IMPROVEMENTS ON PASSIVE VENTILATION: A WORLD WIDE DESIGN TOOL AND ARCHITECTURAL MECHANISMS TO ENSURE COMFORT IN EQUATORIAL TROPICAL HUMID AREAS

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ABSTRACT: Passive solar cooling for hot humid areas represents an important field for innovation, if we want to solve comfort needs in spaces (especially housing) designed to reduce economic, technical and health requirements.

In urban areas or deep valleys and rain forests, which are common in most of the tropical equatorial countries, external breeze is not frequent and air speeds are too low to produce cooling, using a simple cross ventilation system.

Since 1982 the author has developed new designs and constructions using passive solar techniques. After many field tests, comparative analyses and computer modelling, new combined cross/stack systems , based on overpressured flows and increased thermal flows were improved in order to ensure internal air speeds, according to the theoretical predictions

1 Introduction

Many research and application projects have been undertaken to solve comfort needs in equatorial tropical countries. Since the middle of this century authors, such as Bedford, Dick, Caudill, Kukleja, Givoni, Aynsley and others have created powerful tools to calculate, simulate various systems and design strategies to create comfort under the specific climatic conditions of tropical areas. For countries located along the equatorial belt, (many of them are developing countries), effective applications are not often feasible, because architects are unable to find affordable design tools to ensure comfort for a large number of people, or those existing, represent extra costs or cross-cultural problems.

This work, wants to present a flexible, easy, secure and economic *design decision grid*, based on proven architectural mechanisms, able to satisfy design criteria, create standards which could be implemented in any building, any architectural envelopes and different layouts. This is a first step which needs further developement, especially those resulting from computer simulation and field tests.

After 20 years of personal research and implementation through many types of buildings, responding to the specific client requirements, we can find a tested methodology able to ensure the theoretical bioclimatic requirements, especiallly those relating to minimun air speed, heat transfer and solar direct gain control during the critical months, when the humidity raises over 80%, dry bulb temperatures exceed 32°C, and solar radiation reaches 500 W/m^2, which is a common climatic pattern in tropical equatorial areas.

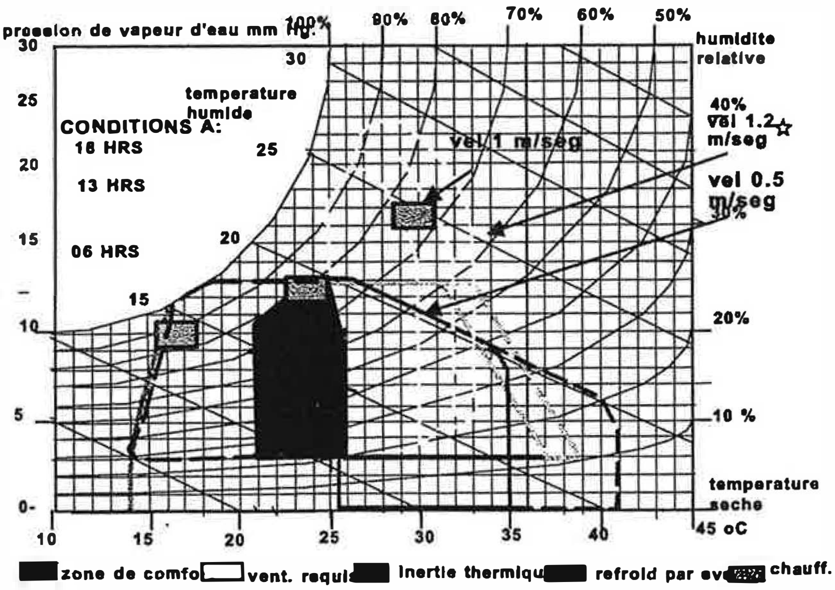
2 Bioclimatic research

2.1 Climatic conditions

In the equatorial humid areas, except on coast lines, the critical months are characterized by wet cloudy and dry sunny periods, with low wind velocities. Many countries, such as Columbia have the "peak seasons" during September/ October which are wet and cloudy. December and January are extremely sunny and dry seasons. In a daily analysis, in deep valleys or rain forest areas, both seasons present climatic indicators above the standard comfort zone. The following table summarizes those parameters:

Parameter	Day	Nigth
Mean maximum temperature	35°C	20°C
Mean temperarure	28°C	18°C
Mean minimum temperature	24°C	15°C
Maximum average humidity	70 %	90 %
Medium average humidity	65 %	80 %
Minimum average humidity	60 %	75 %
Average wind speeds	3.00 m/s	1.5 m/s

For a theoretical prediction of ventilation effectiveness, we can use the bioclimatic chart (A.Adarve 1978), and ventilation requirements chart as proposed by Aynsley (1980) , as follows:



Note: Aynsley proposes for the third ventilation zone (80%RH - 32°C DBT): 1.14m/s.

Fig.1 Bioclimatic conditions during a wet peak month (4°N latitude)

Aynsley (1980) suggests an interior air speed between 1 m/s with 70% of RH - 33°C and 1.1 m/s with 85% of RH with 32°C. Taking into account the above approach, and after a large number of field comparative tests, followed by a study case computer simulation, it is possible to achieve good results using as a design base, the following "decision design chart".

2.2 The decision design grid

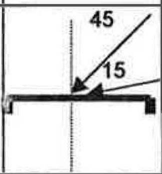
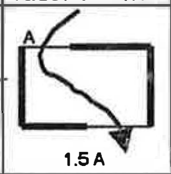
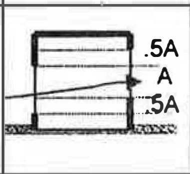
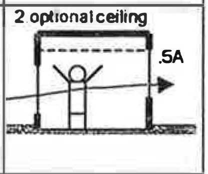
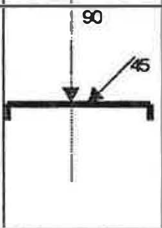
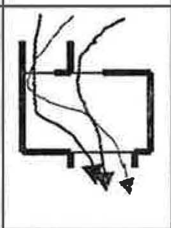
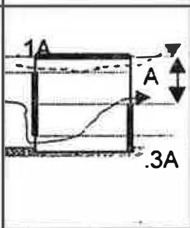
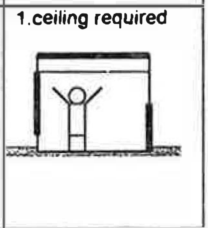
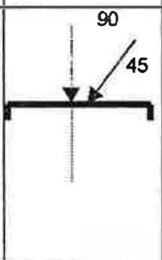
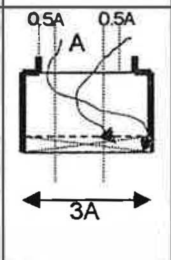
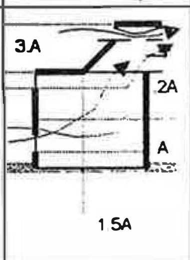
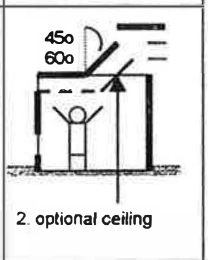
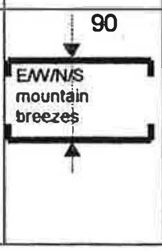
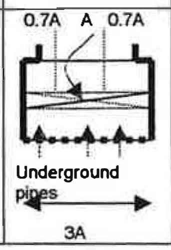
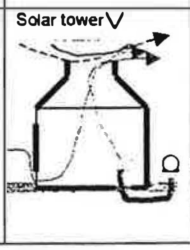
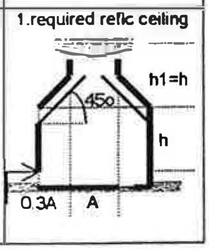
	Ventilation devices				
Type of building Availabilty winds	Orientation to prevailing winds 15o – 45o	Opening position Inlet/outlet Ratio. Envelope ratio: 1 – 1.7	Opening Area % of floor area	Opening Heigth	Roof/Ceiling 1.priority 2.non priority
Cross Ventilated with available winds over 3.00 m/sec			30% - 40%		
Cross Ventilated No available winds under 3.00 m/sec			30%-40%		
Without Cross ventilation. With available winds			Inlet: 10-20% Outlet 30-40%		
Without cross ventilation. No available winds			Inlet: 10-20% Outlet 30-40%		

Fig.2 Basic design decision chart

The proposed envelope is based on a 3 x 3 m module, which could be enlarged proportionally. The theoretical research for this purpose (case 3) takes the air speed patterns of stack effect and cross ventilation developed by Verhoeven (1973). The minimum level difference between inlet and outlet in cases 3 and 4 is 4 m.

3 Field results

The above ventilation patterns are the result of basic calculated predictions, a field implementation, followed by site tests, and a-posteriori computer simulations or comparative case analyses. In all cases studied, the need was found to involve reflective materials on the roof (low emittance foils) and direct sun radiation controls (overhangs) to reach the comfort zone as extended for ventilation effect.

As an example of the field test, the following figure shows the interior air pattern for a single low cost house without ceiling .

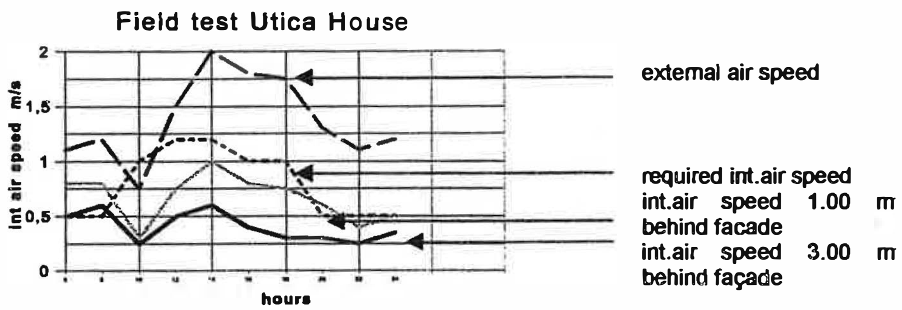


Fig.3 Field test air speeds for a single low cost housing, Utica, lat.10°N

For the same house, a computer simulation test illustrated in Fig.5 shows the improved ventilation system, using the third envelope alternative of the design decision grid. As it is shown, the average indoor air speed reaches 1.1 m/s at 1 m behind the façade and between 0.6 - 0.8 m/s, at 3 m behind the façade. So, the effectiveness is improved by 50%.

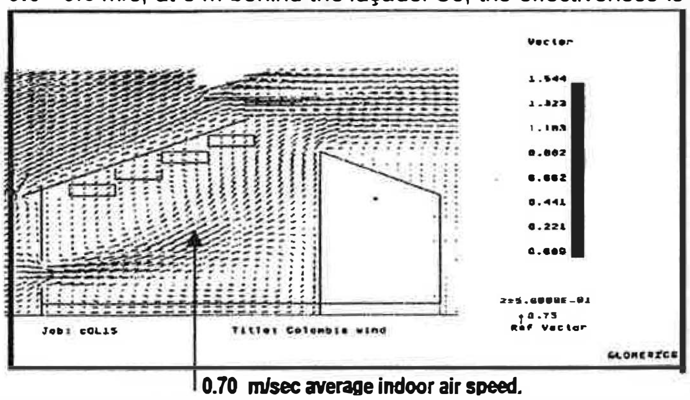


Fig.4 Computational fluid dynamics simulation. Utica house improved system, Lund CHS-Sweden.

For a more complex large industrial buliding, site measurements of internal temperatures and air speeds corresponded very closely to those calculated during the design process. This is an exemple of the fourth envelope alternative proposed at the above design decison grid. Fig.6 shows this feature.

Industrial building at CALI lat.4°N, prevailing. winds: NE/NW .
Average relative humidity : 65%(test hours): critical period during the day.
Main façade not exposed to prevaling winds.

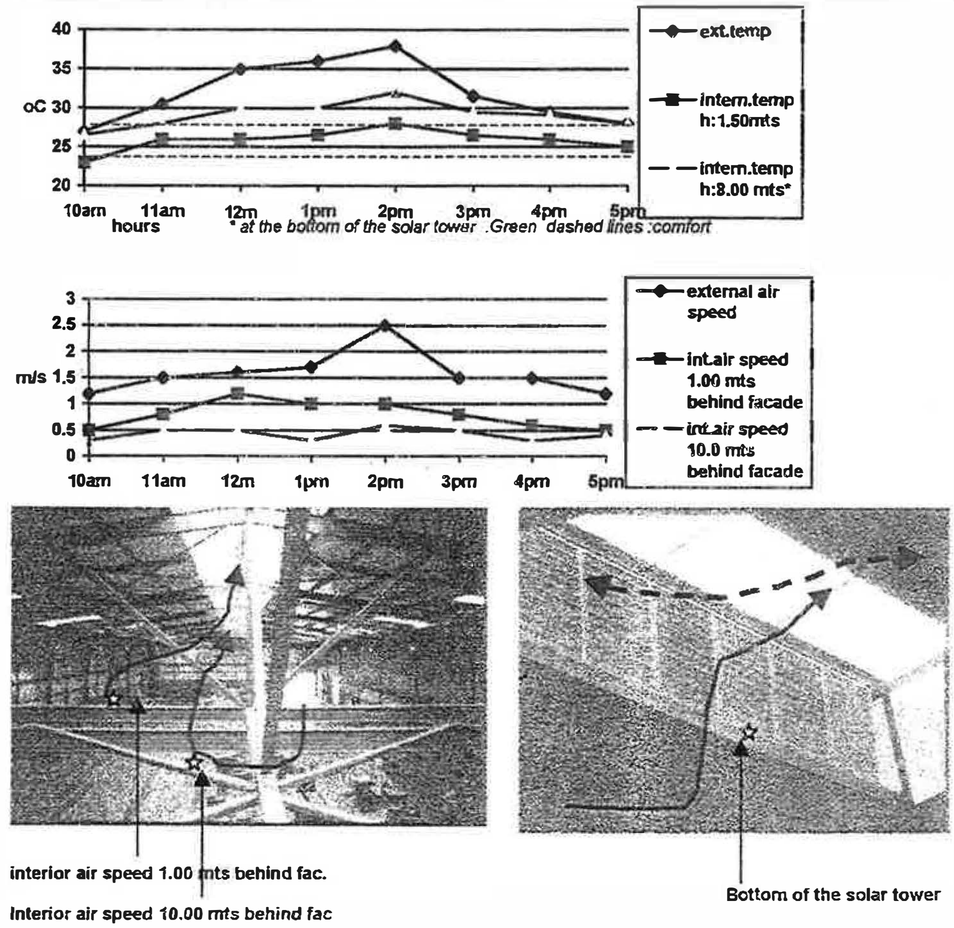


Fig.5 Amanco building, temperatures, air speeds and showing main internal air flows

4 Conclusions

- There are strong limitations to increase air velocities using only stack effect as a main cooling device.
- Cross ventilation is easy to achieve, if the landscape and built urban environment allow the appropriate " boundary" conditions.
- To obtain the best results when there is no good external air movement potential, it is essential to create an over-pressurised façade (low level opening at the bottom of the whole façade).
- Under a tropical equatorial humid climate, the use of ceiling or reflective low emittance foils is essential. This is a useful complementary cooling device, because it can decrease the radiant mean temperature by 3 to 5 K. So, the comfort requirements (included the amount of hot air to pull out) could be located closer to the "basic comfort zone" as defined in the bioclimatic chart. This means that the building has to produce an air speed between 0.5 m/s and 1.00 m/s.
- Shading devices also help to improve the cooling effect, especially if horizontal overhangs are used.
- The sloped roofs or ceilings offer the best possibilities to promote either the stack effect or the combined "horizontal/vertical" air motion, and thus avoid overheating (especially at noon). Fig.6 illutrates this device.

- The above feature works better if on the top, a ""static thermal ventilator" or "solar tower" is located in order to increase both the temperature difference and suction of the breezes coming over the roof. Fig.7 shows a prototype developed by the author.
- In any cases the best results could be achieved if calculations and internal spaces are based on a " modular division system", in order to create "tubular air flows" and to control "boundaries". Therefore, for the calculation of heat gains the envelope needs to be considered as a whole system.

Finnally, we can say that passive ventilation in equatorial tropical areas depends on the architectural innovative and flexible options, adapted to the minimum, more than average external climate potentials (wind, temperature and humidity) which are very variable over a large range during the day. In developing countries, natural ventilation has a large social impact additional to the behavior, as the energy saving, prevention of health problems (air flows help to remove infection vectors), and the most important: the improvement of life quality to a large number of people. In Columbia particularly, it is crucial, if we need to build appropriate social structures and thereby avoid violence.

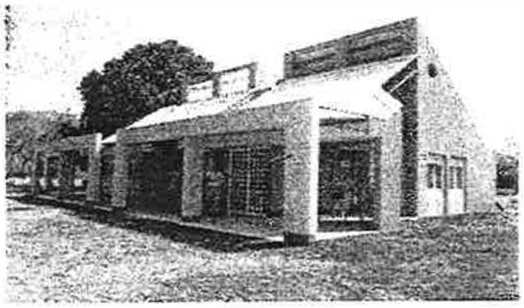


Fig.6 Family house, lat. 10°N, without ceiling, solar tower.

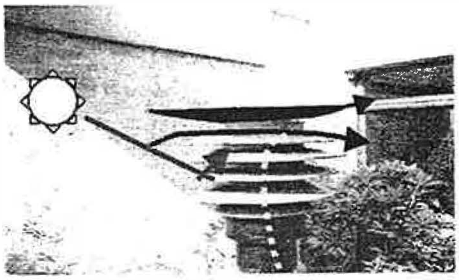


Fig.7 Author's prototype of a static thermal vent.

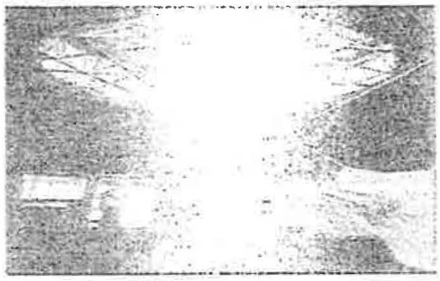


Fig.8 Ecohotel in the Brazilian rain forest (developed by the author)

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