Available online at www.sciencedirect.com
ScienceDirect
Renewable Energy 33 (2008) 1019–1023
RENEWABLE ENERGY
www.elsevier.com/locate/renene

Conceptual differences between the bioclimatic urbanism for Europe and for the tropical humid climate

O.D. Corbella*,[1], M.A.A.A. Magalhães

Faculdade de Arquitetura e Urbanismo, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil

Received 19 September 2006; accepted 14 March 2007
Available online 12 June 2007

Abstract

This article makes part of a series of conceptual papers to continue the discussion about how architecture and urbanism interact with climate, in tropical regions. Students engaged in normal courses of architecture in tropical regions, particularly in South America, develop their knowledge based on concepts generated in the developed countries—usually related to cold environments. Consequently, these students acquire wrong ideas about urban design of open spaces. Integrating urbanism and climate in tropical countries is still very incipient as an approach and many lecturers reject it, since they prefer to continue with a more formal one, dictated by most of the dominant countries. The herein paper underlines several different concepts and perspectives that separate the two conceptions, leading to a reflection about the subject.

Keywords: Urbanism and climate; Tropical countries; Environment; Urban design

1. Introduction

Continuing a series of conceptual articles about the constructed environments and climate in a tropical climate situation [1–3], this article discusses urbanism (or the architecture of public spaces) and its interaction with the environment—normally defined according to the climate of European countries [4–8]—from a tropical country's perspective.

The main changes that urban design should go through are unnoticed in the work of a designer—since his/her theoretical concepts about shape, esthetics, and landscaping have been elaborated without considering local climate and, consequently, without considering the needs of the users, either. As European open spaces need protection against cold winds as well as to take advantage of solar radiation and of low sky luminance, the different climatic conditions in the tropics should be considered for the benefit of all users.

Many of the conceptual differences between the approach to urbanism design in the tropics and in the European countries are not well understood, mostly as a consequence of the economic and, moreover, the cultural dependency since colonial times. Unfortunately, Latin American universities are still working with this uncontested colonialist frame of mind. Thus, the purpose of integrating urbanism and climate in tropical countries is still very incipient (see for example Ref [9]). The several points of view referred in this paper intend to contribute with a reflection about the subject.

2. Concepts about the interaction between climate and urban design

The microclimate of an environment in the tropics—regions characterized by low latitude and excessive solar radiation—is determined by the thermodynamic balance between absorbed solar energy and dissipated energy, based on four mechanisms: the emission of long wave radiation (from the surrounding surfaces), the materials heat conduction, the water evaporation, and heat convection from surfaces to the air [10–12].

*Corresponding author.
E-mail addresses: ocorbella@terra.com.br (O.D. Corbella), mariama@ism.com.br (M.A.A.A. Magalhães).
[1]CNPq researcher.

0960-1481/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.renene.2007.04.004

Energetic balance of external surroundings near the building can lead to two questions: how microclimate elements affect energy consumption in the architectonic space [13] and how the building system affects the microclimate [14].

The manifestation of heat islands is a principal topic to consider. It depends directly on urban design, such as the streets and the grid shapes, the location of green spaces, the building ensemble that modulates the environment shape, the recovering materials, and the quality of surfaces.

In general, reaching thermal comfort and decreasing the electrical energy consumption in the tropics is possible, by working with an urban design that modifies the wind path in a convenient way, the shadows, and the presence of water. The constructed environment with different colored surfaces and with reflective properties is also important in order to control the in-coming solar energy and the wind.

3. Heat islands

Heat islands are microclimate regions with temperatures higher than in their surroundings [15–17]. In countries with cold climate, they are advantageous during the winter time, since they decrease the demand of energy for heating. In tropical countries, these islands may occur when the heat dissipation by infrared radiation is smaller than the thermal energy increase due to a large exposition to solar radiation. They become larger or smaller depending on the size of sky view factors and ventilation, and also on the urbanization design. They directly influence the air-conditioning consumption of electric energy [13].

It is worth mentioning that the rate of ventilation in open spaces may rise or may lower the heat islands' temperature (the latter could be called a "cold island"). Surface colors of paved surroundings with different temperatures, emissivity and reflectivity, different diffusivity and effusivity of materials can modify an environment causing uncomfortable sensations to their users, who withdraw from using the spaces [18]. These elements are important to determine wind standards disturbances, turbulences, and doldrums, and to determine the wind shadow spaces.

Heat islands formation is not always bad. It depends on the influence on the people's thermal comfort and on the energy consumption through air conditioning. It should be acknowledged that temperatures fluctuate throughout the day. A region could be a heat island during the day and a cold island at night, or vice versa. If we take the building occupation period into consideration—or the occupation period of a town section, whose buildings use follows the same pattern—a heat island may lose its importance. For example, a nightly heat island in a district of buildings with daily occupation, such as office-buildings, does not interfere in the thermal comfort issue nor in terms of energy consumption through air conditioning. The same occurs with a daily heat island in a section of buildings with nightly use. If avoiding heat islands formation was possible by urban design, what needs to be taken care of is to prevent their occurrence during the day, in daily occupied sections, and at night, in nightly occupied areas.

That is why several geometric relations that link buildings height and streets width to heat islands need revision based on the above concepts. There is no doubt that the relationship between daylight versus height will not change, but the results may vary when promoting or obstructing the wind corridors. At the same time, the sky view factors must be read from a different perspective in relation to European urban projects, since the differences of solar exposition as well as of infrared emissions should be taken into account.

Therefore, the daily occupation of urban sections should have reduced sky view factors to avoid a great exposition to solar radiation and to be less permeable to daily winds, which bring air masses with higher temperatures than that of the microclimates. Nightly occupation sections, as dormitory buildings quarters, should have large sky view factors and be permeable to winds, so as to dissipate the hot air masses formed during the day.

Regarding the soil occupation, it must be reminded that all anthropogenic heat sources contribute to increase the heat islands temperatures. As it was said, in the case of cold countries, these islands behave as sources that help to produce thermal comfort sensation, which is not true in the tropics. Just to have an idea of how much heat people may produce, it could be compared to the energy that comes from the sun: the solar energy that the city of São Paulo receives by square meter of the horizontal surface is of 150 kWh/m^2 month. The average energy produced by each inhabitant, per square meter, is of 187 kWh/m^2 month, i.e., 20% more energy than the incident solar energy. Certainly, this average proportion increases when considering zones of greater population density—it is well known that park temperatures are always lower than in inhabited areas. The fact that the towns present lower temperatures during weekends confirms the anthropogenic heat contribution to heat islands formation. Many authors have registered the correlation between zones of industrial, commercial, and services concentration—based on a great deal of concrete—and the raise of temperature and pollution.[2]

Therefore, contrary to the conclusions of the cold countries urbanism, cities in the tropics should not have a compact shape, but rather a loose shape of built environment, in order to reduce the possibilities of heat islands. It must be highlighted that this constitutes a real problem in huge cities, but not when it comes to small ones.

4. Streets and grids shapes

The possibility of using local winds to low the buildings' thermal charge also depends on the town's shape. Streets orientation and the shape of its grids were—or are—determined by the European cultural influence or by traffic engineers (town planned for cars flow and not for

[2]LOMBARDO [19] referred to a correlation between heat islands in São Paulo, in regions with more than 3000 inhabit/ha, more than 20 years ago.

pedestrians), instead of influence by local climate and the people comfort.

The choice of the grid and the geometric relations between the buildings height and the street widths determine where and when there should be shadow and which winds should be at pedestrian level. In big cities, the compact shapes—determined by the construction industry speculation—obstruct natural winds. In case the vehicles' circulation is very intense during all the day, the wind will follow the traffic flow up to the third floor level. But, two factors dissuade the use of these air currents: the intense noise and the air mass pollution [20]. Therefore, dwelling apartments should be located over the third floor.

The orientation of streets and urban ways must take into account the local solar trajectories and the principal frequencies of winds. It is strongly unadvisable to design East-West straight streets, because they cause visual discomfort in the early morning and in late afternoon and extreme thermal discomfort near noon.[3]

5. Green spaces

The distribution of green spaces among the quarters is also important because the trees' transpiration by evaporation reduces the air temperature in summer. One needs to be careful with these spaces in humid places, since humidity rises very easily, bearing in mind, also, that if the canopies are too thick they would block the ventilation. Therefore, urban design must consider the kind of vegetation that would adjust better in tropical climate region, humid or dry. Another consideration is about how much solar radiation the vegetation reflects and how much it absorbs, its transmission coefficient (the shadow quality), how many liters it transpires (or takes out from the soil), how much of the infrared radiation emitted by the soil it blocks, how much is emitted by its leaves, etc., because these factors have a decisive influence for the thermal and visual comfort of citizens.

The presence of vegetation or of green areas is of great significance, since it is capable of absorbing almost 50% of the incident solar radiation. The World Health Organization (WHO) recommends a minimum of $12\,m^2$/inhab of arboreous zone.[4] On the other hand, the increase of the impermeable covering area (or the modification of the urban soil permeability) means a decrease of soil evaporation. The greater the area covered by buildings and constructions, the greater impermeability will result from the relation between the paved soil and the naked but compacted soil.[5] Impermeabilization is one of the elements that have influence on the reduction of the relative air humidity, on the infrared radiation increase, which results from the superficial temperature raise, and on the thermal energy accumulated, as well as on floods and mud slides provoked by intense raining.

The size of squares (plazas) or other open spaces will promote the movement of the nearby air at the pedestrian level—knowing that the corridors formed by streets increase the wind flow—creating calm zones near the floor. The width of the open space, the kind of soil covering, vegetation, and type and shape of the closing surfaces determine the air movement [22]. In terms of spaces where people traverse with great intensity, it is fundamental to have control over the incident solar energy, which besides promoting thermal comfort will help to prevent skin cancer. It is possible to take actions to deal with direct and diffuse radiation (obstructing it with different kinds of a coverage) and/or the reflected radiation (obstructing it by confinement or by modifying adjacent spaces) in order to reduce their incidence over pedestrians.

It is worth remembering that once the design's objective related to people thermal and visual comfort is clearly focused, those spaces with intense human occupation can be classified, just for operational aspects, as "Living Spaces" (with specification about the kind of activity and/or the function the space is meant to hold), "Passing Spaces" (where people must pass by to reach to other spaces and/or activities), and "Adjacent Spaces". This work needs to consider knowing the schedules of the population use, the amount of people that use them, the kind of clothing people wear, besides the microclimate data, the seasons' characteristics, topography, and/or the open space surrounding elements.

The fundamental issue here is that solar radiation must be reduced, surface temperatures must also be lowered, in order to decrease the infrared radiation liquid flow, as well as the air temperature (if this is done by evaporative cooling, never exceed 80% of the final relative humidity). The temperature of surrounding surfaces must be reduced by cold pavements, water curtains, and confined water slides or by sprinkled coverings, to reduce the infrared radiation flow. The convective flow reduction can be obtained by lowering the air temperature (sensitive or latent cooling) and by aiding the movement of cooled air (canalize the breezes or use fans or water streams).

6. Environmental shape, materials, and surfaces

Public sideways must be designed for the activities and the period of occupation they are meant for, thus that they may correspond to the thermal and visual comfort of their users. For uncovered places with a great movement of people, the use of vegetal or artificial coverings to protect them from the solar radiation is fundamental. The environmental protection—reflection of inner solar radiation or of the great quantity of infrared radiation emitter by nearby surfaces—must be treated to eliminate or reduce

[3]It is worth noting that this recommendation opposes what is well known suggested to be applied in predominately cold countries (see for example Ref. [21]).

[4]Arborisation data for Brazilian towns: Curitiba, 46; Rio de Janeiro, 36; Belo Horizonte, 6; Porto Alegre, 5; São Paulo, 4 (m^2 of arborized zone/inhabitant).

[5]In São Paulo, there are up to 95% of impermeable area; in original project of Brasilia, in a residential district can be found only 38%.

these sources of thermal and visual discomfort. Galleries, marquises, tense screens, or vegetation over the heads of the pedestrian, or the open places under stilts (“pilotis”), are of extreme importance, protecting them from intense solar radiation or tropical rains.

Materials employed and the buildings sizes affect the thermal comfort of pedestrian on the pavement. The diffusivity of the materials will affect the internal thermal comfort and the electricity consumption of the air conditioning, but its superficial effusivity,[6] i.e., its capacity to retain and send back thermal energy, will be responsible for the pedestrian comfort. The colors of the surrounding surfaces are also important due to its capacity to absorb different amounts of solar radiation. These amounts will be determined by the facility of radiation to reach these surfaces, considering the existing elements that reduce radiation, such as marquises, trees, etc. Surface colors and reflectivity and the surrounding materials diffusivity and effusivity modify infrared radiation and therefore the comfort sensation for pedestrian.

7. Wind, shadows, and water

In the humid tropics, air renewal brings benefits not only because it incorporates air masses with lower temperature, but because the renewed air brings less relative humidity than in the case of inhabited regions. Consequently, during occupation period it is important to promote ventilation where people are present. But, if ventilation with hot winds is promoted in uninhabited regions, the result is the town simply heating without benefits for the thermal comfort, because nobody is there. The direct sprinkling of water on people’s skin raises the comfort sensation. However, this is only true for those persons whose skin have been moistened with droplets; for others, whose skin has not been moistened, the discomfort sensation becomes worse because of the higher air relative humidity. This situation makes it difficult to evaporate transpiration—the most significant way to lower the skin temperature in the tropics.

Shadow and fountains may have a fundamental importance in the dry tropics [23], or in regions with long periods of dryness. In relation to the latter, there are many microclimates with these characteristics in the Brazilian central plateau and in the northeast regions. In these cases, the adoption of an urban design that changes the features with the season’s changes is recommended. As it happens with several European parks, where there are trees with falling leaves with plenty of shadows during the summer, letting the desired sun get trough in the winter, public spaces of tropical regions should also provide fountains and/or water curtains during the dry seasons, forbidding the use of such equipments and promote ventilation in the wet periods. Similar considerations must be made referring to artificial lakes or decorative water mirrors, which can be good for dry regions but lead to thermal discomfort in humid regions. In addition to the solar energy absorption increase—in several hours of daytime—the reflection of the water surface may cause glazing.

[6]For a discussion about the concepts of diffusivity and effusivity and their applications to a built environment, see Ref. [20].

8. Solar and wind control

In open spaces, solar radiation and wind must be considerably controlled to provide human thermal comfort to guarantee the use of these public spaces. Referring to the geometry, sun trajectory diagrams and solar masks, corresponding to the place latitude, must be known and taking into account. Shadowing areas by constructed elements (pergolas, marquises or kiosks) or by the disposition of trees, together with the use of low absorbing or reflective surface materials, can minimize the problems provoked by excessive solar radiation—first by the control of solar radiation that arrives directly on people and also by diminishing the environmental temperature. In the same way, space design must guarantee the penetration of breezes that cause well being and refreshing sensations in the environment, as well as blocking the undesirable winds.

Among the principal effects of wind in urban climate, it can be pointed out the stilts, the corner, the matting, the whirl, the barrier, Venturi, different pressure zones, the canalization, and the pyramid effects, studied by European authors with the principal aim of reducing the thermal (cold) and security discomfort of pedestrian [24]. The security measures for the users of these open spaces will be the same in the tropics, but the effects that control the thermal comfort must be the opposite: the wind must be directed to people instead of protecting people from it, to improve the comfort sensation. The induced air movement, if correctly used, could carry an additional comfort lowering the temperature of surrounding surfaces in the adjacent spaces.

It must be observed that the difference of surfaces temperature, produced by incident solar radiation, creates air flows of climb the hills up and down, or flows between heat islands and parks. Then, the climate of a town will be a function of the soil use, of the geometry of the environment, of the materials and surfaces, and of the presence of vegetation.

9. Colors and reflections

It is worth to acknowledge that daylight design in most cases is not taken into account by tropical urban designers. Since the “tropical sky” luminance is high, all European measures suggested to increase it make no sense in a brilliant sky landscape. Therefore, a usual urban design for the tropics does not take daylight into consideration, but does not realize that other kinds of problems are present. Excessive daylight does not mean visual comfort. Because of this misunderstanding, no attempts are made to reduce the illumination level, nor to reduce the contrast produced by the environmental reflection [25].

In relation to the buildings envelope, to the areas that are too exposed to sunlight, it is well known that highly reflective colors reduce the internal temperature but, on the other hand, they raise the thermal and visual discomfort of the pedestrian. Nevertheless, the mirrored buildings are the main big problem because, besides the inner thermal discomfort created by the large glazing, they multiply the negative effects of solar radiation on pedestrians.

That is why Schools of Architecture in tropical countries must inform to their students that, when they import design solutions from a European town to a tropical one, they are importing factors that will change history and climate. Perhaps, this would be a correct attitude if the urban planner aim is to provoke these changes. But, if the changes occur based on a misunderstanding, in terms of the climate interaction with the town, these solutions are certainly not correct. A simple historical example of an imported change from a different climate: with the introduction of the "city for cars" conception, streets paved with stone bricks were asphalted making the temperature to rise, a very good solution for Paris, but a very bad one for Rio de Janeiro.

10. Conclusions

Integration "climate-town" is sustained by a regionalist politic vision, commonly well accepted by the European governments, but contested by the developed countries' regime (Globalization) when to be applied in Latin America.

Globalization proposes Global Towns for South America, with first world enclaves, surrounded by miserable and violent suburbs. In the enclaves, architecture and urbanism conceptions are dictated by the formal standards of developed countries, but climate and local environment are totally disregarded. As a result of this, huge amounts of money and energy are used to adapt these spaces, thus creating pollution and social differences (basis of violence), as well.

The bioclimatic conception, which should be taught at the schools of architecture in the tropics, searches for integrating architecture and urbanism with the local environment. It redeems the right of citizens to have a better quality of life and a better relationship with their history and climate.

References

[1] Corbella OD, Magalhães MAA. Concepts and differences between bioclimatic architecture for Europe and for the tropics. In: Proceedings of the V WREC, Florence, Italia, 1998.

[2] Corbella OD, Magalhães MAA. Bioclimatic devices in Brazilian modern architecture design. In: Proceedings of the 17th Int. PLEA Co., Cambridge, UK, 2000.

[3] Corbella OD, Magalhães MAA. Reflexões sobre a Concepção dos Elementos Arquitetônicos em Contextos Climáticos Diferentes, Anais do ENCAC, São Paulo; 2002.

[4] Chandler TJ. Urban climates. Series: select papers in meteorology as relates to the human environment. WMO, No. 512, Génève, 1965.

[5] Bach B, Pressman N. Climate-sensitive urban space—concepts and tools to humanize cities, ISBN 90-5269-112-6, NKB, Times/Helvetica.

[6] Eliasson I. The use of climate knowledge in urban planning. Landsc Urban Plan 2000;48:31–44.

[7] Nagara K. Evaluation of the thermal environment in an outdoor pedestrian space. Atmos Environ 1996;30(3):487–505.

[8] Ashie Y, Thanh V, Asaeda T. Building canopy model for the analysis of urban climate. J Wind Eng Ind Aerodyn 1999;81.

[9] Romero MA. Princípios Bioclimáticos para o Desenho Urbano. São Paulo: Ed. Projeto; 1988.

[10] Oke TR. Boundary layer climates. London: Ed. Rutledge; 1987.

[11] Butera F, Corbella O, di Carli A. In: Proceedings of the international ICTP workshop on interaction between physics and architecture in environment conscious design. ENEA, Roma, 1991.

[12] Ojima T, Moriyama M. Earth surface heat balance changes caused by urbanisation. Energy Build 1982;4:99–114.

[13] Santamouris M. Energy and indoor climate in urban environments—recent trends. Invited paper. In: Proceedings of the Annual Brazilian conference on comfort of ambient spaces, Salvador, Brazil; 1997.

[14] Oke TR. Street design and urban canopy layer climates. Energy Build 1988;11:103–13.

[15] Tso CP. A survey of urban heat island studies in two tropical cities. Atmos Environ 1996;30(3).

[16] Yamasita S. Detailed structure of heat island phenomena from moving observations from electric tram-cars in metropolitan Tokyo. Atmos Environ 1996;30(3).

[17] Saaroni, et al. Spatial distribution and micro scale characteristics of the urban heat island in Tel-Aviv, Israel. Landsc Urban Plan 2000;48:1–18.

[18] Soligo MJ, et al. A comprehensive assessment of pedestrian comfort including thermal effects. J Wind Eng Ind Aerodyn 1998;77/78:753.

[19] Lombardo MA. Ilha de calor nas metrópoles: O exemplo de São Paulo. São Paulo: Ed. Hucitec; 1985.

[20] Corbella OD, Yannas S. Em Busca de uma Arquitetura Sustentável para os Trópicos. Rio de Janeiro: Ed. Revan; 2003.

[21] Butera F. Dalla Caverna alla casa Ecologica. Milano: Edizioni Ambientali; 2004.

[22] Barlag A, Kuttler W. The significance of country breezes for urban planning. Energy Build 1991;15/16.

[23] CIEMAT—Guía Básica para el Acondicionamiento Climático de Espacios Abiertos, Madrid, Spain, 1994.

[24] Gademer J, Guyot A. Intégration du Phénomène Vent dans la Conception du Milieu Bati. Paris: CSTB; 1981.

[25] Voogt JA, Oke TR. Complete urban surfaces temperatures. J Appl Meteorol 1997;36.