

# Bioclimatic Buildings Strategies for the Climate of Araras City, São Paulo - Brazil

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**ABSTRACT:** The concept of bioclimatic architecture or passive solar architecture can be defined as an architecture that includes the climate as an important variable in the design process. Through the use of bioclimatic strategies the environment comfort can be obtained naturally for users of buildings, which depending on the climate, the construction techniques and the type of use. Considering these aspects, the main objective of this work is to identify bioclimatic strategies for buildings for the climate of Araras city, countryside of São Paulo State - Brazil, based on climatic characterization of the city and in the study of design guidelines indicated by the Brazilian Code NBR 15220-3, the Brazilian Bioclimatic Zoning. According to the code, the climate of Araras is inserted in Bioclimatic Zone 4. For this climate the main indicated strategies for winter are the use of solar passive heating and massive internal walls in buildings. For summer, the use of evaporative cooling and ventilation are indicated. Based on this information were established initial guidelines for thermal comfort and energy efficiency for projects of buildings in the climate of Araras-SP.

## 1 INTRODUCTION

The architecture has sought throughout history to develop means of environmental control that can provide shelter and comfort for the man, and the mood climate of each city has been the determining factor in defining the architectural concepts, materials and construction techniques used. The study of climate and its relation to design practice is increasingly becoming a differential of the good architecture.

There are different terms related to architecture as "Green Architecture", "Ecological Architecture", "Bioconstruction", "Bioclimatic Architecture", "Eco-Efficient Architecture", "Passive Solar Architecture." There are also different ways of relating architecture with the environment with similar or close meanings, and they are directly related to the sustainable architecture.

The bioclimatic project covers the needs of the human being in thermal, lighting and acoustic aspects, with a concern about the weather conditions and the use of techniques including the study of sunlight, heating and air movement through the building envelope when necessary. This for specific hours of the day and months of the year, using available materials in the region and, in addition, trying to integrate the building with the surrounding space (Givoni, 1998 apud Sacht, 2013). It is believed that the incorporation of bioclimatic building concepts is one of the cheapest and most efficient practice for energy saving.

There are two major factors in the context of bioclimatic architecture, they are: a multidisciplinary approach required to develop an efficient project, and its insertion into the sustainability subject to the search for an efficient passive design is necessary to understand that there is not a perfect solution and that can be applicable to all situations, but numerous mechanisms that must be selected in order to find an appropriate solution for a given site

(Lanham et al, 2004), this will give birth to a more sustainable architecture.

Considering these aspects, the bioclimatic architecture subject is extremely important to the current context of architecture, both in relation to buildings and the urban environment. This justifies the importance of the development in the area. In this research, appropriate bioclimatic strategies to the climate of Araras have been established. The climate characterization of the climatic data is indispensable instruments of assessment and construction planning of sustainable buildings.

## 2 OBJECTIVES

The main objective is to identify bioclimatic strategies for buildings for the climate of Araras city, countryside of São Paulo State - Brazil, based on climatic characterization of the city and in the study of design guidelines indicated by the Brazilian Code NBR 15220-3, the Brazilian Bioclimatic Zoning: Thermal performance of buildings" (ABNT , 2005). This paper presents the initial results of a research in progress.

## 3 METODOLOGY

For the development of this work it were respected the following rules: climatic characterization of Araras city; application of NBR 15220-3 (survey of indicated bioclimatic strategies and compared with the strategies set by the ZBBR program); detailing strategies and observation using them in buildings located in the city of Araras.

### 3.1 *Climate Characterization of Araras*

The climatic characterization of Araras was based on climatic classification of Köppen-Geiger, best known for Köppen climate classification, which is the classification system of global climatic types, most commonly used in geography, climatology and ecology. This classification was proposed in 1900 by climatologist Wladimir Köppen, and it have been improved by him in 1918, 1927 and 1936 with the publication of new versions, prepared in collaboration with Rudolf Geiger (origin of the name Köppen-Geiger) (Sá Jr., 2009). It were also consulted the climatological data of Araras provided by the Center of Agrarian Sciences of the Department of Natural Resources and Environmental Protection of the Federal University of São Carlos (UFSCar).

### 3.2 *Application of Brazilian Code NBR 15220-3*

According to "NBR 15220-3: Thermal performance of buildings", Brazil is divided into eight different bioclimatic regions (Figure 1). The eight areas are relatively homogenous regarding to the weather. For each of them there is a set of technical and constructive recommendations, in order to optimize the thermal performance of buildings through a better climatic adaptation (ABNT, 2005). Araras is included in Bioclimatic Zone 4 (Figure 2).

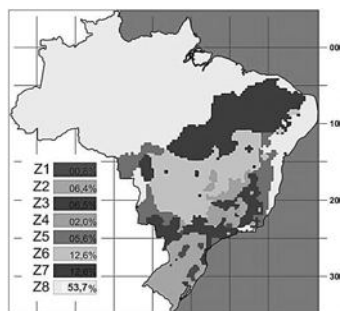


Figure 1. Brazilian Bioclimatic Zoning. (Adapted from Yuriko 2012).



Figure 2. Localization of Bioclimatic Zone 4 on Brazilian map. NBR 15220-3 (ABNT, 2005).

Bioclimatic Zone is a graphic result of the intersection of three different data: human thermal comfort zones, weather data of a region and design strategies (Yuriko, 2012).

Roriz (2012) elaborated a new proposal for the Brazilian Bioclimatic Zoning (Figure 4). According to him, there are several methods of climatic classification, aimed at different goals, such as agriculture, biology, geology, etc. His new proposal applies two parameters to classify climates, the both are indicators of the climatic strictness of each point in the territory: the first is proportional to the total annual heating degree-hours; the second, proportional to the total annual cooling degree-hours. To set these parameters, the author has adopted the comfortable temperature gaps of the Bioclimatic chart proposed by Givoni (1992) for countries in development, in other words, 18 to 28°C, 18°C, the lower limit of the Comfort Zone and 28°C, an average between upper limits for different levels of moisture. Were then calculated values of GhC and GhF for each point on the climatic map and based on the analysis of the results, were defined 16 Bioclimatic Zones.

The Table 1 shows the thermal conditioning strategies that are indicated by the NBR 15220-3 (ABNT, 2005), for Bioclimatic Zone 4 (BCDFI) according to Bioclimatic Chart (Figure 3).

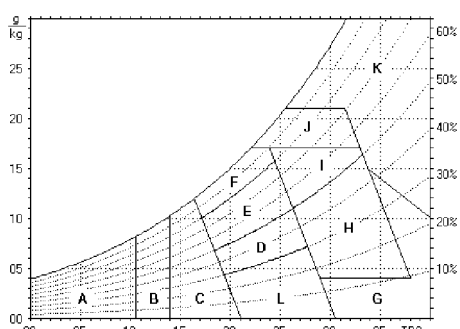


Figure 3. Bioclimatic Charter adapted. Reference: NBR 15220-3 (ABNT, 2005)



Figure 4. Second proposal for the Brazilian Bioclimatic Zoning. Reference: Roriz (2012).

Table 1. Detailing strategies for thermal conditioning

Strategies	Characterization	Detailing Strategies
B	Heating solar zone for edification	The shape, orientation and arrangement of the building, to the correct orientation of glazed surfaces, may contribute to optimize its heating during cold periods through the incidence of solar radiation. The color of the external components also has an important role in the heating of environments through the use of solar radiation.
C	Thermal mass zone for heating	The adoption of massive internal walls can help to keep the interior of the building warmed.
D	Thermal comfort zone (low humidity)	Characterizes the thermal comfort zone (the low humidity).
F	Dehumidification Zone (air renewal)	The thermal sensations are improved through dehumidification of environments. This strategy can be obtained through the renewal of indoor air by outdoor air through the ventilation of environments.
H e I	Thermal mass Zone for cooling	More pleasant indoor temperatures can also be obtained through the use of walls (external and internal) and coatings with higher thermal mass, so that the stored heat in its interior during the day returns to the external during the night, when the outside temperature decreases.
I e J	Ventilation Zone	The cross ventilation is obtained through the circulation of air through the edification environments. It means that if there are windows only on a façade of the environment, the door should be left opened for cross ventilation. It should also be alert to the predominant winds of the region and of the surroundings because the surroundings can significantly alter the direction of the winds.

Reference: Based on NBR 15220-3 (ABNT, 2005).

The ZBBR program was used to confirm the constructive guidelines indicated by NBR 15220-3 (ABNT, 2005), because in the code version, Araras city is not included in the detailed list of municipalities and bioclimatic strategies, being that on the program the strategies are indicated based on interpolated climatic data. The ZBBR program, developed by Roriz (2004) presents the bioclimatic classification of Brazilian municipalities and constructive guidelines are established for social interest housing, also based on NBR 15220-3.

### 3.3 Detailing of the Passives Strategies and Observation of Use in Buildings of Araras

Through a qualitative survey was analyzed the use of the passive strategies in the city of Araras, based on the characteristics of the autochthonous architecture of the city.

## 4 RESULTS

### 4.1 Characterization of climate of Araras

The climate of Araras presents an annual average temperature of 21.4°C, with the minimum in July of 17.7°C and maximum in February of 24,1°C. The annual precipitation in 2011 was 1649.80 mm with hydric deficit between the months of July and August (UFSCAR, 2003). The air temperature regime follows closely the seasons, varying gradually, with elevated monthly averages in summer, slight decrease in the fall, lower values in winter and growth in spring. This climatic pattern is typical of the Cwa climate for the Köppen classification (Table 2) (mesothermal with hot summers and dry season of winter, with average temperature below 18 C, but superior than 3°C in the coldest month, and average temperature over 22°C in the hottest month) (Valladares et.al., 2008).

Table 2. Fundamental Regions and Climatic Classes of Araras-SP, by the Classification of Köeppen.

Climatic Groups	Fundamental Regions	Climatic Classes
C	Cw	Cwa
Rainy Temperate Climate And Moderately Hot.	Mostly Temperate Climate With Summer Rains And Dry Winter.	Mostly Temperate Climate With Dry Winter And Hot Summer.

Reference: Sá Jr. (2009).

### 4.2 Application of the Code NBR 15220-3 for the climate of Araras

Strategies for a project can differ according to the climate of each region where they are applied, but in general, using the shape of the building, the layout of the openings and the thermal performance of the materials. There were initially compiled the established guidelines by the code for Bioclimatic Zone 4, in which the city of Araras is included. Regarding the ventilation vents, the NBR 15220-3 indicates the strategies presented in Table 3.

Table 4 summarizes the bioclimatic strategies for the Bioclimatic Zone 4 for the winter and the summer. In relation to the external walls and the roof, the code indicates of the properties of materials according to Table 5.

Table 3. Bioclimatic Strategies for Vents/Shading for the Bioclimatic Zone 4.

Zone	Vents for Ventilation A (% of the Floor Area)	Shading
4	Averages $15\% < A < 25\%$	Shade the vents.

Reference: Based on NBR 15220-3 (ABNT, 2005).

Table 4. Bioclimatic Strategies According to the Bioclimatic Zone 4.

Bioclimatic Zones	Bioclimatic Strategies	
	Winter Heating Season	Summer Cooling Season
4	A) Solar heating of the building B) Heavy internal walls (thermal inertia)	A) Evaporative cooling and massive wall for cooling B) Selective ventilation (in hot periods where the indoor temperature are higher than the outdoor)

Reference: Based on NBR 15220-3 (ABNT, 2005).

Table 5. Bioclimatic strategies for internal walls and roofs for the bioclimatic Zone 4.

Zone 4	$U$	$\Phi$	$F_{So}$
Internal walls	$\leq 2.20$ (massive)	$\geq 6.50$	$\leq 3.50$
Roof	$\leq 2.00$ (isolated lightweight)	$\leq 3.30$	$\leq 6.50$

Reference: Based on NBR 15220-3 (ABNT, 2005).

Where  $U$  = thermal transmittance of a component ( $W/m^2.K$ );  $\phi$  = heating time delay of a component (in hours); and  $F_{So}$  = solar factor of opaque elements (%).

The verification of the strategies mentioned on the Table 4 was made through the ZBBR program, thus obtaining constructive guidelines for Araras-SP, as in the Figure 5.

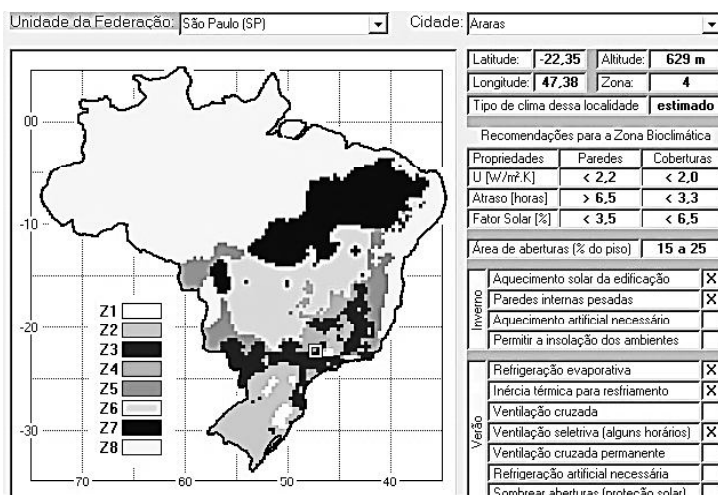


Figure 5. Brazilian Bioclimatic Zoning and Constructive Guidelines for the climate of Araras City. Reference: ZBBR Program (Roriz, 2004).

### 4.3 Detailing the Strategies for Winter

#### Solar heating of the building

Large glazed openings allow the entrance of solar radiation, warming the environment. In Figures 6 to 8 below are observed images of buildings located in Araras, which are application examples of such strategies, through the use of glazed (direct radiation system gain).

It is important to use the adequate glass according to the climate. One can quote the case of the glazings in the green and blue colors, for example, which allow reasonable transmission of radiation in the visible region, therefore providing a good daylighting, while attenuates infrared radiation, thereby reducing the heat that occurs due to the radiation from that region. It is known that these color glasses have a tendency to decrease the transmission of radiation in higher wavelengths (Caram, 1998; Caram, 2002).



Figure 6. Glazed façade



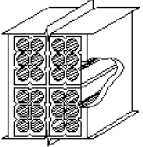
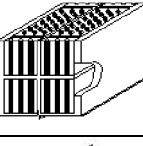
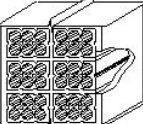
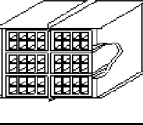
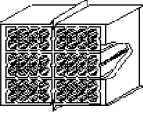
Figure 7. Façade with large glazed windows, and protected balcony.

### Massive Internal walls

Corbella and Corbe (2011) describes that "the inner walls intervene on the persons's comfort, with other internal elements of construction, playing a role in thermal inertia." it is also said that the effusivity of materials, which have areas exposed to indoor air (and exchanging heat with it), can produce a dampening of the outdoor temperature variations." According to the normalization, they are advised for Araras, the types of internal walls in accordance with Table 6.

It should be noted that the use of thicker walls is visible in historic buildings of the city, whose vertical windbreak are solid brick. For choosing these solutions for internal walls must be considered the solutions that are more consistent with the reality of building systems for vertical sealing that are used in local construction as well as the final cost of the solution.

Table 6. Thermal transmittance, thermal capacity and thermal delay for walls que may be used in constructions in Araras-SP.

WALL	DESCRIPTION	$U$	$CT$	$\varphi$
	Double masonry wall Horizontally perforated bricks Brick dimensions: 10,0 x 15,0 x 20,0cm Thickness of the mortar: 1,0cm Thickness of mortar plastering: 2,5cm Total Thickness: 26,0cm	1.52	248	6.5
	Double masonry wall Vertically perforated bricks Brick dimensions: 12,0 x 11,0 x 25,0cm Thickness of the mortar: 1,0cm Thickness of mortar plastering: 2,5cm Total Thickness: 30,0cm	1.54	368	8.1
	Double masonry wall Horizontally perforated bricks Brick dimensions 10,0 x 15,0 x 20,0cm Thickness of the mortar: 1,0cm Thickness of mortar plastering: 2,5cm Total Thickness: 36,0cm	1.21	312	8.6
	Double masonry wall Horizontally perforated bricks Brick dimensions: 9,0 x 19,0 x 19,0cm Thickness of the mortar: 1,0cm Thickness of mortar plastering: 2,5cm Total Thickness: 44,0cm	1.12	364	9.9
	Double masonry wall Horizontally perforated bricks Brick dimensions: 10,0 x 20,0 x 20,0cm Thickness of the mortar: 1,0cm Thickness of mortar plastering: 2,5cm Total Thickness: 46,0cm	0.98	368	10.8

Reference: Based on NBR 15220-3 (ABNT, 2005).

Where  $U$  = thermal transmittance of a component ( $W/m^2.K$ );  $CT$  = thermal capacity of a component [ $kJ/(m^2.K)$ ]; and  $\varphi$  = heating time delay of a component (in hours).

#### 4.4 Detailing the Strategies for Summer

##### *Evaporative Cooling*

Evaporative cooling is a strategy used to increase the relative humidity and decrease its temperature, and can be obtained directly or indirectly (Lamberts et al., 2000). Like examples can be cited the use of vegetation, water sources (Figures 8 e 9) or other features that result in the evaporation of water, providing an increase of relative humidity. However, an indirect form can be obtained through water tank systems that pour the water on the coatings.



Figure 8. Araras's square with a body of water.



Figure 9. Fountain located in Araras's square.

##### *Selective Ventilation*

Ventilation is a natural cooling strategy of the constructed environment, replacing the internal air (warmer) by the external (cooler). The architectural solutions most commonly used are cross ventilation, ventilation of the cover, and ventilation of the floor under the edification (Lamberts et al. 2000). For buildings in Araras is necessary that ventilation be selective, i.e. be used and / or be available only at certain hours of the day, for example in warmer periods. Figure 10 shows an example of cross ventilation which occurs due to the existence of openings in adjacent walls, forming zones with different air pressures. On the face of incidence of the wind there is a high pressure zone, and on the opposite side there is a low pressure zone, thus generating the movement of air. In the case of environments without opening for output wind, it is used the unilateral ventilation.



Figure 10. Windows of a building in Araras, which provide cross ventilation.

## 5 FINAL REMARKS

Currently the relationship between architecture and the climate in the preservation of the environment and energy saving have had greater importance. In this context, the bioclimatic architecture joins the search for answers in the appropriate integration of man and his environment, through changes in design process and execution of habitable spaces, reverberating throughout the productive chain of the construction industry.

Therefore, this initial phase of this research brings up as a contribution the collecting of bioclimatic strategies for the municipality of Araras, through the study of NBR 15220-3 (ABNT, 2005), and as initial results it could be verified that the application of such strategies aim at a better environmental comfort for the users, with consequent energy saving.

This information will form the basis for architects and engineers that work on development of projects in Araras, that most of the time are unaware about the possible application of such strategies, well as for architecture students that may have initial references to develop projects

adequate to the climate conditions. The use of such strategies, joint with the correct selection of materials, contributes to the rise of environmental comfort, as well as saving resources and energy efficiency.

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