619: Thermal Comfort Zone for Outdoor Areas in Subtropical Climate

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Abstract

Climates and microclimates of external areas in different latitudes suggest distinct thermal comfort indices, since these indicators are not only associated with the ambient characteristics, but also with those of the population. The thermal sensation experienced by a population is the basis for definition of the comfort zone interval. So information about people's thermal sensation is decisive for the understanding of the physical, physiological and psychological answers. The objective of this work is to consider parameters for thermal comfort evaluation in external areas in subtropical climate. The case study was a housing area in the region of Campinas, Brazil, characterized by self construction of housings. The adopted methodology consists of: a) a survey of the ambient parameters: air and globe temperatures, relative humidity, wind speed and temperature of the horizontal surface, in areas with and without the presence of trees; b) application of questionnaires to the resident population with questions about thermal sensation using the seven points scale (+3 too hot to -3 too cold), as well as personal information, such as sex, age, activity and clothing. The results allow defining parameters for evaluation of thermal comfort, through a three-dimensional comfort zone for external areas applicable to the subtropical climate. The results allowed establishing a free tool for comfort evaluation in outdoor areas, with or without vegetal protection.

Keywords: Thermal Comfort, Open Spaces, Self Construction Housing

1. Introduction

In recent years, research about thermal comfort in outdoor spaces has been quite an active area. When compared with the indoor environment, the situations encountered are much more complex since there is a larger variation of environmental factors, mainly wind speed, but also an extremely important factor, the incident solar radiation. Studies about thermal comfort in outdoor spaces usually take into account the metabolic rate, the thermal resistance of clothing, and the solar radiation. They also consider the physiological responses to the combined effects of the climatic factors and activity, particularly the reaction to the sweating rate [1-5]. The psychological factor has also been thoroughly considered [6,7].

Thermal comfort in outdoor spaces is affected by many factors, like building design and disposition in urban areas, heat-absorbing construction materials, pavement surfaces and the presence of vegetation, not only concentrated in green areas or parks, but also as isolated individuals. The amount of natural elements, in the form of urban vegetation and landscaping, which permeate urban tissues influence directly thermal conditions in large urban conglomerations and indirectly the quality of life in cities [8].

The importance of the natural element in relation to the comfort conditions of buildings and urban areas depends on the types of plants (species), the foliage, treetops area and density of tree distribution. The preservation of the vegetation cover in urban areas, on the other hand, depends on the population's attitudes towards natural elements, the stimulus to plant, maintain and care for gardens and parks. In Brazil some studies have shown that urban vegetation is not valued or preserved [9]. Also the population attributes problems to trees. They cause damage to garden walls and foundations, invade sewage and water systems and clog drains. Trees produce "dirt" in yards, which increases domestic chores. Thus, trees are indiscriminately cut down. Most of these problems may be traced to the wrong choice of plants and their proximity of buildings. This type of evidence calls for a further investigation to ascertain the low-income population's attitudes towards open space and vegetation, and develop programs to improve the urban landscape and its comfort conditions.

In a previous paper [10], a proactive study conducted in two urban areas with predominantly owner-built houses in the region of Campinas, Brazil is presented. The investigation is part of a continuing research on the self-built housing phenomenon of this region. Thermal comfort was assessed in open spaces around owner-built houses. Private, semiprivate and public open spaces were evaluated through: technical measurements (air velocity and temperature), observations (use of spaces, presence, type and density of vegetation, shading and ventilation conditions), iconography (drawings of perception of open spaces) and photographic records. A sense of thermal comfort was assessed through a questionnaire applied to a group of self-builders of the two areas.

Ahmed [6] presents findings on outdoor comfort based on field investigations conducted in Dhaka, a city in the humid-tropics. Findings from a survey conducted on a large number of randomly selected people from urban spaces are presented, including factors affecting comfort outdoors for this tropical city and a comfort regime based on environmental parameters for urban outdoors. The author studies different spatial categories and how these configurations can better favour outdoor comfort. A summer comfort zone was obtained in a bioclimatic chart for tropical climate, supposing 1 Met for metabolic rate and 0.35 to 0.5 clo for thermal resistance of clothing (figure 1). His conclusion is that it is not essential to establish a single comfort value in the context of outdoor spaces as it has been found that comfort perception outdoors is a dynamic phenomenon and a person's comfort preference, keeping within a range, continually adjusts to ambient situations.

The aim of this work is to propose parameters for thermal comfort evaluation in outdoor spaces, in a subtropical climate.

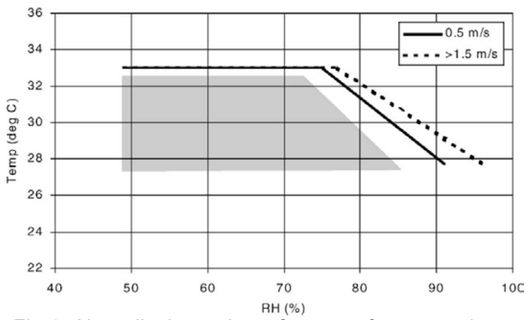

Fig.1: Ahmed's thermal comfort zone for external areas in summer [6]

2. Methods

2.1 The city and the place

The research was performed in the city of Campinas, Brazil, at latitude 22º54' S, longitude 47º03' W, and altitude 680m. According to historical series of climatic data for this region (period of 1998 to 2005, from the IAC (Agronomic Institute of Campinas), the hottest months are from January to March with maximum averages between 29.4 to 29.7ºC, and the coldest months are June and July with 13.3 and 12.7ºC respectively. The average relative air humidity is 82.6% from December to June, and 76.1% from July to November. The rains' period goes from December to March, with 287 mm in January.

The research was carried out with trees or vegetation grouping in the public green areas and sidewalks in the urban settlement Sao Jose, a specific owner-built suburb.

2.2 Data collection

Collected data were environmental parameters: air temperature, relative humidity, globe temperature and wind speed, in selected fixed points in the shadow of individual or grouping of trees and simultaneously in the sunshine.

Simultaneously to the measurements interviews were done with passers-by, with questions about thermal sensation and thermal preferences. The seven-point scale was adopted for thermal sensation. Personal information such as sex, age, clothing and activity were also gathered. This set of data allowed defining the comfort zone.

2.2 Measurements

Measurements were carried out in five days. Research in the sidewalks was performed in November 2005, from 21 to 23. In public green areas, measurements occurred in April 2006.

Equipment was a set of dataloggers Testo 175-2 for air and globe temperatures, Testo 175-1 for relative humidity and an anemometer Testo 405-V1. All equipment was protected from solar radiation, only the globe thermometer – a 32mm grey globe was exposed. Values were registered every 30 minutes.

Measurement points were chosen according to existing vegetation and the surroundings. These characteristics are shown in tables 1 and 2. Locations of fixed points are shown in figure 2 (sidewalks) and figure 3 (public spaces). In this case, points from 1 to 3 were located in the shadow and points 4 and 5 at sunshine.

Table 1 – Characteristics of measurement points in sidewalks

Points	Vegetation	Surroundings
01	Isolated species with dense canopy	Sidewalk with ground cover near to a ceramic wall.
02	Isolated species with sparse canopy	Cemented sidewals and wall covered with vegetation
03	Isolated species with dense canopy	Cemented sidewalk and cement-covered walls

Table 2 - Characteristics of measurement points in public spaces

Point	Vegetation	Surroundings
01 (Square 03)	Grouping of trees	Ground cover with sparse grass
02 (Square 02)	Isolated species	Ground cover with sparse grass
03 (Square 01)	Grouping of trees not tôo close	Ground cover with sparse grass
04 Reference point	None	Cemented sidewalk and cement-covered walls
05 (future station for sewage treatment)	None	Grass

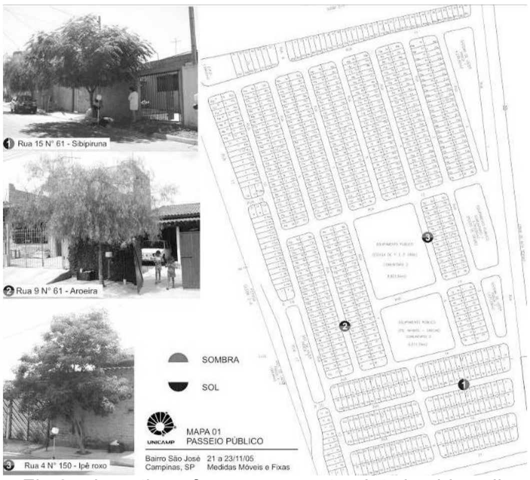

Fig.2 – Location of measurement points in sidewalks

Fig.6 – Location of measurement points in public areas

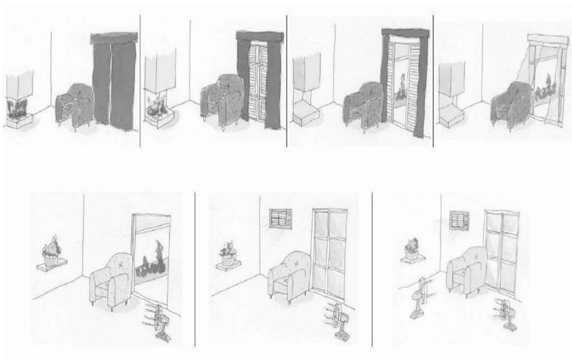

Fig 7. Questionnaire for thermal preferences

2.2 Questionnaires

Interviews with passers-by were realized simultaneously to environmental data collection. Questions were about personal data, interest about green or leisure areas in the neighbourhood, importance of vegetation for thermal comfort, as well as thermal sensation and preference. These ones were illustrated with drawings (figures 7 and 8), since in previous research [11] it was observed that drawings could facilitate the understanding of the different scale degrees. Activity and clothing were annotated by the interviewer. 108 questionnaires were obtained. Sampling tests showed that this number of questionnaires was adequate for the purposes of the research, with a 10% error for the population of the community.

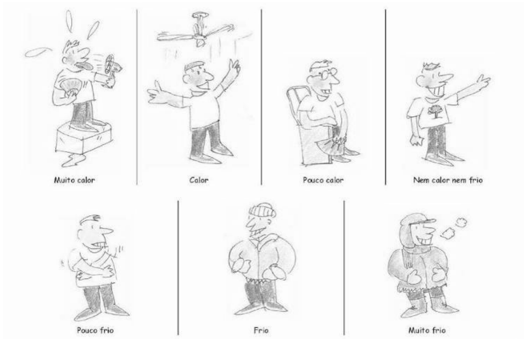

Fig.8 Questionnaire for thermal sensation

3. Results

To delimit the comfort boundaries, the values corresponding to thermal sensation from -1 to 1 were considered. A gradation was established for (C) Comfort and (RC) Reasonable Comfort for insertion in the comfort zone. Results for the thermal sensation as compared to the environmental parameters are shown in Table 3. Data were plotted in graphs covering three variables – air temperature, relative humidity and air speed. These graphs are shown in figure 9, corresponding to point 3 in Square 1.

Table 3: Thermal sensation and environmental data: Air Temperature (°C), Air velocity (m/s), relative humidity (%)

Thermal sensation	Comfort	t_{air} (°C)	V_{air} (m/s)	RH (%)
3	RC	25.3	0.10	74.5
3	U	28.8	0.71	62.4
3	RC	29.2	4.18	60.4
2	RC	29.2	4.18	60.4
2	RC	25.5	1.22	71.2
2	C	26.3	1.04	70
1	RC	26.9	2.45	65.6
1	RC	29.5	0.88	58
1	D	27.9	1.93	64.4
0	C	25.9	0.55	71.5
0	C	28.9	0.92	63.5
0	C	26.7	3.79	69.5
-1	C	25.5	1.22	71.2

Results show the positive effects of vegetation. Even when data do not fit the comfort conditions, results show that in the shadow air temperatures are at least 1ºC below that in sunshine, with the corresponding increase in relative humidity.

Point 3 was very representative of the situation. Thermal comfort in this case was achieved till 11:00 a.m.

Influences of the surroundings were also observed. A better comfort was verified when there is some vegetation in the surroundings – ground grass in public spaces or green wall in the sidewalks.

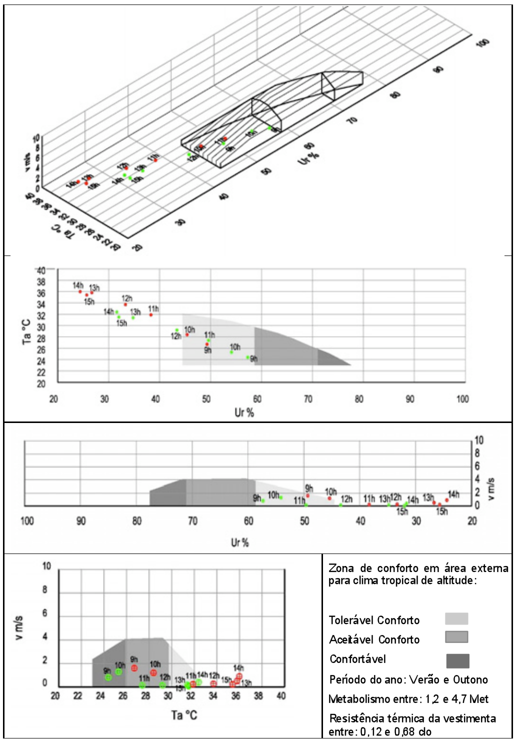

Fig. 9 - Result for 21/11/05 – Point 3, plotted in the Comfort Zone.

3. Discussion

These results show that isolated species present good comfort condition, comparable to those of arboreal groupings. The conditions of the surroundings play a meaningful role in achieving thermal comfort.

The tri-dimensional comfort zone is a powerful tool for the analysis of thermal conditions, since it shows simultaneously the influence of wind speed, together with air temperatures and relative humidity.

4. Acknowledgements

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