

Natural cooling in the tropics and user responses SET 2007

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ABSTRACT: This paper shows a comparison between predicted cooling conditions, site measurements and user's responses into two type of buildings designed to be naturally cooled under tropical conditions .

The monitored buildings are two commercial malls and a large industrial building located in Colombia.

Regarding predicted cooling conditions, adequate strategies were addressed to restore comfort : Air movement, solar direct gain control and thermal mass control were encouraged in a balanced way. Some devices were introduced to assure bioclimatic requirements as ventilated sky lights, transparent solar control polycarbonate or reinforced polyester roofing and double skin or low -E thermal sheets walls. After the construction process was finished, efficiency tests was carried on into the selected buildings. According to the predicted requirements some of them were allowed, specially the internal temperature ranges and air changes in order to exhaust overheating and hygienic air removal. Nevertheless, internal air speeds were variable in a large range depending on exterior wind , which are also variable under the Colombian conditions.

Under occupied conditions , users were asked to know their comfort perceptions. After setting a crossway analysis, relevant facts were founded:

1. The comfort effect of convection air movement produces a differential temperature of 3oC -4oC between different commercial mall levels. This has a direct impact on user comfort behaviour.
2. Some air movement, at minimum speeds (0.10 m/sec- 0.30 m/sec) produced an adequate user response , even if predicted air movement was established to produce 0.50 m/s.
3. Regarding solar and thermal mass devices, users response suggest a satisfaction perception compared with external maximum temperatures over 30 oC. (not exceeded 38oC)
4. Into the industrial building, due to a high thermal stratification, minimum solar gains trough envelope and continuous overheat exhaust by ventilated skylights , the worker responses were acceptable , corresponding to site measurements and predicted requirements.

Keywords: tropical architecture, comfort

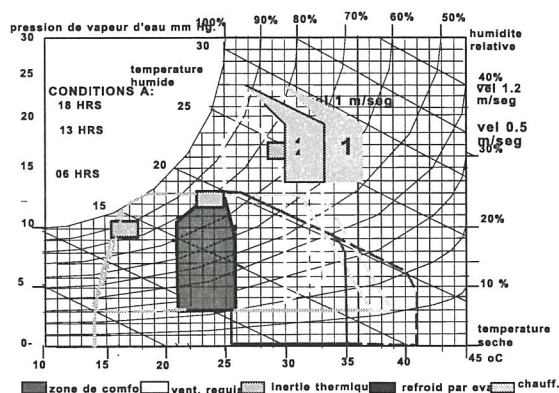
1. INTRODUCTION

The purpose of this paper is to show how the bioclimatic strategies response to different user comforts requirements. To achieve this goal it has been established a comparison between the performance into two types of buildings (with similar air flow pattern) naturally cooled and basic comfort design parameters. In this case the comparison analysis is based on the comfort standard of Markus & Morris, and the followed arguments stetted by Bo Adamsom [1]. The site measurements were based on indoor/outdoor temperatures, relative humidity and air speed. Finally the paper shows a “realistic” building performance which could be achieved using appropriate cooling devises according to the tropical context..

2. INDOOR CLIMATIC CONDITIONS

2.1 Comfort limits

Under a tropical climate, we are interested in the upper limits of comfort or when discomfort starts. According to the Givoni’s bioclimatic chart- Figure No 1 [2], it is necessary to improve indoor air speeds, reaching 1, 16 m/sec [3], which is impossible in many cases to allow, by commercial malls or industrial buildings , because of their “enclosed” space . The experience demonstrates the limits of the indoor comfort performance using an improved stack effect, a good insulation and sun protected envelope.



1: External comfort conditions

2: Comfort with required cooling strategies (indoor air speed 1.16 m/sec and a adequate envelope).

Figure 1: Adapted Givoni’s bioclimatic chart [4].

The indoor performance on tested buildings could allows at least, 0,5 m/sec of indoor air speed with a maximum temperature decrease of 4 oC.

Under the above situation, the alternative strategy requires a comfort criteria based on operative temperatures and discomfort-DISC standard as follows:

DISC= 0.5 : upper limit for optimal comfort.

DISC= 1.0 slightly warm.

DISC= 2.0 : warm

DISC= 3.0: hot.

DISC= 4.0: very hot

DSIC=5.0: painful.

Below the discomfort values are given for some combinations of operative temperature and air velocity. It is assumed that the relative humidity is high= 70%, the activity is 1, and the clothing = 0 and 0,6, which corresponds to a light clothing respectively. The table 1, shows the comfort parametric analysis [5].

Air velocity m/sec	Operative temperature oC			
	DISC: 0.5	DISC :1.0 2.0	DISC: 2.0	DSIC=3.0
0.1	28	30	32	33
0.5	30	32	34	35
2.0	33	35	36	36

Table 1: DISC index

2.2 Building responses.

The first building which has been tested is a commercial mall located at Bogotá, where cooling is required at mid day during the hot and dry season (December). The figure No2 shows the building response as follows:

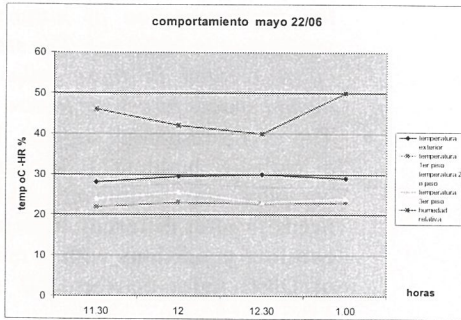


Figure 2: Measurements SantaFe commercial mall.

The second tested building is a commercial mall located at Villavicencio a tropical city. The figure No 3 shows the recorded measurements:

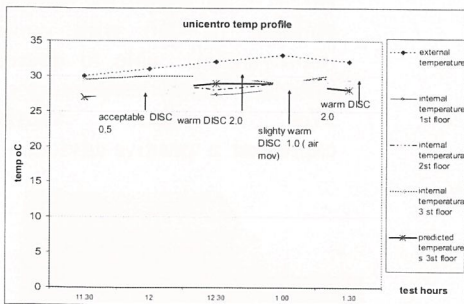


Figure 3: Unicentro Villavicencio temperature measurements.

The 3st tested building is an industrial PVC manufacture located at Cali, witch is a tropical area. The following figure No 4, shows the measurements:

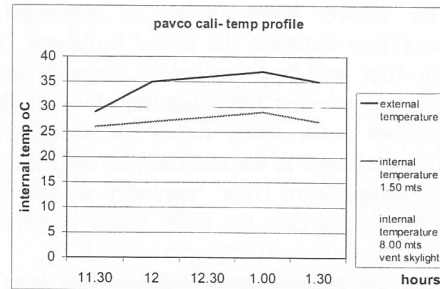


Figure 4: Measurements PAVCO-Cali

3. USER RESPONSES

3.1 Comparative analysis

In order to establish a comparison between the user's response to the indoor climate and the DISC index done by the buildings, we show the following tables:

- user response*
- 1 *good*
 - 2 *acceptable*
 - 3 *unacceptable*

floor	user response 12.00-3.00 pm	building response ave DISC index	Int air speed m/sec
1	1	0.0	0,1
2	1	0.0-0.5	0,1
3	1	0.5	0,1

Table II: Santa Fé commercial mall Bogotá

floor	user sensation 12.00-3.00 pm	building response ave DISC index	air speed m/sec
1	1	0.5	0,1
2	2	1.0	0,1
3	2	1.0-2.0	0,1

Table III: Unicentro commercial mall Villavicencio.

floor	user sensation 12.00-3.00 pm	building response ave DISC index	air speed m/sec
1	1	0.5	0,3

Table IV: Pavco industries - Cali

The above tables show a differential behaviour between the tested buildings. In the first building located at Bogotá with external average temperatures close to the comfort zone, users found an acceptable indoor climate at the tree mall levels, even if the temperature rises specially at the 3st floor. In this case the DISC index is stetted between 0.0 (comfort zone) and 0.5.

In the second tested building the user's response is different. At the 3st level the thermal perception is acceptable but not desirable (if compared with desired AC standards). In this case the DISC index average is 1.0 which corresponds to a slightly warm thermal condition.

Finally at the industrial building, the user's response (in this case workers), is satisfactory. In this case the perception goes in the same way of the DISC index done by the indoor building climate, which is between 0,5 : upper limit for optimal comfort. The reason of this result is due to the building space design considering a single level and with a high ventilated roof.

3.2 Towards a "realistic" building

Taking into account the above analysis we can stress some criterion in order to design commercial or industrial buildings under tropical conditions.

- Stack effect (trough the atrium space) is a basic ventilation strategy if a high well ventilated skylight is placed at the top of the roof.
- Over pressured façade inlets directly linked to a central atrium are strongly desirable to produce a minimum indoor air speed.
- Double envelope and a high reflective insulated roof plays a major role in the decrease of the maximum external temperatures.
- Shadow devises avoiding 100% of the direct solar radiation allows best performance. This has a direct effect on the income ventilation flow temperature.

- To increase the stack effect flow is desirable in all cases to have an overheat ventilated skylight as it was demonstrated at the industrial building . Cali. This effect was particularly studied by F. Allard [6] who comments: "*Atria are particularly suitable for the implementation of naturally ventilation in buildings. The stack effect created in these solar – heated spaces forces air to rise*"
- The user's responses suggest that a realistic building (specially complex an multilevel malls) needs to offer **different thermal comfort conditions** with a range of DISC index between 0.0 and 1.0.
- A "psychological feeling " plays an important role in the user comfort response , when the difference between outdoor and indoor temperature (operative level) reaches 5oC or more. As an example of this feature figures No 5 – 5a shows an industrial building in Cali with cooling improvements able to decrease internal extreme temperatures of 37oC to 34oC. Workers expressed a positive advice.

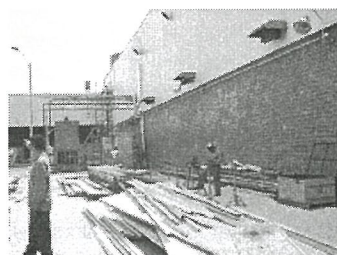


Figure 5: Building before improvements

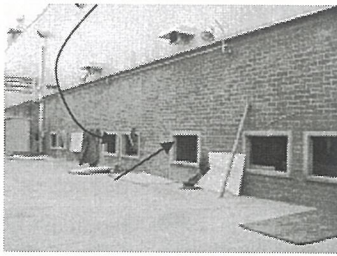


Figure 5a: Actual building conditions

5. CONCLUSION

As conclusion some design guidelines could be proposed to guarantee at the same time a good response to the user expectancies and the building performances. The figures No.6 -6a shows a recommended typology to industrial buildings in the tropics:

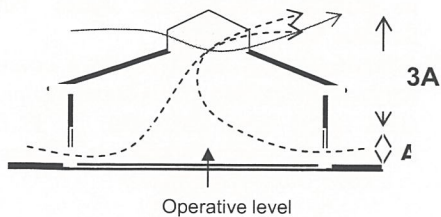


Figure 6. Air flow pattern

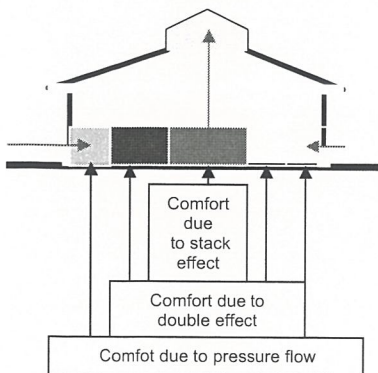


Figure 6a: Comfort condition zones

The figures No.7 -7a shows a recommended typology to commercial buildings in the tropics:

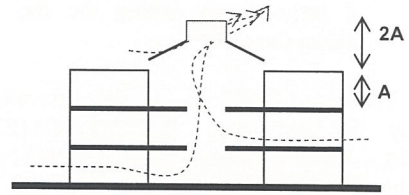


Figure 7: Air flow pattern

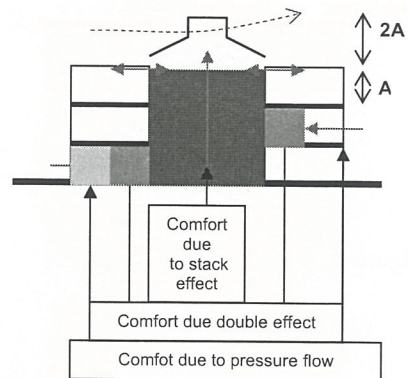


Figure 7a: Comfort condition zones

It is important to comment that high tech cooling strategies, in many times are not the best alternative under the developing countries context.

Finally we can say that passive cooling performances appropriate to the user real requirements (associate with cultural conditions) need to be achieved only if a good architecture involves:

- Variety of cooling devices.
- Flexible options.
- Knowledge of the local user requirements.
- Avoiding to assume high comfort standards.
- Use simple but effective cooling devices with appropriate calculation

techniques or flow computer modelling.

- To be careful with the real climate potentials, which is very variable for a large range during the day and along the year.

The tested buildings has been developed bay the contractors : PEDRO GOMEZ Y CIA,- Pinto y Gomez Arch, PAVCO S.A with a bioclimatic design done by this paper author.

The figures No 8, 9, 10 shows the tested buildings:



Figure 8. Commercial Mall SantaFé



Figure 9. Unicentro Villavicencio- Thermograph tests [7]

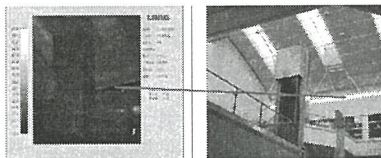


Figure 10. PAVCO industries Cali

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