Human factor in thermal performance of natural ventilated buildings

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ABSTRACT

This paper presents some results of the research project "Domestic Violence and Architectural Space", sponsored by several Mexican Governmental Offices and Citizen Organizations. One of the purposes of this project was to find the probable correlation between several physical characteristics of houses and violent behavior of their inhabitants. In this paper we report the results of the indoor climate exclusively. These results confirm the findings of Givoni and others (2002, 2003), about the human activities like the principal factor affecting the indoor climate of natural ventilated buildings.

1. INTRODUCTION

The thermal performance of 11 natural ventilated houses was analyzed, focusing the role of human behavior, and obtaining the correlation between the thermal properties of buildings, the indoor temperatures registered and the incidence of domestic violence situations.

The houses of study are in Colima, a small city of 200,000 inhabitants placed in the middle of the west coast of Mexico (Fig. 1): 19° N, 104° W, and 1640 feet of height over the sea level. Colima is localized in a hot and subhumid region with a rainy season of five months. The climatic data of Figs. 2, 3 were obtained from the Mexican National Meteorological Service.

2. METHOD

The project was performed in two stages. In the first stage, a sample of 100 houses was chosen randomly, without considerations of socioeconomic factors. In that sample a large survey was applied to find houses where a domestic violence event happened in the last six months. The survey was designed and validated by the National Institute of Statistics, Geography and Informatics, who applied it previously in Mexico City (INEGI, 2000).

Two study groups were established from the inhabitants’ responses: houses associated to violent events, and houses not associated to violent events. Also, the particularities of the events, the kind of violence, as well as its frequency and involved participants were established. The kind of violence was classified into four categories: psychological, intimidation, physical and sexual. The survey about domestic violence indicators was performed from August 2001 to April 2002.

The results of this first stage show that the domestic violence is a frequent phenomenon. Violent events were recognized in 41% of the surveyed houses, which belong to all the socioeconomic stages. However, the problem is more frequent in the middle strata (43% with violence) and high (50%) than in the low strata (27%).

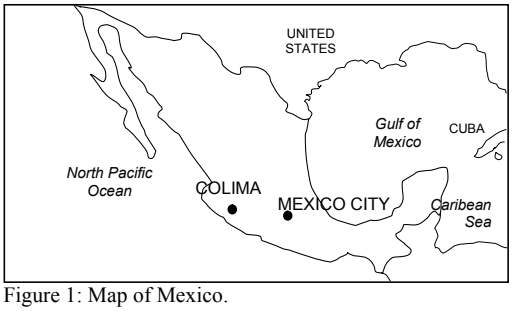

Figure 1: Map of Mexico.

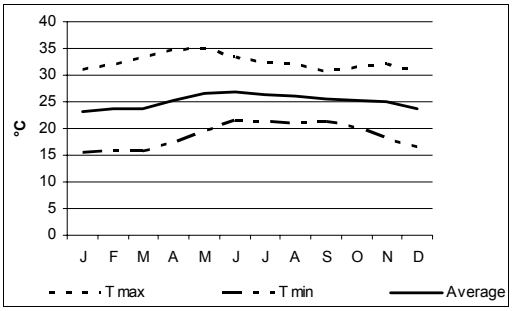

Figure 2: Annual Dry Bulb Temperature in Colima.

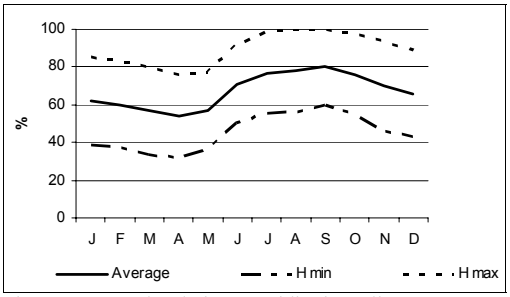

Figure 3: Annual Relative Humidity in Colima.

As a consequence of this survey, the address of 41 houses where recognized events of domestic violence were obtained, as well as the address of those 59 where these types of events were not registered. From these two clusters, two study groups were selected at random way too: one group, (A), of five houses where their inhabitants did affirm that they did not experience violence events; and a second group (B), of six houses where their inhabitants acknowledged some violence events in the same period. Originally, the research was planned with a sample of 14 houses: seven with violence and seven without violence, but at the end, the permission of only five families occupying no violence houses and six with violence, were obtained. None of these houses have air conditioning equipment, very common situation in the region.

In the second stage of project, the indoor climate data of houses was registered through electronic data loggers “HOBO” from Onset Computer Co. Each data logger has four channels; they register indoor temperature, outdoor temperature, relative humidity and day lighting level. The measurement period was since September 2002 to January 2003. The registration kits always were placed in the living room. The research was complemented with a survey where the inhabitants answered questions about their own perception of indoor climate in their houses.

It is pertinent to clear up that the information about which house belonged to the group of houses with violence and which belonged to the group of no violence houses, it was not available for the research team, except the director, to avoid that the preliminary results were slanted in any way.

The climatic data were processed in Microsoft Excel work sheets. Once organized, the data of each group were compared among them, and among comfort parameters.

The parameter of thermal comfort utilized was the Neutrality Temperature equation of Brager and de Dear (2001):

$$Tn = 17.8 + 0.31\ Tem \qquad (1)$$

where:

Tn: Neutrality temperature
Tem: Annual mean indoor temperature

But, the comfort zone was considered in a range of 3.5 K about Tn, because the inhabitants are not accustomed to the use of air conditioning equipment, and therefore their capacity of adaptation is wide. This temperature range is according with Givoni (1998).

On the other hand, the parameter of humidity comfort was 50% of relative humidity, with a range of 20% to 80% RH.

To characterize the thermal performance of envelopes, the sum of thermal transmittance by area (UA) was utilized, determined by the thermal conductivity and the thickness of each layer of material that compose the elements of building, and multiplied by the area of each architectural element (wall, roof and window).

To perform the correlations, a value was assign to each studied house in accordance with the kind of violence (Table 1).

3. RESULTS

Nine of the studied houses have similar kind of construction, consisting in clay or cement brick walls and reinforced concrete ceiling, with small windows of around 20% of the wall surface, protected with 3 mm of single glass. Three houses A14, B03 and B11 have roof of asbestos

Table 1: Value assigned according the kind of violence.

Kind of violence	Value
Free Violence	0
Psychological violence	1
Intimidation	2
Physical violence	3
Sexual violence	4

Table 2: Violence, UA and Daily Oscillation values.

House	Kind of Violence	UA w/ºC	Daily Temperatures Oscillation ºC
A01	0	102.76	3.7
A02	0	78.80	5.8
A05	0	51.14	3.6
A14	0	137.65	7.8
A16	0	80.14	6.7
B03	3	147.83	10.1
B10	1	111.85	6.9
B11	2	94.87	11.0
B13	4	116.37	10.2
B17	1	64.37	6.0
B19	1	79.05	6.8

sheets, and one of them (B03) has walls of asphalted cardboard, while the A05 house presents a low UA value because it does not have windows.

The correlation between the kind of violence of each house and the UA value of buildings is poor (r = 0.47), because the highest UA values correspond to the asbestos sheet ceiling, but not necessarily to the highest values of violence. Consequently the violent behaviors may occur independently of the kind of building. However the hourly temperature averages registered in the free of violence houses remained inside the limits of comfort, according to equation (1) and the hourly temperature averages registered in all the other houses surpassed the upper limit (Fig. 4). The cases of physical and sexual violence surpassed the lower limit too. So, the diary temperature paths of these cases present a greater thermal oscillation, and therefore a closer adjustment to outdoor temperature, as if the dwellings serve of very little shelter.

In this issue the correlation between the temperatures oscillation and the kind of violence is strong (R = 0.8) and the phenomenon is especially clear in the three most serious levels of aggression (Fig. 5). The results indicate that while the aggression level increase, the indoor thermal oscillation is greater too.

On the contrary, the correlation between the average values of temperatures oscillation and the UA values achieve barely a moderate value (R = 0.6) (Fig. 6), quite smaller that the previous correlation. These correlations indicate that indoor temperatures registered do not respond significant to the physical attributes of building, represented by their UA value, but to the inhabitants' behavior.

This situation remains clearer observing a

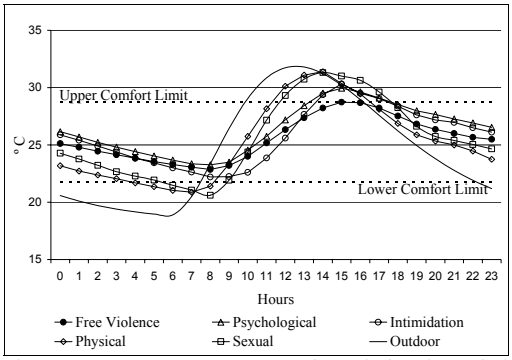

Figure 4: Average temperatures regimes during the period of study.

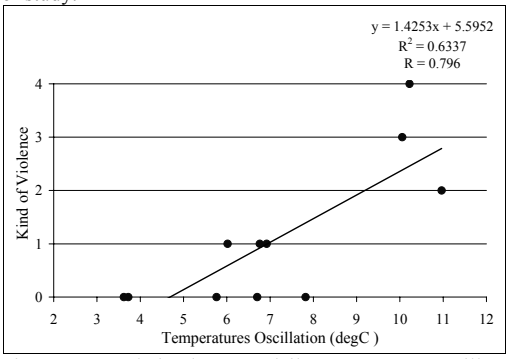

Figure 5: Correlation between daily temperatures oscillation and kind of violence.

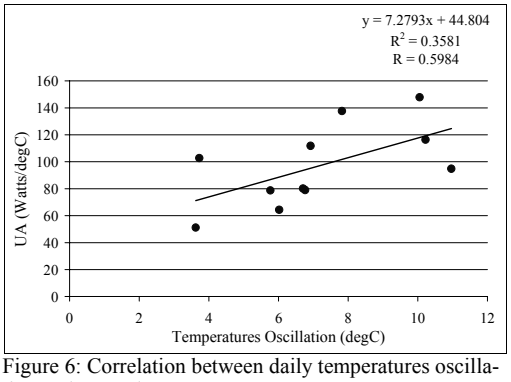

Figure 6: Correlation between daily temperatures oscillation and UA values.

free of violence house (A14) which is built with materials of meager thermal resistance, similar to the houses where happened sexual or physical abuses (B13, B03), nevertheless the temperatures oscillation of the no violence house (7.8ºC) is lower than those violent houses (10.1 and 10.2ºC respectively). Likewise the house B11, in which aggressions by intimidation were identified, is built with conventional materials, of similar UA value to that of the majority of the houses without violence, but it registered the greater oscillation of the sample (11ºC), while the oscillation values of no violence houses were always below 8º C (Fig. 5).

4. OTHER PARAMETERS STUDIED

Other aspects were studied, like territorial parameters, e.g. the need for personal space; topological parameters, e.g. the interconnection of spaces; and semiotic parameters about the signs of internal space, like colours, furniture and decoration, perceived by inhabitants at first sight.

Considering territoriality we found that the relationship between the house surface and the inhabitants' number is not relevant (R = -0.37), but, the inhabitants' number by bedroom is relevant (R = 0.84).

Regarding topological parameters, we found that violent events are moderately correlated with the need of movement of persons through intimate spaces in daily situations (R = 0.62).

The mostly used colour in internal decoration of “witness” houses is white, but the range of other colours used by them is very abundant. On the contrary, the mostly used colours in internal decoration of “cases” are white, grey and brown, but the range of others colours is very short. Curiously, yellow is the colour most used in houses associated with psychological violence.

5. CONCLUSIONS

The most important conclusion is the evidence that the interaction between the people activities and its closer environment plays an important role in the establishment of habitability conditions. Factors apparently so independent of the people action as the thermal performance of buildings, presented a significant correlation with the violent behavior, but a moderate correlation with the physical attributes of materials from which dwellings are built. The evidence indicates that “human factor” is the determinant factor in this subject.

These conclusions coincide with the findings of Kruger and Givoni (2003) and others, who have find, in occupied houses, poor correlations between the thermo-physical properties of naturally ventilated buildings and summer indoor maximum temperatures. Givoni concluded that the inhabitant’s "management of the houses" can be assumed to be the principal factor affecting the indoor climate of that kind of buildings.

Therefore, different ways of life, that of the tolerance or that of the violence, by example, should have also different effects in their closer environment, especially regarding the physical climate into the houses. The information obtained indicate that the families with the problem of violence have a minor aptitude to interact successful with their environment, compared with those that live free of that trouble, independently of the physical properties of the envelopes that shelters them.

More, that evidence suggests the existence of a behavior pattern, a sort of “environmental intelligence” that it can be defined as the capacity of individual to understand the conditions of their closer environment and their own alternatives to interact in. This behavior pattern can be recognized through the ability, dexterity and experience engaged in resolve habitability challenges. The “environmental intelligence” concept has been utilized to appoint the relation between individuals and virtual environments through handle objects – “interfaces” as the mouse or the keyboard in computers or the lever in video games–. The concept proposed here, exceed that delimitation and extend their meaning including every people interaction with all their virtual and physical environments –one of them can be the cybernetic one– through habitual interfaces that involve results skills.

The results show that each one of the families that occupy the studied houses perform an operation more or less successful over its environment in comparison with the others, independent of the quality of their dwellings. The interesting point is that exactly the families declared free of violence had a better performance upon their habitat. It seems to have a correspon-

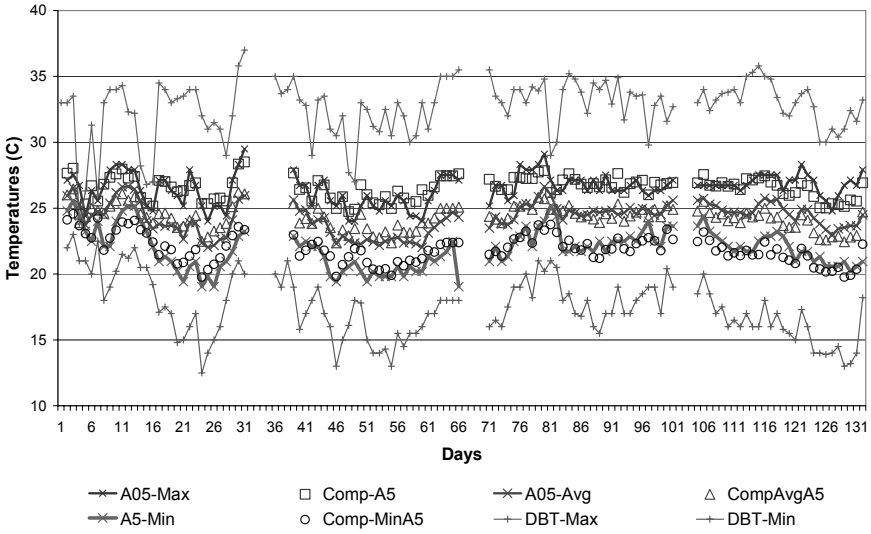

Figure 7: Daily registered and computed temperatures in house A05.

dence among the ability to live together peacefully with other individuals and that of participate successfully in their environment configuration. Also, the results of this project suggest that the positive management of the emotions in the interaction among the individuals has its parallel in the good performance that these same individuals exercise on its physical environment, thus “environmental intelligence” seems to maintain links with emotional intelligence of people.

Salovey and Mayer (1990) defined to Emotional Intelligence as a form of social intelligence that involves the ability to control the emotions and feelings, owns and of others, for discriminate among them and for use that information as guide of thought and action.

Now, a new field of studies is visualized, in which the correspondence between both not cognitive intelligences is seeking, under the hypothesis that those individuals that are more skillful in the management of its emotions are also more skillful to respond with flexibility to the changes in their physical environment and for practice adaptations that impact in better conditions of habitability. For it, the design of dependable instruments to measure the environmental intelligence is necessary.

Currently, some research groups are working in the development of methodologies related to similar subjects, as the spatial psychology, to increase the knowledge about the space-environmental abilities of people and to develop instruments of measurement. But we didn’t find any project engaged specifically on the aspects here related.

The temperatures data of this survey was analyzed, following the Givoni's method, and respective formulas to predict the indoor temperatures of each house were obtained. Examples of such results are showed below, in Figure 7 a violence-free house, and in Figure 8 a violence house, both houses under the same outdoor climatic conditions.

Procedures like this can support the development of innovative methodologies of environmental intelligence measurement. For it, research efforts to determine the value of human factors, like behavior, activities and routines, affecting the performance of the closer environment, are essential.

When engineers and architects have available values that characterize the environmental intelligence of inhabitants, they can introduce them in calculations to predict the thermal performance of natural ventilated buildings with better prospect of success.

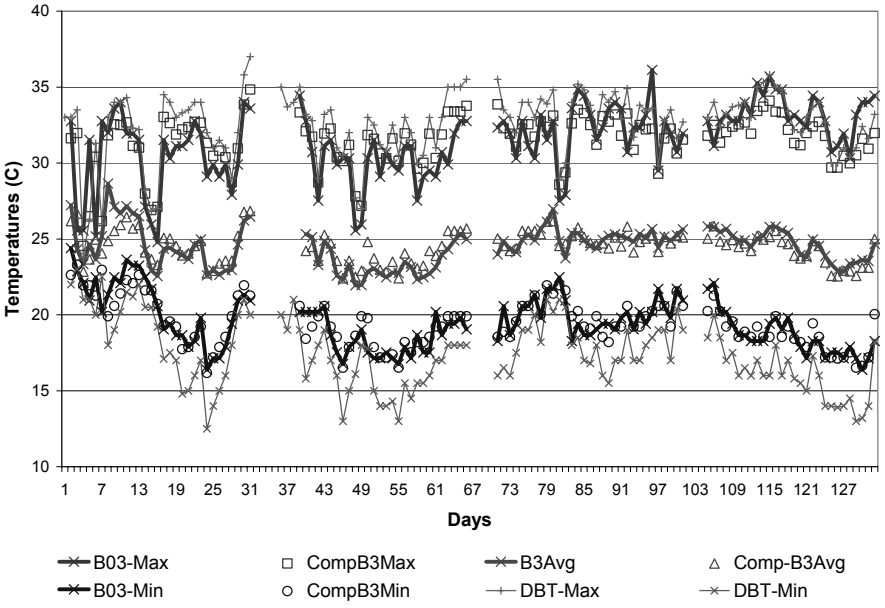

Figure 8: Daily registered and computed temperatures in house B03.

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