Cooling buildings in hot humid climates – a decision model for ventilation

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ABSTRACT

The study that is being undertaken at the University of Porto, Portugal, aims at creating a decision tool, based on the appropriate ventilation strategies for the cooling of buildings in hot humid climates. The climatic conditions of the Amazonic region of Manaus are taken as an example of this type of climate.

First, we have to identify every single architectural or climatic parameter related with the ventilation of indoor spaces and evaluate their impact on ventilation efficiency. Considering all the relevant variables, a decision model will be proposed so that the designer can consciously choose between alternative solutions and the occupant can appropriately use the ventilation system, for a specific micro-climate dynamic. Some considerations about the creation of this model and its predictable results will be presented in our paper.

1. INTRODUCTION

In the last decades, the globalization trends have had an increasing expression in architecture.

In some hot and humid climates, the adoption of architectural solutions suitable for totally different climatic conditions has caused an important thermal discomfort inside the buildings and a strong increase in cooling energy consumption.

A building design practice based exclusively in economic and aesthetic considerations, without an environmental analysis, leads almost always to a prejudice for the final user, resulting in buildings strange to the environment and with comfort parameters far above the tolerable limits.

There is sometimes a lack of an effective implementation of local researchers work and also an irresistible economical appeal from some globalized technological solutions.

For example in the Amazonic Region, namely in Manaus (latitude of 3º South), there is an undeniable trend for the "artificial climate". Simple and basic bioclimatic principles are often forgotten.

For the hot humid climate of Manaus a bioclimatic strategy would recommend:

a) Solar protection of windows and walls;
b) To consider high and large openings to promote ventilation and indirect lighting;
c) To enhance air circulation with high ceiling levels;
d) To promote ventilation through the roof and to choose reflective roofs with separate and insulated ceilings;
e) To adopt elevated floors to allow for its cooling and to reinforce ventilation;
f) To design an open internal layout;
g) To choose lightweight constructions duly insulated;
h) To strength new urban design solutions which may facilitate natural ventilation of the area, considering namely wind corridors (Brandão Alves, 2003): to design both building and landscaping in order to use in the best way the available cooling winds and, if necessary, to deflect them;
i) To plan the use of shade-producing trees since they filter the sunlight, reduce air temperature and reduce glare from bright overcast skies.

Even in regions with a mild temperate climate, like Portugal and the European Mediterranean region, there is a need to control overheating in summer and to avoid the increasing use of air-conditioning (Ferreira et al., 2004). The optimization of a natural ventilation system, as the most economical way of cooling the buildings, will be always a benefit. Of course, the aleatory nature of climatic phenomena hinders the exclusivity of natural ventilation in certain periods of time. Nevertheless, the use of an optimization model that allows the adequate choices in a preliminary design stage, in terms of air inlets and outlets throughout the building, in a net configuration, facilitating air circulation in an adverse environmental scenario will minimise the need for auxiliary systems.

2. ENVIRONMENTAL PATTERNS

Manaus is located in an equatorial region with well-known extreme climatic conditions: high air temperatures with a small daily and seasonal variation, intense diffuse solar radiation, very high relative humidity and low air velocity. Given these extreme conditions, urban environment is almost always outside of the Comfort Zone established by the diagram of Ogyay (Bonetti, 1999). The Brazilian National Institute of Meteorology, INMET, gives us for the mean of monthly maximum temperatures the value of 31,5°C and of monthly minimum temperatures the value of 22,5ºC (Fig. 1).

The Bioclimatic Diagram presented by Kelly Loureiro for the town of Manaus, shows us a discomfort situation in almost 100% of the time, considering temperature and humidity simultaneously. Ventilation is essential, as the most adequate cooling strategy, for about 65% of the time (Fig. 2).

The final report produced by Analysis Bio Tool shows that thermal comfort is practical absent in Manaus, representing 0,24% of the time in the year. In 99,76 % of the time there is thermal discomfort associated with excessive high temperatures and humidity (Table 1). As we can see in Table 1, solar protection is also essential and it is needed 100% of the time.

Under these climatic conditions, natural ventilation is obtained mainly through the wind effect. However, the study of the climate of Manaus determined that wind is available only for 28,6% of the time. This means that in 36,6% of the time mechanical ventilation is needed.

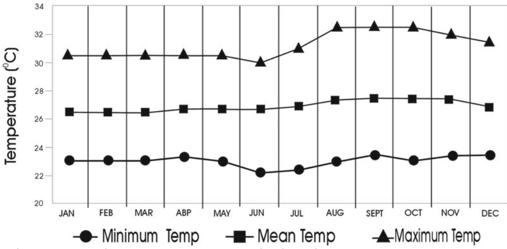

Figure 1: Air temperature variation in Manaus INEMET (1961 – 1990) (Loureiro, 2003).

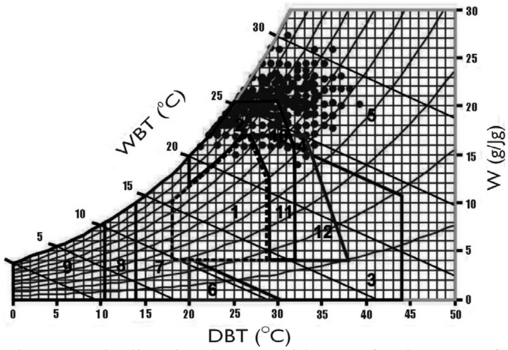

Figure 2: Bioclimatic Diagram with TRY for the town of Manaus (Loureiro, 2003).

Table 1: Bioclimatic strategies (Loureiro, 2003)

Year: 1994			Place: Manaus
From 1st January till 31st December (8760 hours)			
COMFORT 0,24%			
DISCOMFORT (high temperatures)	Ventilation	65,2%	99,76%
	Evaporative cooling	0%	
	Thermal mass	0,07%	
	Air-conditioning	34,1%	
	Humidification	0%	
	Ventilation + Thermal mass	0,13%	
	(Ventilation + Thermal Mass + Evaporative cooling)	0,23%	
	(Thermal mass + Evaporative cooling)	0,03%	
SOLAR PROTECTION			100%

Furthermore, taking into account the 34,1% of the hours that air-conditioning is needed, we conclude that there will be a significant cooling energy consumption. In this scenario an optimized ventilation system is fully justified, concerning both external and internal features of the building (site plan included).

3. THE CONSTRUCTION OF THE MODEL

3.1 Preliminary considerations

The type of model we will consider is a graphical one that uses a net of geometrical symbols, which are linked to qualitative and quantitative techniques of systemic analysis, leading to an algorithmic resolution of the problem.

In order to avoid uncertainties related to the definition of each unit (sub-system) of the model and their inter-relationship, some basic rules must be followed:

a) *To establish clearly the main objective of the whole system* – final use of the building, regulation to be fulfilled, comfort requirements, energetic targets, etc;
b) *To identify the operation mode of each sub-system* – use of each room, individual requirements;
c) *To define the role of each sub-system within the architectural system* – similarity and proximity between each indoor space. This may lead to the coordination of optimum parametric criteria of comfort and energy consumption and to successive adjustments to the spatial organization of the building;
d) *To consider the functionality and organization* – the original relationship between the form and the function may be submitted to reanalysis when meeting the use and comfort requirements.

A preliminary theoretical study of the global air flows throughout the building leads us to the choice of a model based on a "process/response" kind of system (Christofoletti, 2000). This kind of system is formed by morphologic sub-systems in sequence (sequential global system). The morphological analysis considers basically the physical characteristics of each sub-system associated with the geometrical and constructional parameters of the architectural proposal.

The study of the sequential system considers the links between each sub-system in terms of spatial integration and also in terms of the physical dynamics created within the sequence of units.

The multiplying character of the same systemic module, placed as in the architectural plan aims to simplify possible changes to the original architectural design originated by the ventilation optimization process that constitutes the final scope of our work (Fig. 3).

3.2 Predictable results

The main result of our work will be the construction of an open decision model, based on the operational research techniques (Andrade, 2000), that allows for an interface of adjustment between the physical model (representing the preliminary architectural proposal) and the building physics results.

The application of building physics tools will determine (Fig. 4):

a) The internal and external climatic conditions, for a given situation of the model;
b) The optimized use of natural ventilation as the first strategy for the cooling of buildings;
c) The quantitative and qualitative skills of the architectural components in promoting and enhancing the air circulation through the whole building, working as an integrated net.

The results of the application of available building physics tools, Aiolos (Allard, 1998) and Vortex, will be taken as inputs in a worksheet. Reports of graphical codes will then be produced defining "critical paths" for air circulation through the building and the most suitable characteristics for the architectural components.

The application of the simplified model will produce recommendations, in each step of an iterative process, leading, for example, to the redesign and relocation of ventilation ducts, inlet and outlet grilles, doors, windows, ventilated roofs or to the replacement of materials or constructional systems not compatible with thermal comfort optimization, by natural means.

The solutions defined by the simplified decision model will be, at the end, validated by comparing them to the solutions defined by the direct simulation with a building physics tool.

Aiolos software will be used mainly to calculate air flows, energy consumption and number of hours of overheating. Vortex software will be used to characterise patterns of air circulation through the internal spaces of the building and also in the immediate external environment.

4. FINAL REMARKS

The good knowledge of technical specifications

Initial configuration of the model based on the architectural proposal

Configuration of the model to be used in ventilation optimization study

Figure 3: Configuration of the model (to be adapted successively).

for each part or component of the construction and of its individual performance is not enough for the architect. It is important to evaluate the capacity of each part to interact with and contribute for the whole construction behaviour.

A methodology, a model or a tool should lead the designer to a conscious conception that profits of the interacting architectural features, simultaneously related to the human being, the environment, the aesthetics requirements, the construction materials, etc. In this way, a higher global quality can be achieved, namely in terms of environmental conditions.

Although the factors thermal comfort depends upon are variable in time and in space, it is essential to identify the minimum conditions to assure the most favourable air flows through the architectural components, for heat dissipation, taking into account the physical mechanisms of natural ventilation, making good use of urban dominant winds, deflecting them, if necessary and/or inducing air flows by creating intentional temperature gradients between different parts of the building.

Usually urban areas are places that generate specific problems for air circulation. If buildings are tall and close to each other the effect will be to elevate the breezes to highest zones of the city and create a more or less intense stagnation of the air at floor level. The absence of wind in

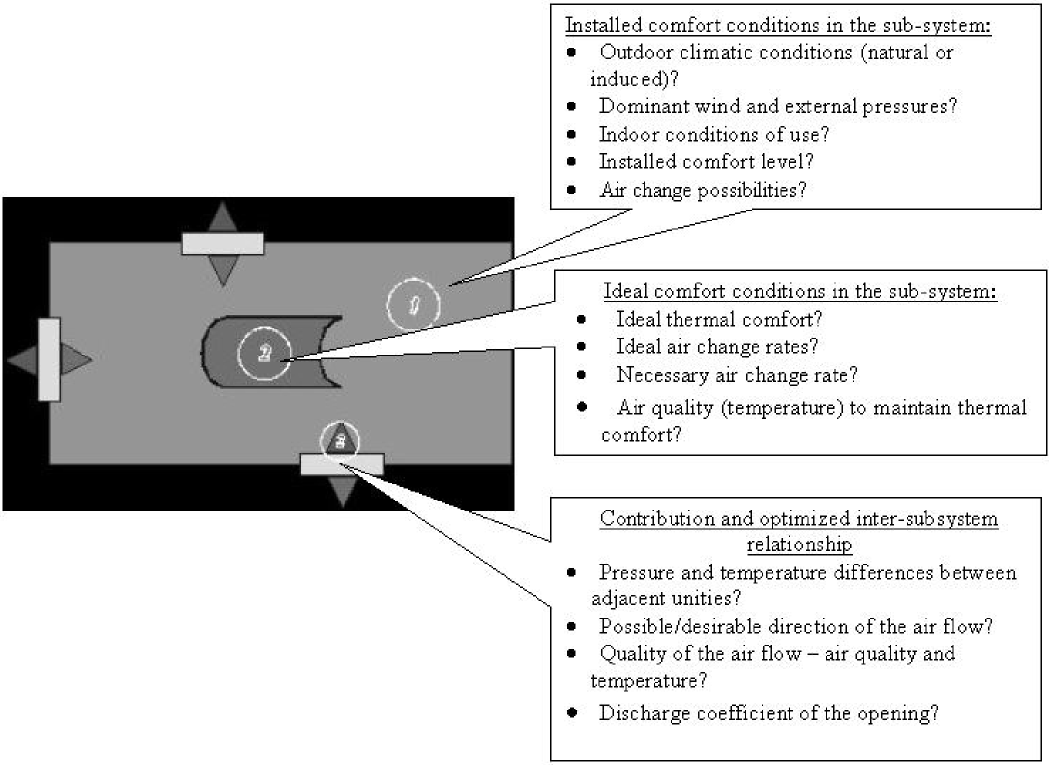

Figure 4: Input requirements for each sub-system of the model.

dense urban areas jeopardizes air circulation through the buildings and reinforces the excessive humidity and pollutant concentrations of indoor air. These adverse environmental conditions cause discomfort, tension and sometimes illness to the building users. Besides, a non-healthy environment can also originate building pathologies.

The easy-to-use design tool for the optimization of ventilation, under preparation, aims to provide daily design practice with means to prevent all those undesirable situations

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