Potential of Natural Ventilation in a Tropical Climate

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ABSTRACT

Sustainable architecture design for tropical climates requires the use of natural ventilation beside several strategies, as appropriated materials, site location, façade orientation, solar shading, etc. The indoor thermal comfort and thermal performance of the building depends on the bioclimatic zone where is located. The new Brazilian Norm ABNT NBR 15220-3 has established bioclimatic zones and guidelines for low-income houses. Due to the lack or scarcity of meteorology wind data, certain regions as Amazon and Northeast coast were inserted in a same zone. This will pose problems to architecture design. To overcome this problem this paper proposes an average wind zoning map for all the country, considering two heights from the ground; 1.5 m and 6m. The average wind velocities were calculated using a logarithm profile with available average velocities from theoretical-empirical data chart (meteorology data + WasP simulations) at 50m height, used for site analysis of wind electricity generation.

KEYWORDS

Natural Ventilation, Tropical Climate Comfort, Sustainable Architecture

INTRODUCTION

Nowadays, in order to fulfill a building sustainable approach the architecture designer needs to consider the site microclimatic analysis beside several other important subjects. Energy adequacy use and environmental problems are points to be taken in account along the architectural design process and they are related with the site building location.

In Brazil the architecture design of low-income houses is a challenge, Barroso-Krause, 2005. One problem is related with the indoor comfort, due to the climatic diversity, cultural aspects, and the use of low price and performance materials. Thus, natural energy resources as natural ventilation come to play an important role for this building segment. The role of natural ventilation as a mean for cooling the house envelope and to improve indoor thermal comfort and health, needs be considered in architectural design process.

Despite this importance of natural air infiltration and ventilation to provide healthy and comfortable indoor ambiances in Brazilian income houses , it is observed that there is a lack or scarcity of wind data turned to the architectural purposes. This problem was found in the new Brazilian Norm NBR 15220-3 (2005) establishing eight bioclimatic zones and building guidelines for low-income houses: certain regions as Amazon and the Northeast coast were inserted in the same bioclimatic zone, and this will pose to architecture design, because the wind fields and flow regimes are not the same. In order to overcome this problem the present work proposes, an average wind zoning map for Brazil, considering two heights from the ground: 1.5m and 6m. This solution was based upon the analysis of existing wind charts performed to aid-site design of wind turbines to electricity generation, Eletrobrás (2001), Rio de Janeiro State (2005).

AVAILABLE WIND DATA

The general wind distribution over the Brazil is controlled by large atmospheric scales (synoptic and general planetary). This general profile presents large amount variations in the meso-scale (regional level) and micro-scale (local level) due to the site characteristics, topography and altitude and water masses. These factors acting on the small scale can generate local wind regimes with specific patterns, which vary in time (hours or days). This occurs under a predominant daily regime dictated by the local and regional influences. The annual and seasoned wind regimes depend on the large atmospheric scales.

In the present work were utilized several data, determined at 50m height from ground, from the Wind Charts, published in Brazil from 2001 to 2005. It was considered the wind regime distribution, average annual velocities, main direction and terrain rough. The wind turbines for electricity generation operate with average wind velocities between 2,5 to 15 m/s and are at 50m height or more from the ground. The wind regime distribution is presented trough seven regional meso-scales.

WIND REGIONAL MESO-SCALES

Occidental and Central Amazon Basin

It is the region comprised between 10ºS and 5ºN latitudes and 77ºW and 55ºW. The climate is equatorial humid, with an average temperature of 25ºC and a rain level of 2000 mm/year. The atmospheric pressure gradients are low and the trade winds from east are of low intensity. The wind speed at 50 m height is lower than 3,5m/s. The average terrain rough is Zo = 0,8m. Calm winds at the night period. During the day, there are localized winds due to the non-uniform heating of the surfaces, vegetation and water reservoirs. At the portion North of this basin there is an elevated region Serra da Paracaima (Roraima State) that has constant winds from East to Northeast, reaching average annual velocities from 6 to 9 m/s at 50m height, and a terrain rough Zo = 0,2m.

Oriental Amazon Basin

This region comprises a 100km width band from the 55ºW longitude, Santarém city (Pará State) up to the Atlantic coast region of the Amapá and Maranhão States. At the North portion there is trade winds from East to Northeast, and at the South portion the winds are from East to Southeast. The annual average wind speed at 50m eight is lower than 3,5m/s, and the terrain roughness is Zo = 0,5m. On some hills near the ocean coast, the average velocities reach 7,5m/s to 9m/s at 50m height from ground.

North - Northeast Atlantic Coast

Coast region with 100 km width band from the Amapá State to the São Roque cape, Rio Grande do Norte State. The dominant trade winds are from East and breezes. On the North portion (Amapá and Pará) the average annual wind velocities at 50m eight reach 5m/s to 7.5m/s, for a terrain roughness Zo = 0.4m. On the South portion, (Maranhão, Piauí, Ceará and Rio Grande do Norte States) due to the land-breezes effect the wind velocities reach 6 to 9m/s at a height of 50m and Zo = 0.2m.

Notheast-Southeast Coast

This zone has 100km width from the São Roque Cape up to the Rio de Janeiro State. On the North portion the average wind velocity varies from 8 to 9 m/s toward the South direction. 50m height and Zo = 0.3m/s. More to Southeast the wind velocity range is reduced from 3.5 to 6m/s. In the region situated between the latitudes 21ºS and 23ºS at 50 m eight, the average annual velocities are 3.5 to 4.0m/s from East-Southeast direction, and Zo = 3m. On the mount region Serra do Mar, the average annual velocity is around 6,5m/s , 50m height and terrain rough Zo = 1m. For the marshy coast region the velocities are from 6 to 7 m/s,
Zo = 0,005m. Considering the Rio de Janeiro city region, the average annual velocities at 50m height are from 3.5m/s to 4m/s, towards South quadrant, Zo = 3m.

Northeast - Southeast Hills

This region is composed by hills and elevated plates inside the country situated 1000 km from the Atlantic coast , from the Rio Grande do Norte State up to Minas Gerais State (Diamantina e serra do Espinhaço). The average annual velocities are 6.5 to 8.5m/s on the Central and South portions, and 5.5 to 7.7m/s for the other sites, at 50m height and Zo = 0.4m.

Central Plateau Region

This region is situated from the Amazon Basin and the left side of the São Francisco river to the boundary limits with Bolivia and Paraguai. The winds blow East-Southeast directions. In the North portion, Amazon Basin limit, the wind average annual velocities at 50m height are from 3.5 to 4m/s, and more to the South (Mato Grosso do Sul State) the velocity range increases from 5 to 6m/s, Zo = 0,2m.

South Plateau Region

Region comprised from the 24º S latitude (São Paulo) up to the South frontier of the country (South of the Rio Grande do Sul State) . The windows are toward Northeast and are within the band of 5.5 to 6.5m/s (50m height) and at land elevations reach 7.0 to 8.0m/s, Zo = 0,45m. On the South coast there is the land-breezes mechanism and the wind blows East-Northeast. The average annual velocities reach values above 7m/s (50m height) and Zo = 0.1m.

AVERAGE ANNUAL WIND VELOCITIES FOR ARCHITECTURE

In order to examine the potential of natural ventilation for a low-income housing , it was assumed two heights for apertures above ground 1.5m and 6m (one-family and multi-family houses). Calculations are performed using the available average annual wind velocities data chart (meteorology and WasP simulations) at 50 m height for all the country , Eletrobrás (2001), Rio de Janeiro State(2005).

The average annual wind velocity profile can to be approximated by a logarithmic law, Eqn. 1:

$$\mathbf{U(Z) = (Uo/k) \ln(Z/Zo)}$$

Where U(Z): wind velocity at the eight Z; Zo: terrain rough; k : Von Kármán constant; Uo: shear velocity (square root of the shear stress to air specific mass ratio).

This equation can be written for two heights Z1 and Z2 for a same site position, and it is obtained the Eqn.2:

$$\mathbf{U(Z2) / U(Z1) = \ln (Z2 / Zo) / \ln(Z1 / Zo)}$$

The required wind speed U(Z2) for ventilation purposes at several eights Z2 can be obtained from Eqn.2, where Z1 = 50m, U(Z1) is the available velocity at this level, and Zo is the terrain rough. Thus for each of the seven described Brazilian wind regions can be estimated the average annual velocity profile at heights near the ground . The obtained results are presented in Table 1.

TABLE 1
Potencial Range of Wind Velocity for Regional Brazilian Housing

Region	Region portion	Wind (m/s) à 1,5m	Wind (m/s) à 6m
Occidental and Central Amazon Basin	General	< 0,53	< 1,7
	North	2,2 - 3,3	3,7 - 5,5
Oriental Amazon Basin	General	< 0,8	< 1,9
	Hills	1,8 - 2,0	4,0 - 5,0
North – Notheast Atlantic Coast	North	1,4 - 2,0	4,2 - 6,3
	South	2,6 - 3,9	4,4 - 6,6
Northeast – Southeast Coast	North	2,5 - 2,9	4,7 - 5,3
	NE(RJ),S(ES)	3,1 - 4,7	4,2 -6,0
	Rio (RJ)	-	1,4
	Serra do Mar	0,67	3
Northeast – Southeast Hills	Central and South	1,6 - 2,0	3,6 - 4,5
	General	1,5 - 2,0	3,1 - 4,2
Central Plateau Region	North	1,1 -1,5	1,8 - 2,5
	South	1,8 - 2,2	3,1 - 3,7
South Plateau Region	General	1,4 - 1,7	3,0 - 3,6
	Hills	1,8 - 2,0	3,8 - 4,4
	South Coast	> 3,0	> 4,6

These estimated presented results for the wind potential near the ground do not consider specific conditions for the house: boundary interferences, envelope form, local topography, etc. From these calculated velocities values incident on the house surfaces, is possible also to estimate the average indoor air velocity. Suppose by example, one floor house with equal open windows in opposite walls faced to the wind. From Givoni (1978) it can be used Eqn.3 to calculate the average indoor air velocity Vi (m/s), being x the window area/ wall area ratio.

$$\mathbf{Vi = 0.45\ [\ 1- exp(\ -3.48x)]\ U(Z2)}$$

WIND AND BIOCLIMATIC MAPS OVERLAPPING

From the above considerations were generated eight maps showing the overlap of the bioclimatic zones proposed by the Brazilian Norm and the seven wind zones selected with the help of the available wind charts. In Figure 1 is presented, as an example, the map relating the bioclimatic zone (gray) and the specific wind zones(several colours). Thus a bioclimatic zone defined by the Norm comprises several wind zones, and this is a real problem. This result is important from the architecture point of view in a tropical climate and shows that this Norm needs to be reviewed.

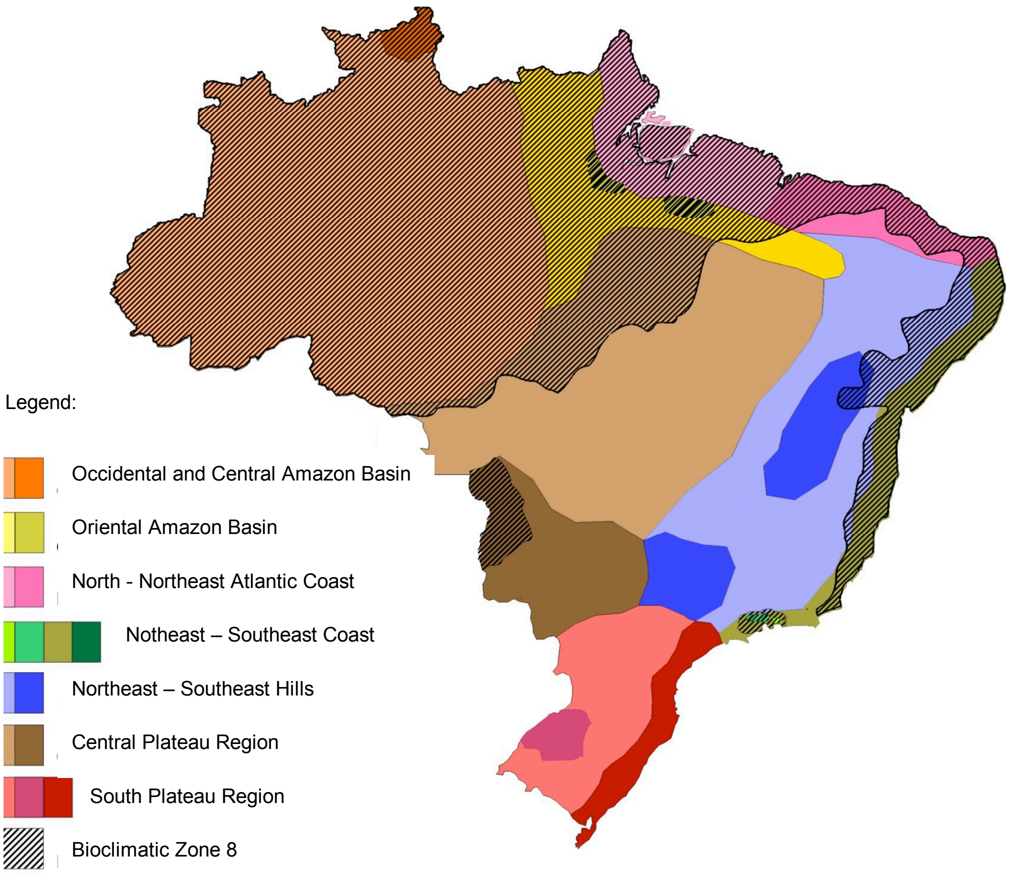

Figure 1: bioclimatic (zone 8) and wind zones overlapping map

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