Thermal Comfort in the Pedagogical College of the State University of Maringá, Brazil

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ABSTRACT: The construction of the Pedagogical College (CAP/UEM) of the State University of Maringá, Brazil was part of a nationwide project, called Centres for the Integral Care to Children and Adolescents – CAICs, created in the 1990s. The initial design, conceived by João Filgueiras Lima (a.k.a Lelé), was acknowledged for its concern for the environmental comfort of users in their activities. Current paper evaluates the thermal comfort of the CAP/UEM building and verifies the performance of passive strategies that promote the students´ indoor thermal comfort and thermal feeling. Methodology consists of a project analysis for the identification and the characterization of passive solutions for comfort and the measurements of environmental variables measurements that were undertaken concurrently with the application of a questionnaire to students during the summer. Results show that, despite the passive strategies observed in the facades´ shading system and in other devices to enhance crossed ventilation, the roof of the building practically causes large thermal gain and dissatisfaction in users all the time. In fact, it jeopardizes the comfort conditions inside the building. Lack of maintenance of public buildings and users´ awareness for devices that may support thermal comfort are important topics of current study.
Keywords: Thermal comfort; passive strategies; public schools; João Filgueiras Lima

INTRODUCTION

The Pedagogical College (known as CAP/UEM) of the State University of Maringá, Maringá - PR - Brazil, lies on the campus of the University and is maintained by the government of the state of Paraná, Brazil. The premises was inaugurated in 1995 and integrated a Brazilian nationwide program called Centres for the Integral Care to Children and Adolescents, (also known as CAIC) which, in its turn, belonged to the program labelled Integrated Centres for the Care to Children and Adolescents established in 1990 during the administration of the Brazilian president Fernando Collor de Melo. The program´s main feature was the building of five thousand schools throughout the country at a full-time schooling regime [2].

Owing to his accumulated knowledge and practical experience with rationalized structural mortar systems, the architect João Filgueiras Lima (a.k.a Lelé) was invited to develop the building project [3]. However, political issues impaired the participation of Lima´s team in the experience except for the execution of two prototypes and the preparation of the projects, which were later modified to such an extent that the initial project design was actually de-characterized [5]. Lima and his team had a plan to make the projects locally adapted, but due to their remoteness, it was not done and the schools all over Brazil were made in a very similar way, which does not meet sustainable design. Featuring fastness in building and low costs, Filgueiras Lima created several devices for the users´ thermal comfort in an architecture which became the hallmark of the governmental program (Fig. 1).

Current paper evaluates the thermal comfort in the Pedagogical College of the State University of Maringá, Maringá PR Brazil, and relates the building´s thermal performance to the users´ thermal feeling. Research is highly relevant due to the importance of the architect who conceived the plan and to the great number of premises (totalling 444), featuring the same typology, throughout the country, which in fact denotes the research´s range and extent. Further, it is expected that an improvement in educational premises triggers a bettering of the country´s educational quality.

Figure 1: Pedagogical College on the campus of the State University of Maringá

METHOD

Methodology in current research comprises three stages: analysis of the architectural project; measurements of the environment variables coupled to the questionnaire for students during the summer; investigation on the difference in vertical temperature in the classrooms.

The analysis of the architectural project was undertaken by reading the project and specialized literature and by visits to the premise so that the passive solution of thermal comfort could be identified and characterized. Studies on solar exposure were performed to identify how the sun rays penetrate the building. In hot climate countries, as is the case in Brazil, solar radiation is the main cause of heat gain in a building, which should be characterized by well-protected apertures. Studies were foregrounded on the solar chart for latitude 24º S, approximately the latitude of Maringá at 23° 25' 31".

Measurements of the environmental variables of the premise included air temperature, globe temperature (calculated by mean radiation temperature), relative humidity and wind speed. Data loggers (TESTO models 175-T2, 175-H1, 177-H1, 445) and anemometer (TESTO 405-v1) were employed. Variables´ measurements were taken on November 28 and 29 and on December 1st, 2011, between 07h30 and 11h30 and between 13h30 and 17h30, at 10-minute intervals. Four classrooms, the library and an external reference site were evaluated. The classrooms were selected according to their facades´ orientation, or rather, two facing northeast and two southwest (Fig. 2). Whereas Classrooms 1 and 2 lie on the upper storey in the only storied building, Classrooms 3 and 4 were on the ground floor and surrounded by a 2-meter-high external wall.

Measurements were performed to calculate Predicted Mean Vote Index (PMV) and the Predicted Percentage of Dissatisfied Index (PPD) which estimate people´s thermal feeling and the percentage of dissatisfaction within a seven-score scale (-3 to +3) based on the heat equilibrium of the human body with the environment. ISO 7730 [4] defines thermal comfort as a state of satisfaction with the thermal environment and non-satisfaction may occur through warming or cooling of the whole or certain parts of the body, called localized discomfort. ISO 7730 [4] specifies that an environment is acceptable as thermally comfortable if less than 10% of the population claim body discomfort (PPD<10%) and if PMV ranges between -0.5 and +0.5. Due to individual differences, the establishment of thermal comfort conditions that would satisfy everyone within a large group is impossible.

Results of the first measurement stage showed the need to measure the internal surface temperature of the ceiling and the floor. In fact, high discomfort was reported due to the heating of the roof cover. Measurements were taken in the above-mentioned room at 07h, 09h30, 12h, 13h, 15h30 and 18h on April 4th and 5th 2012, by digital thermometer (Minipa MT-350) employing infrared irradiation system.

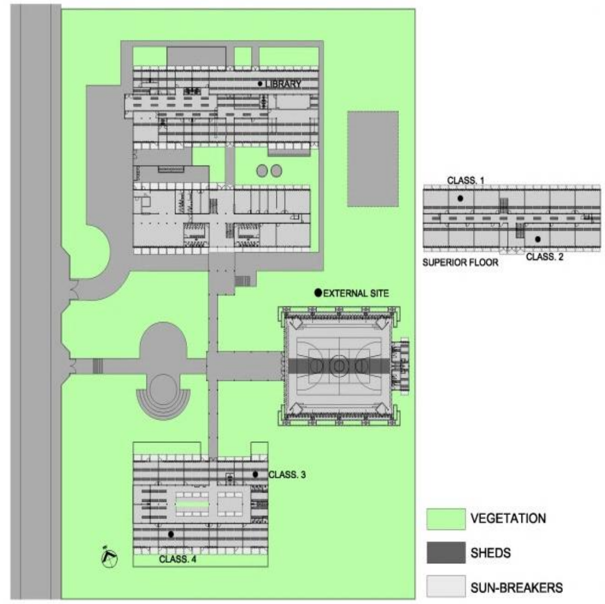

Figure 2: Sites of measuring

ANALYSIS OF THE PROJECT

Passive strategies were identified by site visits and project analysis. They included surrounding vegetation (Fig. 3a), natural illumination produced by several protection devices to ward off direct sun radiation (Fig. 4a) and the correct establishment of natural crossed ventilation, specifically northeast in Maringá (Fig. 5). The whole building is equipped with sheds for illumination and ventilation through the ceiling (Fig. 3b), and with horizontal brise-soleil or sunlight breakers over the windows (Fig. 4a). Further, the design of the window frame is actually a movable sunlight breaker (Fig. 4b).

Figure 3: Vegetation (a) and roof openings (b)

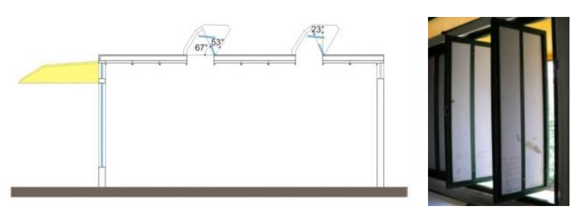

Figure 4: Cross-section of the classroom (a) and pivot-moving window (b)

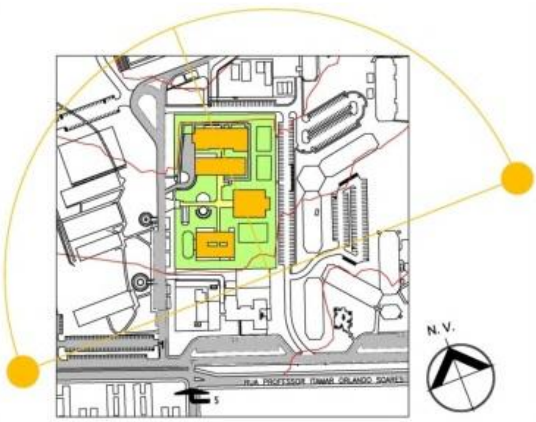

Figure 5: Premises and ground

Windows´ horizontal protection items have different widths according to the window sills. Lower sills have wider sun-breakers and higher sills have narrower protections so that the protection period of the two conditions is practically the same (Fig. 6). According to the solar chart of Maringá, if the sun-breakers were not extant, the northeast facade (21.6°) would practically be in sunlight throughout the whole year, or rather, the morning sunlight (between 06h and 12h) in the summer; till 15h in the equinoxes; the whole day (between 06h45 and 17h15) during the winter. The southwest facade would receive the afternoon sunlight during the summer (between 12h and 18h30); between 15h and 18h in the equinoxes; and no sunlight in the winter.

Due to the sun-breakers, the northeast facade is completely protected in the summer and sunlight is received in the early morning (between 06h and 08h20) in the equinoxes. During the winter, the same façade receives sunlight throughout the whole morning (between 06h45 and 12h). The above is an excellent device since bioclimatic strategies for Maringá require passive heating during the winter, although summer is the most problematic period. The efficiency of these sunlight protection devices is thus a fact.

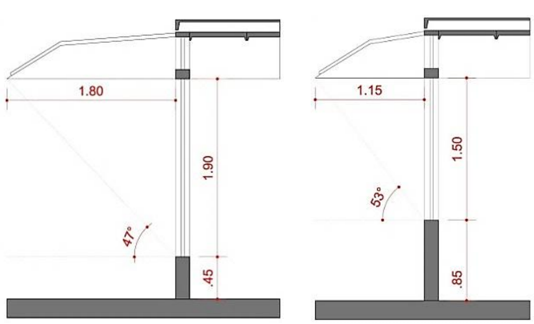

Figure 6: Cross-section of different sills

The walls of the Pedagogical College building under analysis are made of 19x19x39 cm non-plastered concrete blocks, externally painted white. In the original project, architect Filgueiras Lima´s walls consisted of double panels of structured mortar. The structural pillars and beams of the current building and the ceiling flagstone system are made of structured mortar as in the original plant. The roof consists of two structured mortar panels in the midst of which lies a non-ventilated air cushion, or rather, a system with low thermal inertia that provides high heat exchange with the external environment (Fig. 7).

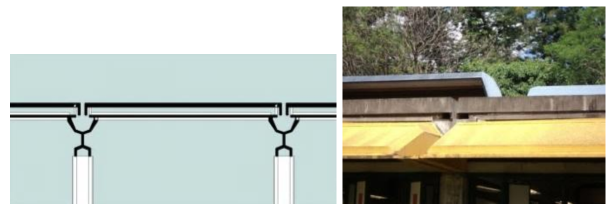

Figure 7: Cross-section and details of roof

MEASUREMENTS OF ENVIRONMENTAL VARIABLES

Temperature rates revealed similar behaviour during the three days of observation. Figure 8 shows mean temperatures and dotted line represents temperature and humidity data measured at the external site. No measurements were undertaken between 11h30 and 13h30 and a gap may be seen in the graph. The gray area on the graph shows the acceptable temperature band for naturally conditioned spaces, following ASHARE 55 (2010) which, according to calculations for the climate in Maringá, lies between 21º and 29ºC.

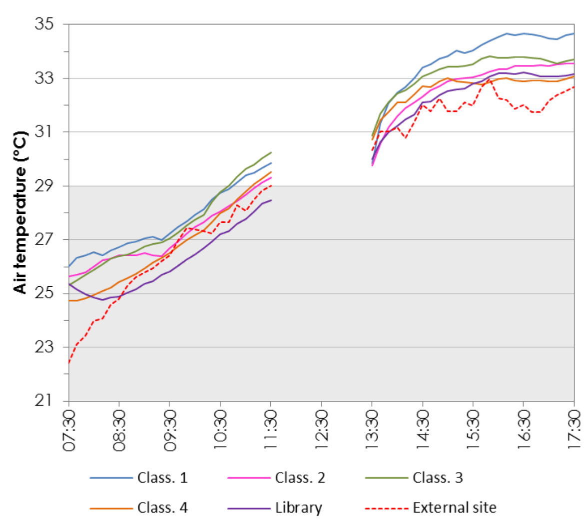

Figure 8: Graph showing air temperature

In the morning, up to approximately 10h30, temperatures were within the acceptable band, according to ASHRAE 55 [1]. No temperature was acceptable at any time during the afternoon since temperatures were over 30ºC. It is highly relevant to note that the external temperature in the afternoon is lower than that in the classrooms. Therefore, if students had lessons at the shade outside, they would have felt more comfortable during the period.

Analysis of graphs showing mean temperature at the different places under analysis demonstrated that, albeit with similar behaviour, Classrooms 1 and 3, facing a northeast direction, had slightly higher temperatures. Classrooms 2 and 4, facing a southwest direction, showed slightly lower temperatures than those given above. The lowest temperatures among the rooms were registered at the library facing a northeast direction. Although during the morning the library registered lower temperatures than those on the outside, in the afternoon the external temperatures were lower and indicated a critical situation for students and teachers. Since the same direction provides the highest and the lowest temperatures, it may be stated that the highest heat gain is provided by the premise´s roof.

Maximum external relative humidity reached 79.9% on the 3rd day at 07h30 (Fig. 9) and minimum humidity was 31.8% at 17h of the same day, with a 47.9% variation. On days 1 and 2 maximum external relative humidity rates were 72.2% and 77.7% at 07h30; minimum humidity for the same days reached 36.8% at 17h30 and 37% at 15h10, respectively. Heavy rate decrease in relative humidity throughout these days was due to high solar radiation levels which evaporated water particles in the air and caused a rise in temperature.

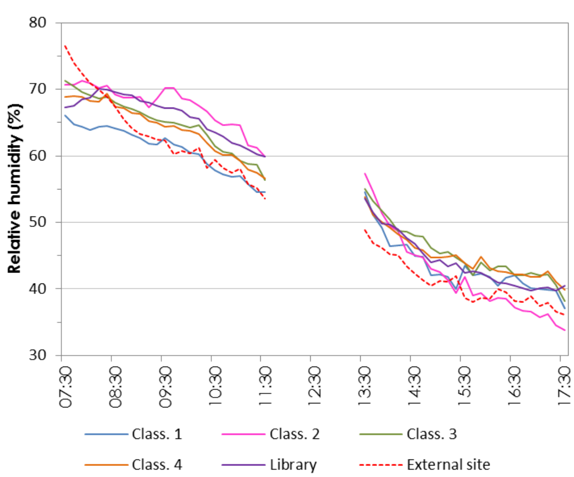

Figure 9: Graph showing relative air humidity

Mean external wind speed was 0.94 m/s (Fig. 10), with no significant potential for any cooling strategy. Classrooms 1, 2, 3 and 4 registered a mean air speed of 0.65m/s, 0.20 m/s, 0.28 m/s and 0.26 m/s, respectively, whereas mean air speed in the library was 0.22m/s. The above data present means during a day with fans switched off and two days with fans switched on.

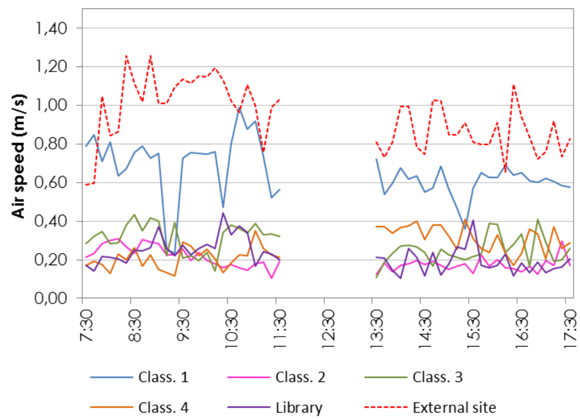

Figure 10: Graph showing mean air speed

Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) indexes were calculated from data on air temperature, mean radiant temperature, relative humidity and air speed. They revealed a comfort bracket up till 10h00 in which -0.5<PMV<+0.5 and the percentage of non-satisfied people (PPD) was less than 10%. It is very difficult to feel comfortable with external temperatures higher than 30ºC in the afternoon without the use of other complementary systems.

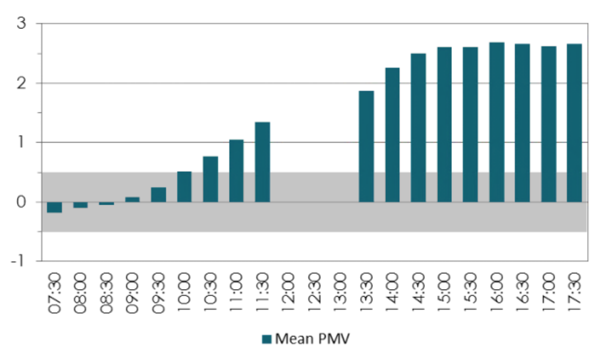

Figure 11: Graph showing PMV

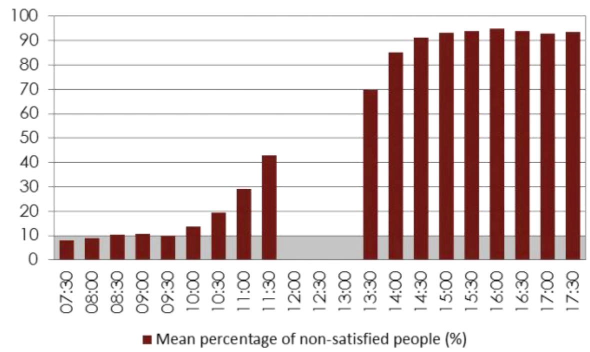

Figure 12: Graph showing PPD

QUESTIONNAIRES

Responses from the questionnaires indicated heat discomfort (Fig. 13). However, the percentage of people feeling comfortable during the early morning period (M1) was higher than that for the rest of the day where heat discomfort was prevalent. The above fact may be corroborated by the comfort bracket for air temperature, PMV and PPD until approximately 10h30. When asked about thermal preference (Fig. 14), most preferred a cooler environment (between -3 and -1). Greater preference was again given to the early morning period (M1) with no desire for change since the students felt comfortable.

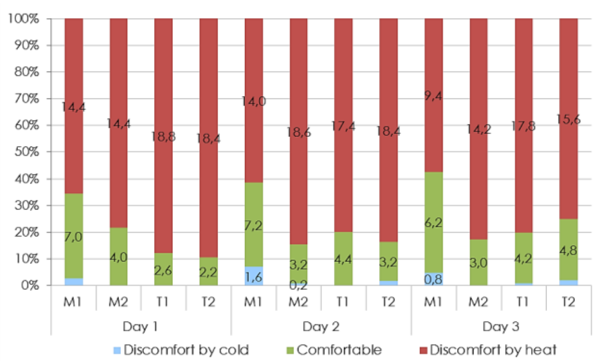

Figure 13: Mean thermal feeling – questionnaires

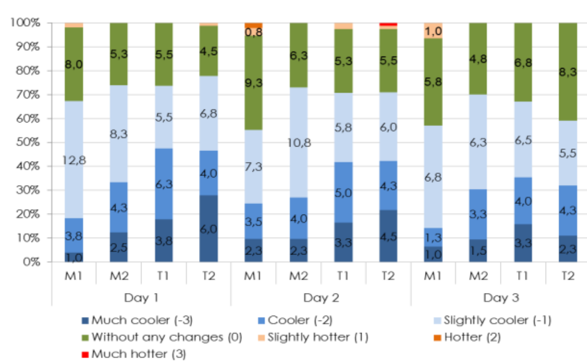

Figure 13: Mean thermal preference – questionnaires

SURFACE TEMPERATURE

Since building´s facades were well protected and the classrooms in the same direction had a better or worse performance, measurement data showed that the heat gain problem was caused by the roof. Consequently, measurements of the ceiling´s surface temperature (internal measurement) and floor of classrooms were conducted.

Figure 13 shows a graph with mean measurements for all classrooms during the days under analysis. Highest temperatures of ceiling occurred at 15h30 since the roof had received heat throughout the day. Heat penetrated the inside of the building around 15h30 at higher temperature rates than that on the outside. The overheated ceiling at a height of 2.80 m caused a discomfort feeling since the difference in radiant temperature was great.

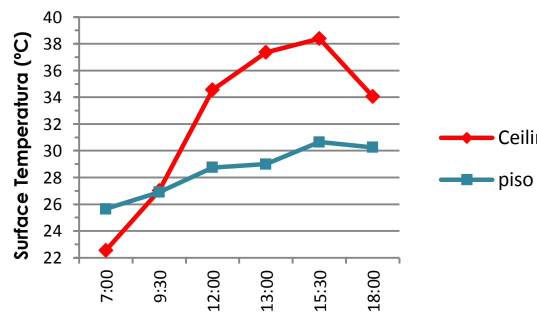

Figure 13: Graph showing surface temperatures

Table 1 records the greatest differences between the ceiling and floor temperatures in the afternoon, at approximately 15h30. Difference reached 10.5ºC in classroom 4. It may be observed that the ceiling was cooler than the floor in the early morning, at 07h. The former cooled during the night when temperatures were low. Data above demonstrated the building´s low inertia: the situation inverted close to 10h; throughout the day, the ceiling´s temperature received heat and caused great discomfort feelings in the students.

It became clear that the thermal performance of the ceiling has to be improved. A solution to the roof´s heating problem would improve the students´ satisfaction with regard to their thermal comfort during the hottest days of the year.

Table 1: Difference in surface temperature: ceiling - floor

Hour	Day 1					Day 2				
	Lib r.	Class 1	Class 2	Class 3	Class 4	Lib r.	Class 1	Class 2	Class 3	Class 4
0700	-3	-3	-3.5	-3	-3.5	-2.5	-3.5	-3	-3.5	-2.5
0930	-1	-0.5	0	1	1.5	-1.3	-0.5	-1	1	2
1200	2.8	5.5	6	6	7.5	2.8	6	6.5	7	8
1300	5.8	9	9	9.5	10	6.4	8	9.5	8	8.5
1530	6.7	9	9.5	9.5	**10.5**	5.2	6.5	6	6.5	8
1800	5	5	5.5	4.5	5	4.2	1.5	2	2.5	3

CONCLUSION

When the analysis of the project is taken into account, results show that the building placed within a green area is well directed and its facades are well protected from sun radiation. Horizontal sunlight-breakers of different sizes, in proportion to the sill height, and pivot frames for vertical brise-soleil show the architect´s concern for environment comfort.

Measurements revealed internal temperatures higher than the external ones, with a small comfortable period in the early morning period, as PMV and questionnaire responses showed. Worst results in Classrooms 1 and 3 facing the northeast direction and best results in the library, also facing a northeast direction, showed that heat actually derived from the roof and the ceiling. Owing to the difference of more than 10ºC on surface temperatures of the ceiling and floor and a height of 2.80m, an architectural intervention is mandatory.

The above great discomfort may be explained as a result of lack of maintenance that caused a blackening of the roof´s external surface with a subsequent great absorption of heat and low inertia of the construction system. Comfort conditions in the building´s interior and the teaching-learning process were jeopardized.

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