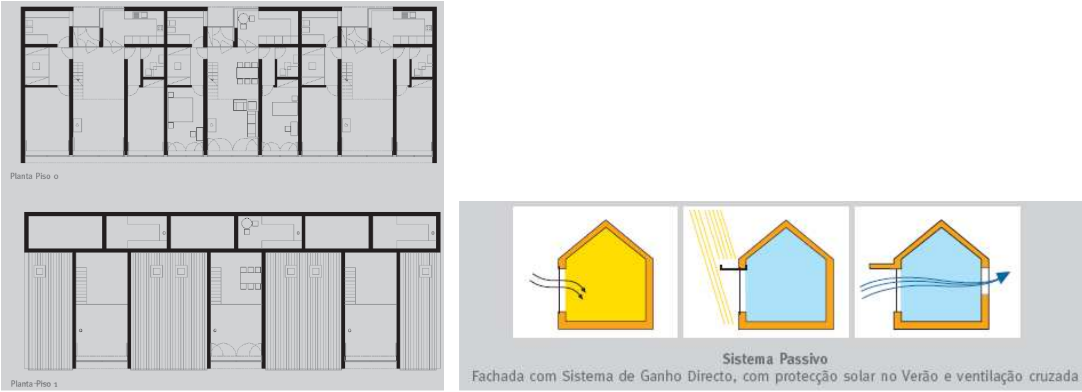

Figure 8. Floor 0 and floor 1 Plan / bioclimatic strategies used in these buildings.

In each house the living room and bedrooms are face south, enjoying the winter sunlight, whereas the kitchen and bathrooms are face North. The first floor (mezzanine) develops from the living room and is a working space, facing South.

Figure 9. Photos of the buildings.

Constructive Characteristics

The building has a portico structure of pillar, beam and slabs of reinforced concrete, with the slab floor installed over a ventilated air chamber insulated with extruded polystyrene. The exterior walls are simple masonry (20 cm), insulated from the outside with a 6 cm polystyrene system (Dryvit), totally eliminating thermal bridges. The slabs are massive and insulated from the outside by extruded polystyrene. The base slab has a 4 cm insulation layer over a ventilated chamber and the cover slab has a 10 cm layer of insulation covered with copper foil.

The separating walls of the houses are solid in order to increase the effect of the building's inertia and soundproofing of the adjoining spaces. The other interior walls of each house are made of clay brick rendered with plaster. The windows are colorless double-glazed with wooden frames and wooden interior shutters to provide shade and improve the insulation of the building at night. The openings have structural visor shades at ground level and exterior canvas awnings were considered on the upper level, for better shade in the summer.

Figure 10. Thermal conductivity coefficient of walls and glazing.

Energy Analysis

The RCCTE check gives excellent ratings for winter and summer with the canvas awnings down. The thermal behavior of the building is excellent and users approved of the overall thermal comfort of the houses. Neither west nor central house users (the only ones occupied) has used any auxiliary heating. In the summer cross-ventilation and shading of the openings have proved capable of coping with the specificity of local climate.

5 CONCLUSIONS

- The main objective of bioclimatic architecture is to achieve sustainability in construction, reflected in the improvement of energy efficiency parameters, reducing the need for lighting, ventilation and artificial air conditioning, replacing conventional energy consumption with a renewable one and reducing the construction "ecological footprint";

- Bioclimatic Architecture allows substantial energy savings, making the building comfortable in any season through renewable sources without additional costs;

- Buildings designed based on bioclimatic architecture are more energy efficient, have a healthier indoor environment and have good levels of comfort;

- The vast combinations of bioclimatic solutions can be implemented in new projects, historic settlements, rehabilitation or recovery of buildings;

- The methods of bioclimatic architecture can and should be complemented with active measures to retain solar energy through solar panels, photovoltaic panels or mini wind turbines;

- Bioclimatic techniques should be studied, weighted, designed and integrated so that their placement is an asset to the formal composition and architecture of the building and not something strange and crumbled that is applied later;

- The placement of solar or photovoltaic panels should be included in the plans of buildings’ roofs, attics and façades either in rehabilitation or in new constructions;

- On the rehabilitation of historic buildings there should be particular care taken regarding the placement of exterior shading or other mechanisms on window frames, so as not to hurt the building’s architecture and historical integrity.

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