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Bioclimatic Architecture: Housing and Sustainability

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Abstract:

The aim of this paper is to discuss the idea of bioclimatic architecture from its genesis to the presentation of the most advanced contemporary examples. Different ways of adapting dwelling to the climate are compared and analysed. The basic solutions are commonly found in vernacular building. Some modifications and improvements can be also observed while particular methods differ depending on the regional traditions, available materials, developed techniques etc. Today, with the application of cutting-edge technology, bioclimatic building is based on much more advanced systems, both passive and active. Also the respect towards nature is declared by most of the architects. However, in many cases a more detailed investigation reveals the lack of understanding of the complexity and fragilness of the existing ecosystems. So called green or sustainable buildings, although constructed from renewable materials and even awarded with energy certificates, are often designed without proper analysis of the specifics of local environment, neither natural nor cultural. The opportunities created by the building location, especially in terms of occurring bioclimatic conditions are usually ignored. The author of this paper describes how indigenous climatic solutions from vernacular building evolve from simple to more complex systems and how they are smartly combined with the newest technology to create mature and conscious bioclimatic architecture. Two presented case studies are some of the best examples illustrating how the concept of bioclimatic architecture works in practice and what opportunities are created by that.

Key words: Bioclimatic architecture, clean environment, passive cooling, energy efficiency, environmental passive and active Strategies, sustainable building, climate responsive facade.

1. Introduction

The aim of this paper is to explain and discuss the idea of bioclimatic architecture as one of the most actual and important phenomena in Residential Building. Although the necessity to develop the built environment with the respect towards nature is commonly declared, most of edifices are still erected without proper understanding of bioclimatic design. In purpose to

make this complex issue more clear both to the architects and to the building users, the author of the paper presents the formative process and evolution of bioclimatic architecture from its genesis to the most advanced contemporary examples. Therefore, the paper describes how indigenous climatic solutions from vernacular building evolve from simple to more complex systems and how they are smartly combined with the newest technology to create mature and conscious bioclimatic Architecture. Different ways of adapting dwelling to the climate are compared and analyzed.

This analysis is used as an exemplification how the authors of presented buildings take advantage of specifics of local climate and natural environment. The effective application of clean energy combined with proper understanding of complexity and fragileness of the existing ecosystems is another distinguishing feature of the chosen case studies. These issues are extremely important, especially in the light of accelerating climate changes, which compel to undertake actions that would lead to the immediate reduction of global warming potential as well as to more conscious exploitation of Earth's resources. Applied solutions are described also in terms of their vernacular origins which are new approach to the topic proposed by the author of this text.

The Concept of 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; N Bioclimatic Architecture Potential in Buildings

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.

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.

Passive Solar Architecture

Passive solar design refers to devices embedded in a building's construction with the purpose of contributing

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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.

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.

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.

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.

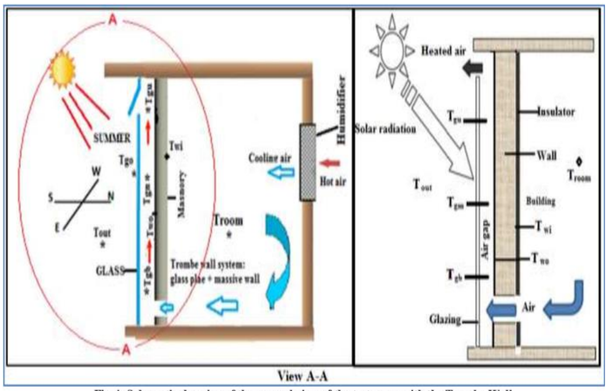

Fig-4: Schematic drawing of the general view of the test room with the Trombe Wall.

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.

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.

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.

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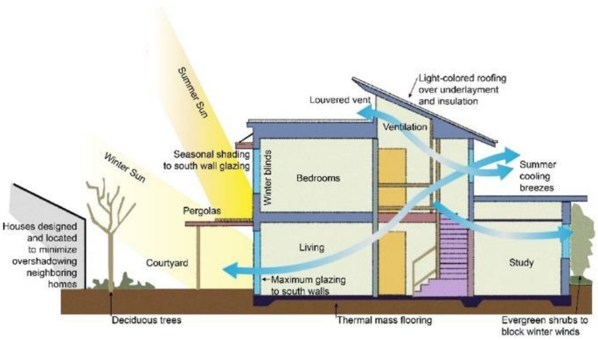
Some of the strategies to take into account for passive cooling systems are:

- 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.



Bioclimatic Design in Traditional Houses

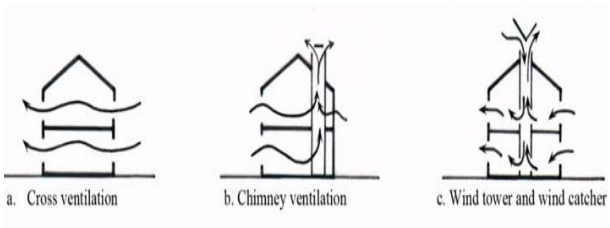


Fig. 1 Basic models of natural ventilation: 1a-Cross ventilation, 1b-Chimney ventilation, 1c-Wind tower and wind catcher.

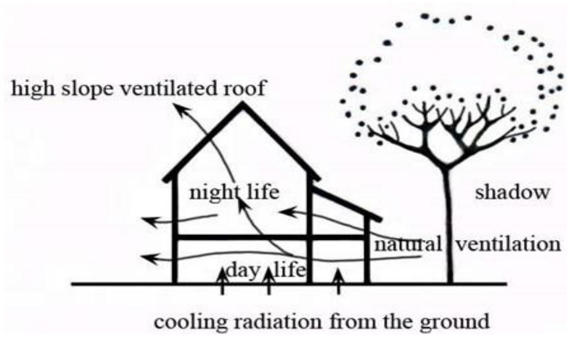


Fig. 2 Natural cooling in Thailand traditional houses with openwork structure built on high stilts. Cross ventilation combined with the elevated floor

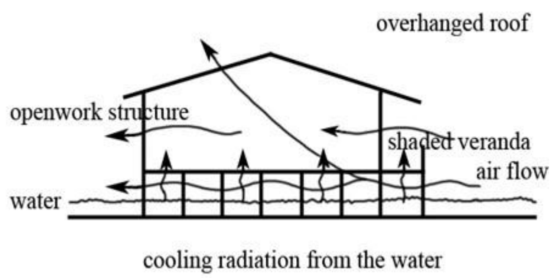


Fig. 3 Natural cooling in Caribbean traditional houses with openwork structure built on stilts and located above water. Cross ventilation combined with the elevated floor and radiating cooling from the water surface.

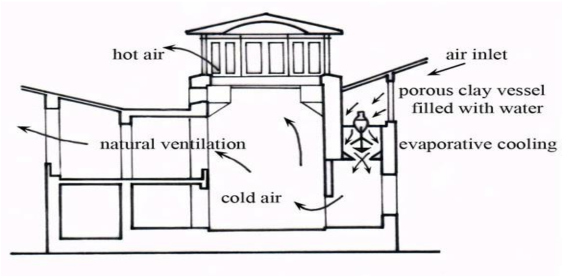


Fig. 4 Evaporative air cooling system in Egypt.

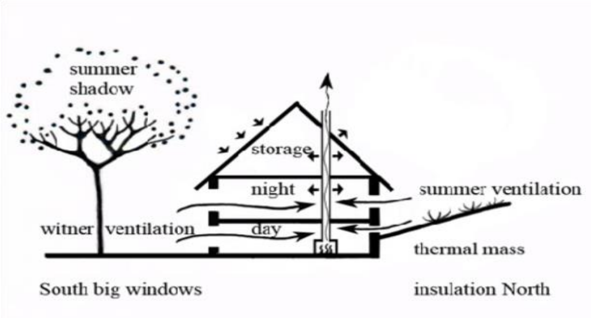


Fig. 5 Passive strategies in temperate and colder climate: thick massive walls, thermal mass and additional insulation provided by natural slope, big windows on the South, small on the North, natural ventilation combined with chimney heating.

Discussion: Vernacular versus Bioclimatic Architecture

There is a lot of similarities between vernacular and bioclimatic architecture. First of all both of the ideas are characterized by the proper adaptation of the building to the climate specifics. Second issue is the concept of living in a balance with the natural environment which is very obvious in vernacular structures and consciously created in bioclimatic edifices. Bioclimatic approach involves in-depth understanding of complexity and sensitiveness of the ecosystem. Also the respect for the cultural heritage of the place, where the building is erected can be noticed in both architectural phenomena.

However, vernacular and bioclimatic building differ a lot regarding the applied technology level. Traditional dwellings are usually based on knowledge developed in particular region of the world and transferred from one generation to another as a part of the heritage. Contemporary bioclimatic architecture combines indigenous methods with the most advanced technology. Nevertheless, the critical point in this active methods, based on multidisciplinary research (including e.g. energy efficiency, environmental impact, cost analysis etc.) and not just the affirmation of the technology itself. Finally “the main difference between vernacular and bioclimatic building lies in the ability to select the technological solution most appropriate to the climate”. Consequently, bioclimatic architecture should use the most suitable traditional methods together with cutting-edge technology in purpose to achieve optimal adjustment to the local climate and to the modern user expectations. Hybrid systems and real-time modifications are applied to optimize performance of the building perceived as a whole.

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.

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.

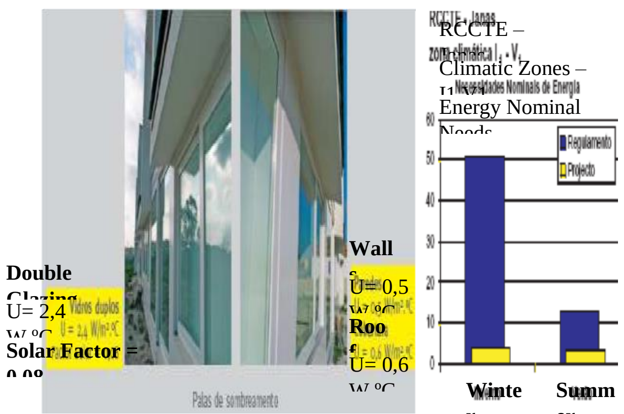
Figure 8. Floor 0 and floor 1 Plan / bioclimatic strategies used in these buildings.

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.

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.



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.

Conclusion

The study described the idea of bioclimatic architecture from its genesis and showed how basic methods of adapting architecture to the local climate originated in vernacular building evolved from simple to more complex systems. The author of the text explained how indigenous solutions, developed in different regions of the world, gained support by the application of cutting-edge technologies and how contemporary knowledge transfer increases the awareness of the available possibilities. That allows to choose strategies most appropriate to the climate and ecosystem which is especially helpful in the regions that did not develop their own suitable vernacular examples. The research revealed how basic passive methods were successfully hybridized with the most advanced technologies to provide comfortable indoor microclimate and optimal building performance. The study explained the importance of individual analysis of biological and climatic determinants that must be carried out for each location which excludes the practice of copying some techniques and producing dwellings without complete checking their potential environmental impact. Finally the research results with the conclusion that contemporary bioclimatic architecture can be defined as one that is based on traditional systems of adapting dwellings to the climate but combines them creatively with advanced research, design and technological methods. This approach results with developing innovative systems designed specifically for the location needs. The main goal is the architectural environment, which is comfortable for the user and maximally integrated with the ecosystem in purpose to retain its natural harmony and continuity.

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