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Thermal acceptability assessment in buildings located in hot and humid regions in Brazil

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ABSTRACT

The objective of this paper was to perform an analysis on thermal acceptability in naturally ventilated (NVB) and air-conditioned buildings (ACB) located in hot and humid climates in Brazil. Experiments were carried out in April and November 2005 with 1.301 questionnaires based on ISO 10551:1995(E). Indoor and outdoor climatic variables were monitored simultaneously. The results revealed that 53% of the occupants of NVB and 78% of ACB were thermally satisfied. However, some restrictions were observed with the applications of the following methodologies: ISO/FDIS 7730:2005(E); ANSI/ASHRAE Standard 55:2004; Adaptive Temperature Limits (ATG) and prEN15251: 2005(E). Differences were observed between thermal sensation (TSV) and predicted mean vote (PMV) and between the subject's percentages expressing thermal unacceptability of the environment and the PPD calculated according to ISO/FDIS 7730:2005(E).

1. Introduction

Since the presentation of the Fanger model in 1970 [1], the evaluation of the thermal acceptability in indoor environments began to be expressed in terms of the PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) indices. Initially adopted as an international model in 1984 (ISO 7730) [2], the limits of$-0.5 \leq$ PMV $\leq +0.5$ and PPD $\leq 10\%$ which defined the environment thermal acceptability were altered by the annex A of the ISO/FDIS 7730:2005(E) [3] adopting3 bands or classes: A, B and C. Nevertheless, this new regulation was not enough to solve the question about the evaluation of the thermal acceptability in naturally ventilated buildings. Its indiscriminate application has generated discrepancies in different parts of the world. Among the probable justifications is the fact that the model was originally developed in acclimatized chamber where the environment is completely under the researcher's control.

In the search for a solution for this question, several methodologies have been suggested.

In this way, it was recently suggested a new classification to the thermal environments which are to be submitted to an evaluation of the thermal acceptability [4]. Others, which are more specific to the analysis of only the thermal acceptability, are also at our disposal, considering that the sensation, satisfaction and thermal acceptability also allow the required evaluation.

In relation to the thermal acceptability, specific object of this work, a research carried out in Hyderabad, India, revealed that the thermal unacceptability is low in elderly people, high in women and in people from a low economical class [5].

In order to obtain comfortable indoor environments, one can observe with relative frequency, the use of artificial acclimatization in an inadvisable way, a fact that besides contributing to the emission of gases, which pollute the atmosphere, is contrary to the patterns of energetically efficient buildings. However, we have to consider the publicizing of researches which aim was to search for technological alternatives to the production of thermally comfortable, ecologically correct and energetically efficient indoor environments [6,7]. This concern has reached the housing located in rural areas. Recently, the comparison between the thermal acceptability verified in rural and urban houses, indicated to the same operative temperature that both the thermal sensations votes and the percentage of votes of acceptability obtained in the rural area are higher than those from the urban area [8]. It has been deduced that such fact is probably due to the lower thermal comfort expectancy of the referred population.

According to the standards, thermal acceptability is indirectly inferred from Predicted Mean Votes (PMV) calculated from Fanger's model [1], ranging from negative (cool) to neutral to positive

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Table 1
Categories of thermal environment according to ISO/FDIS 7730:2005(E) [2] and prEN 15251:2005(E) [5] for conditioned indoor environments.

Category	Thermal state of the body as a whole	
	PPD (%)	PMV
A	< 6	−0.2 < PMV < + 0.2
B	< 10	−0.5 < PMV < + 0.5
C	< 15	−0.7 < PMV < + 0.7

(warm). The environmental quality is classified into three classes (or categories) according to ISO/FDIS 7730:2005(E) [3] and prEN 15251:2005(E) [9]. Table 1 summarizes these requirements. The work which discusses if the applicability of the "A" class proposed by the ISO/FDIS 7730:2005(E) [3] is realistic or desirable was presented recently [10]. As a conclusion, the authors state that the "A" class is unsustainable as a base of control of office buildings due to the cost of energy for the maintenance of the required specifications. ASHRAE Standard 55 [11] suggests a graphic method for typical indoor environments in a range of operative temperatures resulting in 80% of acceptability (Fig. 1a), based on the 10% dissatisfaction criterion for general (whole body) thermal comfort according to the PMV-PPD index.

If this classification can be questioned for conditioned indoor environments, in naturally ventilated building (NVB) the scenario is far more complex. Especially in NVB, the results of field experiments indicated that occupants consider temperature fluctuations acceptable and desirable. Considering these aspects, standards also provide methods in order to maintain 80% or 90% of thermal acceptability inside the environments. Specific requirements are therefore necessary, and they are particularly related to the occupants' free adaptation of their clothing to indoor thermal conditions.

ANSI/ASHRAE Standard 55:2004 [11] suggests an optional method for determining acceptable thermal conditions in NVB (see Fig. 1b). According to the graph and based on indoor comfort temperatures, limits for 80% and 90% of thermal acceptability are possible. This criterion is applicable for spaces equipped with operable windows, without mechanical cooling system (mechanical ventilation is allowed) with occupants engaged in almost sedentary activities and being able to freely adapt their clothing insulation. The operative temperature limits proposed are monthly mean outdoor temperatures lower than 10 °C or higher than 33.5 °C. prEN 15 251:2005(E) [9] also suggests a graphic method in order to define thermal acceptability for NVB.

The applicability of Fanger's PMV model [1] on which those classes are based has raised discussions and controversies because studies showed discrepancies between the occupants' TSV and PMV, particularly when the experiments were developed inside real buildings. Alternative models have been presented. [12–28]. However, those discrepancies are not just related to the normalized model of calculus of the PMV. Recently, a new formula of calculus was presented due to the discrepancies verified with the application of the model proposed by Fanger after an experiment carried out in a hot and humid region [29].

Especially for hot and humid climates, where design strategies for NVB or ACB resulted in different envelopes for thermal indoor conditions, standards and methods play important roles. Keeping in mind that a significant part of the research used as reference for standards has been developed in cold and temperate climates, the hypothesis that methods and targets can vary for hot and humid contexts is reasonable.

This paper focuses on thermal acceptability analysis inside ACB and NVB located in hot humid regions in Brazil, considering the requirements and methods proposed by the following standards: ISO/FDIS 7730:2005(E) [3], prEN 15 251:2005(E) [9], ANSI/ASHRAE Standard 55:2004 [11] and Adaptive Temperature Limits (ATG) [30].

2. Method

The method consists in a comparative analysis between the results for thermal acceptability values from field experiments and the requirements specified in ISO/FDIS 7730:2005(E) [3], prEN 15 251:2005(E) [9], ANSI/ASHRAE Standard 55:2004 [11] and Adaptive Temperature Limits (ATG) [30]. Questionnaires (1301) based on ISO 10551:1995(E) [31] and comprehensive measurements of the indoor climatic were analyzed simultaneously. Detailed information about climate background, indoor environments and measurement protocol are given below.

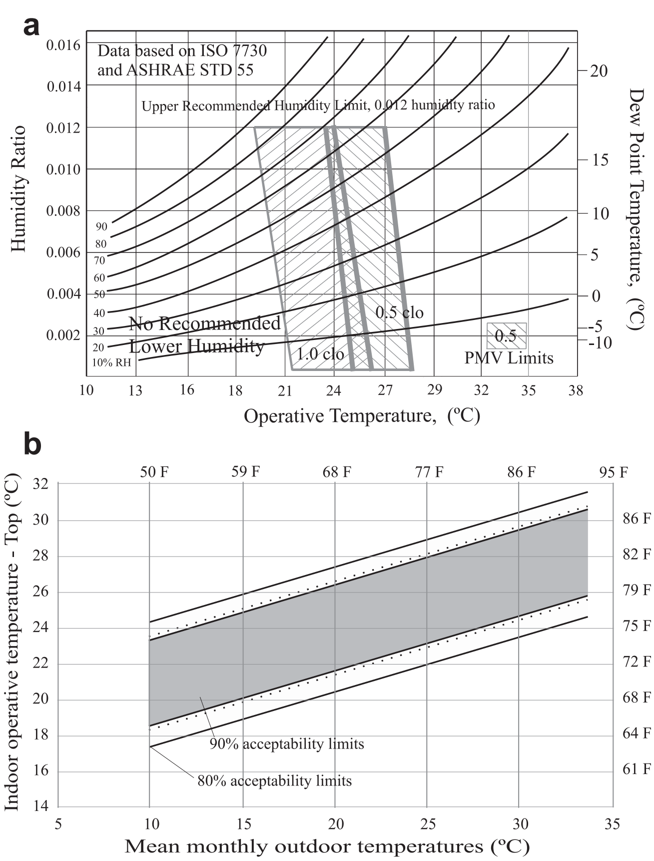

Fig. 1. (a) Acceptable operative temperature ranges for typical indoor environments according to ANSI/ASHRAE Standard 55:2004. (b) Acceptable operative temperature ranges for naturally conditioned spaces according to ANSI/ASHRAE Standard 55:2004.

Table 2
Mean monthly outdoor air temperatures in Corumbá, Coimbra and Campo Grande.

City	Month	Mean outdoor temperature			
		1961/1990		Field experiment period	
		Max	Min	Max	Max
Corumbá	April	30 °C/32 °C	20 °C/22 °C	32 °C/34 °C	20 °C/22 °C
and	November	32 °C/34 °C	22 °C/24 °C	34 °C/36 °C	22 °C/24 °C
Coimbra	April	28 °C/30 °C	18 °C/20 °C	30 °C/32 °C	22 °C/24 °C
Campo Grande	November	30 °C/32 °C	18 °C/20 °C	30 °C/32 °C	20 °C/22 °C

Source: www.cptec.inpe.br/clima/monit/monitor_brasil.shtml (02.10.2005)

Fig. 2. (a) Occupants' typical activities and clothes in naturally ventilated buildings. (b) Occupants' typical activities and clothes in air-conditioned buildings.

2.1. Climate background

The field experiments were carried out in three NVBs and one ACB. The NVBs are located in Coimbra (57°46′W/19°55′S and 93 m altitude), Corumbá (57°38′W/19°01′S and 158 m altitude) and Campo Grande (54°37′W/20°28′S and 564 m altitude). The ACB is located in Campo Grande.

According to Köppen's classification, these cities are located in a hot and humid region and "Aw" Rainfall characterizes the seasons which can be classified into two: dry (May to September) and humid (December to February). Table 2 summarizes the mean monthly outdoor air temperatures during the experiments and presents a historical series from 1961 to 1990. In April, the mean outdoor temperatures ranged from 32 °C to 34 °C in Corumbá and Coimbra and from 30 °C to 32 °C in Campo Grande. In November, the mean outdoor temperatures were slightly higher in Corumbá and Coimbra, ranging from 34 °C to 36 °C. In Campo Grande, during the same period, the mean outdoor temperature remained the same, 30–32 °C.

2.2. Indoor environments and occupants

The NVBs have housed the Brazilian Army Headquarters and has been occupied mainly by individuals developing classroom activities (1.2 met), (Fig. 2a). Inside these environments, operable windows and ceiling fans are the main source of natural ventilation and occupants could freely change their indoor environment. The occupants were wearing military uniforms that could be adapted according to the army garment specifications for different seasons.

Values for clothing insulation were obtained according to these slight seasonal differences (0.34 *clo* for April and 0.54 *clo* in November) based on ISO/FDIS 7730:2005(E) [3].

The ACB is a Federal Bank with cellular layout where occupants develop typical office activities (1.3 met), (Fig. 2b). In this environment, the occupants are allowed to adapt their clothes; however, there is a "non-official" dress code that contributed to the slight differences of *clo*-values identified for each season (0.48 *clo* in April and 0.49 *clo* in November).

Table 3
Values obtained in NVB.

Month	City	Mean op. temp (°C)	Mean air vel (m/s)	PMV	TSV	PPD	Thermal Acceptability (%)
Apr	Coimbra	34.5	0.22	3.0	1.4	99	59
	Corumbá	33.3	0.15	2.8	1.9	98	31
	Campo Grande	24.0	0.09	0.6	−0.5	13	86
Nov	Coimbra	30.6	0.18	1.8	1.1	69	61
	Corumbá	27.4	0.13	0.9	1.3	25	54
	Campo Grande	28.9	0.19	1.3	0.6	42	73

2.3. Measurement protocol

Standard questionnaires were applied focusing on the occupants' thermal acceptability. The occupants were required to answer the following question: "Do you accept this thermal environment?" proposed by ISO10551:1995(E) [31]. Occupants answered the questionnaire after 30 min of their arrival at the building (acclimatization period) while receiving a detailed explanation about the purpose of the experiments. The occupants

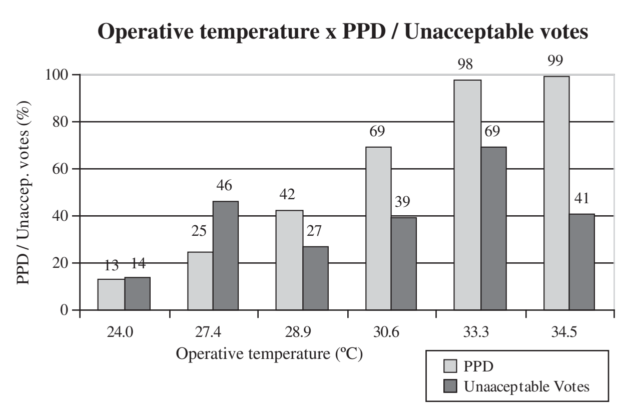

Fig. 3. Dissatisfied occupants (voted and calculated PPD) in relation to operative temperature values in naturally ventilated buildings.

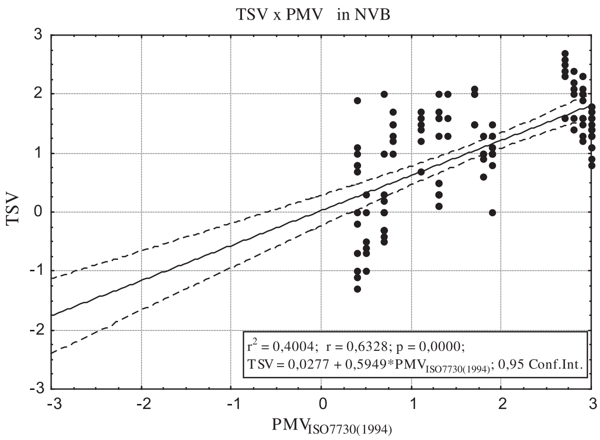

Fig. 4. Cross-tabulated votes for thermal sensation votes and PMV.

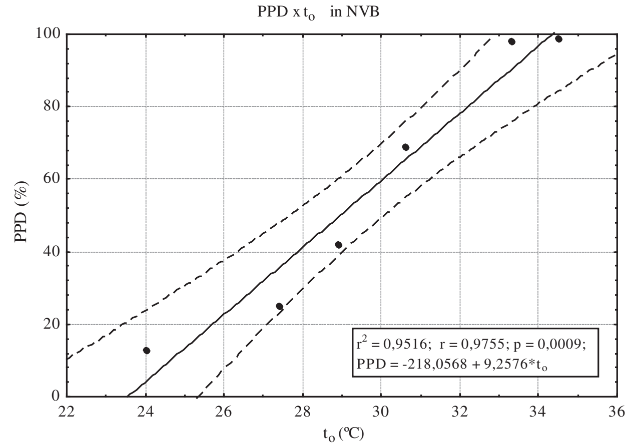

Fig. 5. Cross-tabulated results for PPD and operative temperature values.

also provided information about their age, height, weight and clothing. They answered the questions listed in ISO10551:1995(E) [31], repeated three times with a 20-minute interval, yielding 1301 questionnaires.

Simultaneously, comprehensive indoor and outdoor measurements were carried out based on ISO 7726:1998(E) [32] requirements. Indoor environmental data were collected within one minute interval with a microclimatic station. The data collection comprised the main variables necessary for this research such as air temperature, mean radiant temperature, air velocity and humidity.

Outdoor temperature and humidity were obtained every 15 min based on different stations. In Corumbá, climatic variables were obtained from the Aeronautic Meteorological Division for Flight Protection (SBCR/Corumbá) and in Campo Grande from the Cattle Research Centre (CNPGC) of the Brazilian Agricultural Research Agency (EMBRAPA). No climatic data were available for Coimbra. In this case, the same data of Corumbá were adopted, because of the short distance between the two cities, sharing the same microclimate region and characteristics.

3. Results and discussion

3.1. Naturally ventilated buildings – NVB

Table 3 summarizes the occupants' thermal acceptability votes, PPD, PMV, TSV and the values of climatic variables in each experiment for NVBs. The occupants' answers in Coimbra indicated that, in April, 41% of them did not accept their thermal environment. On the same occasion, the PPD calculated according to the ISO/FDIS 7730:2005(E) [3] was 99%. In November, the results were 39% and 69%, respectively. Differences were also reported in Corumbá, namely, 69% and 98% in April; and 46% and 25% in November. In Campo Grande, in April, probably due to a cold front that lowered the temperature, the difference was not significant (1%) whereas, in November, it was reasonably higher (15%).

According to the ISO/FDIS 7730:2005(E) [3], thermal acceptability limits should be at least 80%. However, this percentage was never found in these experiments. It should also be considered that the limits imposed for the operative temperature might make the application of this methodology unviable for the region, since values higher than those reported are frequently observed. Such inapplicability should not be neglected even in view of the results of Campo Grande during the April survey that maybe related to the cold front that started in the late afternoon of the previous day, making air temperature lower 7.3 °C in few hours, as explained before.

Significant differences between the percentages resulted from the occupants' unacceptable votes and the PPD calculated values were seen. PPD calculated values overestimated the percentages of occupants dissatisfied with their thermal environment. It is seen that in Campo Grande, in April, PPD = 13% implies that 87% of the volunteers accepted the environment temperature, a result almost identical to the formal manifestations (86%). This certainly occurred because, during the experiment, the outdoor temperature (16.3 °C) was extremely low for the region standards during the autumn.

In the same way, differences were seen between the PPD and the votes of temperature unacceptability manifested by the volunteers. These differences are shown in Fig. 3. In only one experiment, did the PPD values equal 14% and the votes of temperature unacceptability indicated close values: in Campo Grande and in April, when a cold front occurred.

Incoherence between the PPD and the votes of thermal unacceptability was also observed in relation to the operative temperature; mean air velocity and air relative humidity. This is shown by the fact that, for **to** = 34.5 °C, **va** = 0.22 m/s and **RH** = 50%, the percentage of vote of thermal unacceptability was 41% whereas the PPD was 99%. On the other hand, for **to** = 33.3 °C, **va** = 0.15 m/s and

Table 4
Thermal requirements of the three classes of indoor environments according to ISO/FDIS 7730:2005(E).

Month	City	Mean op. temp (°C)	Mean air vel (m/s)	PMV	TSV	PPD	Thermal Acceptability (%)	Category
Apr	Coimbra	34.5	0.22	3.0	1.4	99	59	–
	Corumbá	33.3	0.15	2.8	1.9	98	31	–
	Campo Grande	24.0	0.09	0.6	−0.5	13	86	C/B
Nov	Coimbra	30.6	0.18	1.8	1.1	69	61	–
	Corumbá	27.4	0.13	0.9	1.3	25	54	C
	Campo Grande	28.9	0.19	1.3	0.6	42	73	–

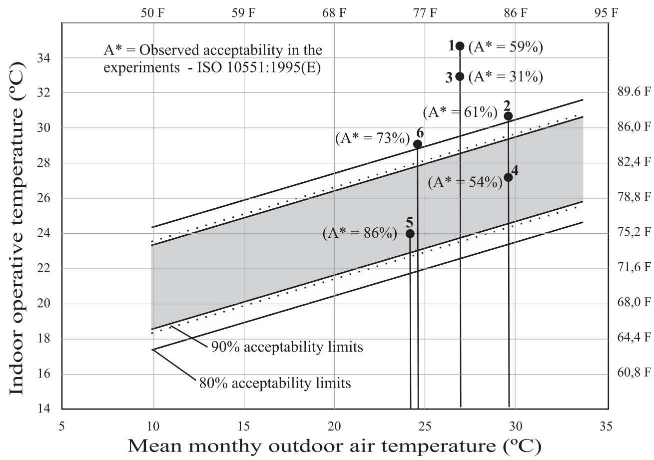

Fig. 6. Thermal acceptability according to ASHRAE 55 for naturally ventilated indoor environments.

RH = 70%, a coherently higher percentage of thermal unacceptability was seen (69%) and PPD remained steady (99%).

Table 3 also shows that, according to the values of each experiment, the difference between TSV (1.3) and PMV (0.9) was not significant. This occurred in Corumbá in November, probably because during the experiment the mean air temperature (27.0 °C) was fitted in the interval proposed by Givoni [33]. This did not occur with the air velocity, as a mean value of 0.13 m/s was observed.

Fig. 4 illustrates the correlation between PMV and TSV, where one can see the absolute prevalence of PMV and TSV higher than zero, indicating heat discomfort. It is also seen that most volunteers lie outside the comfort band indicated by the votes of thermal sensation ($-0.5 \leq$ TSV $\leq +0.5$). It is also worth considering in the graph the indication of the volunteers who reported cold discomfort, a fact only accounted for subjective judgment, an individual feature that has not been explained yet in the studies about thermal comfort.

If we consider that, for ISO/FDIS 7730:2005(E) [3], PPD of 10% represents thermally acceptable environment, Fig. 5 shows optimal operative temperature close to 24.6 °C. This result is coherent with those presented in Table 3, in which for **to** = 24.0 °C the percentage of thermally unsatisfied people was 13% (Campo Grande in April). However, it is worth noting that the region was under the impact of a cold front on the day the experiment was carried out.

With the specific aim of assessing the environment thermal acceptability, ISO/FDIS 7730:2005(E) [3] proposes a typified methodology (item 7) exemplified in Annex A. Table 1 shows the three categories of environments proposed by item 7, according to values of PPD and PMV. It was seen that in only one experiment could the methodology be applied; this occurred because the other PMV presented values higher than those allowed did. In the experiment carried out in April, the environment in Campo Grande was the only one that could be classified into category C. Again, it is worth observing that this classification results from the climate records on the day of the experiment, which were uncommon in the region. Such a phenomenon, together with the low mean air indoor velocity (0.09 m/s), played a significant role for the indication of PMV equal to 0.6. It becomes evident that the norm is not suitable to the region, even for values of air temperature lower than the upper limit of 30 °C defined for its application.

The ISO/FDIS 7730:2005(E) [3] still proposes assessment using another table, presented previously in this paper (Table 1). It was seen that, rigorously, only in one occasion there was a possibility of classifying an environment as category B: Campo Grande in the experiment carried out in April. This occurred because both operative temperature (24.0 °C) and mean air velocity (0.09 m/s) have met the limits established in the aforementioned table for the winter. The environment of Corumbá in November, however, could be fitted into category C, as its operative temperature (27.4 °C) remained very close to the upper limit established for the summer (27.0 °C). The other environments did not meet the limitations of operative temperatures imposed by the methodology.

In conclusion, the methodology for analyzing the thermal acceptability proposed by ISO/FDIS 7730:2005(E) [3] maybe considered not applicable in the region at issue in spite of its recommendation for temperate climate. On the other hand, its use is justified in this paper as Fanger [1] allows the application of the equation of thermal comfort in different regions, for example, in the tropics where people are more acclimatized to hot environments. Table 4 indicates the obtained categories of acceptability. It has also to be taken into account the fact that the volunteers of AVN were not allowed to alter their clothing. This fact has probably influenced the results, implying that new experiments should be carried out with a view to obtaining a definite conclusion.

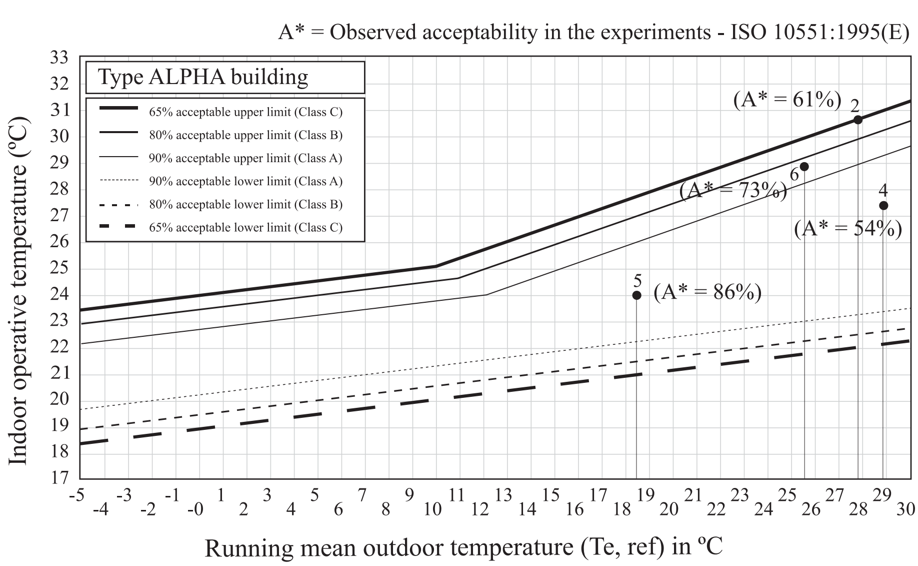

Fig. 7. Thermal acceptability according to the Adaptive Temperature Limits for naturally ventilated indoor environments.

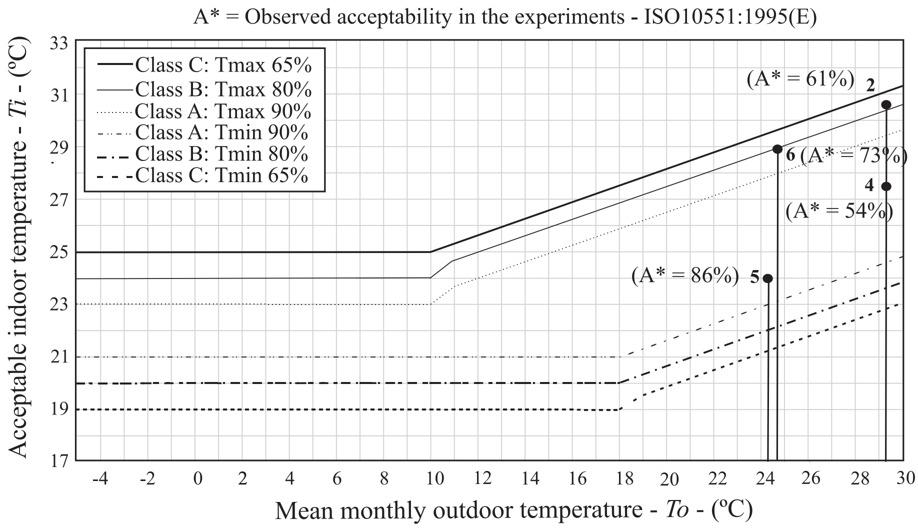

Fig. 8. NATVENT thermal acceptability according to prEN 15251:2005(E).

Fig. 6 shows the results of the analysis of thermal acceptability according to the ANSI/ASHRAE Standard 55 [11].

All mean outdoor temperatures were considered lower than the upper limit of the methodology. However, two operative temperatures exceeded the limit. In spite of this, the mean monthly outdoor air temperature and its operative indoor correspondent show, in some cases, discrepancies between the normalized degree of acceptability and those indicated by the volunteers. Considering A* as the result of the volunteers' indication, it becomes evident that the graphic result is incoherent, even for indications 4 and 5 which refer to the environments of Corumbá (November) and Campo Grande (April). Thus, it can be concluded that this methodology is not suitable for the region, therefore unadvisable, maybe because the volunteers could not alter their clothing. Again, more experiments should be carried out in order to reach definite conclusions.

For Adaptive Temperature Limits (ATG) model [30], all environments were previously classified as "C" (thermal acceptability level of 65%), as they were not newly built or temporarily occupied and the indoor temperature is accepted. In the graph suggested by the methodology (Fig. 7), the entry temperatures (**Te,ref**) in the graph were calculated from the mean values of higher and lower outdoor temperatures of the day at issue, and also of the previous three days.

Following this methodology, the limit imposed to the operative temperatures hindered the analysis of the environments where the values 34.5 °C and 33.3 °C were observed. This discrepancy, and also the difference between the percentage of the methodology (90%) and that manifested by the volunteers (54%) in point 4, which relates **Te,ref** = 28.8 °C and **to** = 27.4 °C, made evident that this methodology is not suitable in the region. Thus, in further studies the graph should be adapted to allow for higher values of indoor operative temperatures and running mean outdoor temperatures.

Fig. 8 below shows the results obtained for thermal acceptability according to prEN 15251:2005(E) [9]. This methodology classified the environments as category "C", which indicates a moderate level of thermal expectancy. Considering that, and in spite of the difference in terminology, entry scales are identical to those of Adaptive Temperature Limits (ATG) [30]. The experiments in Coimbra and Corumbá in April indicated acceptable indoor temperature indices I (*Ti*) above the upper limit allowed.

Due to the great similarity with the ATG, two values of operative temperature exceeded the upper limit allowed (33 °C). Likewise, it is also seen that there is no coherence in the values *To* = 29.3 °C and *Ti* = 27.4 °C. As in the ATG this point refers to the experiment carried out in Corumbá in November in which 54% of the volunteers manifested acceptance of the environment whereas the graphic indication showed that the acceptance was 90%. Thus, like the ATG one may conclude that due to the limitation imposed by the operative temperatures frequently occurring in the region and because of the incoherence pointed out, the application of this methodology is unadvisable until new experiments are carried out.

3.2. Air-conditioned building

Table 5 shows the cross–tabulation of PPD and the volunteers' answers, PPD and PMV values and the climate variables observed. Both in April and November unacceptability indices are relatively close to the PPD calculated through ISO/FDIS 7730:2005(E) [3]. The

Table 5
Values obtained in ACB.

Month	Mean op. temp (°C)	Mean air vel (m/s)	PMV	TSV	PPD	*Class*	*% Thermal Acceptability*
Apr	23.3	0.17	−0.7	0.0	14	C	80
Nov	24.3	0.09	−0.1	0.3	5	A	82

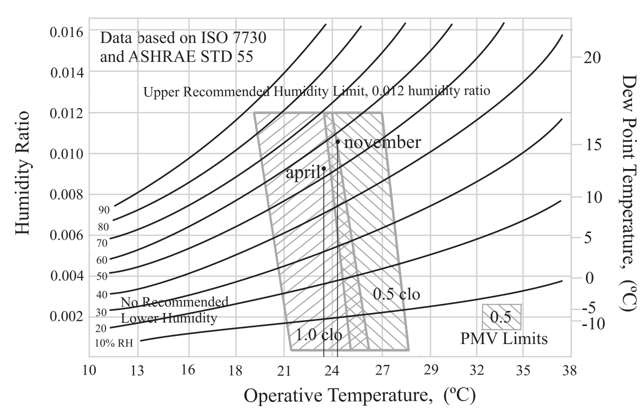

Fig. 9. Acceptable range of operative temperature and humidity for spaces according to ANSI/ASHRAE Standard 55:2004 [3] for 80% occupant acceptability.

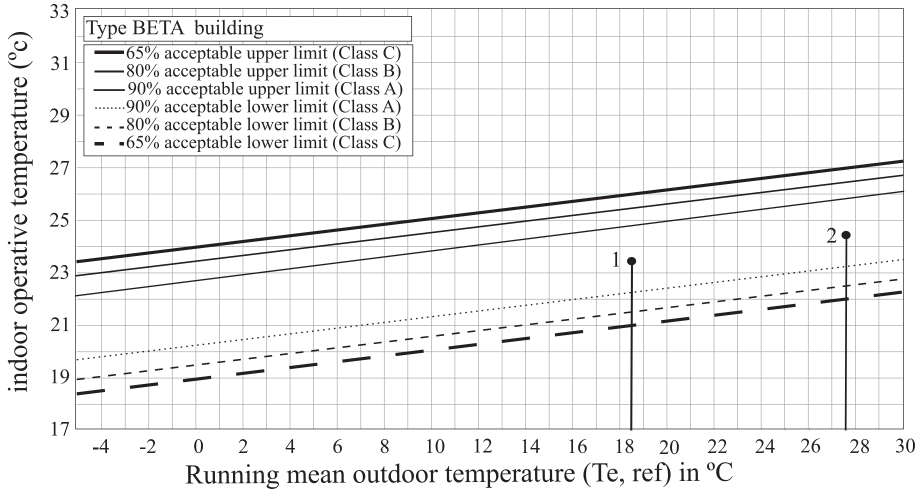

Fig. 10. Thermal acceptability according to Adaptive Temperature Limits for air-conditioned indoor environments.

greatest discrepancy was seen in the experiment carried out in November, where PPD was 5% and among all participants, 18%, regarded the environment as thermally unacceptable. In April, the difference was even smaller: The PPD was 14% and dissatisfaction accounted for 20%.

These indoor environments could be classified as category "C" in April and "A" in November. In category "C", the PPD should be lower than 15% and PMV should be ±0.7 whereas in category, "A" the PPD should be lower than 6% and PMV should remain ± 0.2. On the other hand, Table A.5 of ISO/FDIS 7730:2005(E) [3] that considers space, activity level, operative temperature and upper air velocity, showed that the environment reached, in both months, category "B". The limits are: **to** = 24.5 °C ± 1.5 °C in the summer and 22.0 °C ± 2.0 °C in the winter; upper **va** of 0.19 m/s in the summer and 0.16 m/s in the winter. The results showed that the methodology is suitable for the analysis of ACB.

Considering the indices of thermal resistance of the clothing in the experiments, we can observe that the environment was strictly inserted in the comfort zone only in November, which was confirmed by PMV = −0.2; PPD = 5% and TSV = 0.3, the latter very close to the neutral thermal sensation. In April, for the values of operative temperature and relative humidity, the graph (Fig. 9) showed that the participants must have been wearing clothes with insulation indices equivalent to 1.0 *clo*, which was confirmed by PMV = −0.7 and PPD = 14%. Thus, we can likewise affirm that the methodology is suitable for the analysis of thermal acceptability in this kind of environment and in climatic regions similar to that of this study.

Fig. 10 shows the analysis of the thermal acceptability according to Adaptive Temperature Limits (ATG) [30]. Both in April and in November, the temperature remained with 90% of thermal acceptability: a percentage relatively close to the result of the occupants' expressions (80% in April and 82% in November). Therefore, this methodology is also suitable for analysis of thermal acceptability in this kind of environment and in climatic regions similar to those of this study.

Finally, for the analysis of thermal acceptability according to prEN 15251:2005(E) [9], the environment should be inserted into category "A", which indicates a high level of thermal expectancy, since the participants belonged to the upper middle class (engineers and architects), consequently more demanding in relation to their work thermal environment. Under this condition, Table A.1 in which for each of the categories "A", "B" and "C" an upper percentage of thermally dissatisfied people and limits for the predicted mean vote are admitted, showed that the calculated PPD corroborated the initial definition. Nevertheless, it did not occur in April. When PPD = 14% determined that the environment should be inserted into category "C" (moderate level of thermal expectancy) and not "A" (high level of thermal expectancy) as considered previously. Therefore, in April, the environment was thermally acceptable, PVM (−0.7 in April and −0.1 in November) ratified this classification, as expected. Thus, this methodology is also suitable for the analysis of thermal acceptability in this kind of environment and in climatic regions similar to those of this study.

4. Conclusions

This paper focused on thermal acceptability values in three NVBs and one ACB with occupants developing sedentary activities. Occupants were required to answer the question "Do you accept this environment thermally?" Based on these results, a comparative analysis was carried out considering the following methodologies as reference: ISO/FDIS 7730:2005(E) [3], prEN 15251:2005(E) [9], ANSI/ASHRAE Standard 55:2004 [11] and Adaptive Temperature Limits (ATG) [30].

4.1. Naturally ventilated buildings

Differences have been found among the volunteers' answers and the PPD values calculated in accordance with ISO/FDIS 7730:2005(E) [3]. Those differences were insignificant in only a single opportunity. Accordingly, the limit of thermal acceptability of 80% proposed by the aforementioned norm was never reached, maybe due to the limits of the operative temperature observed in the region.

Differences were also seen between predicted mean vote (PMV) and thermal sensation vote (TSV); only when the mean air temperature was 27.0 °C did they remain close, 0.9 and 1.3, respectively.

In relation to the methodologies for assessment of thermal acceptability that this paper aimed at analyzing, it was initially demonstrated that the two proposals of ISO/FDIS 7730:2005(E) [3] are partially suitable for the region.

Similar results were found in both the application of prEN 15251:2005(E) [9] and ATG [30] methods because of the values of operative temperatures that usually occur in the region.

4.2. Air-conditioned building

The application of ISO/FDIS 7730:2005(E) [3] in the ACB showed relative coherence between the volunteers' indications and the predicted percentage of dissatisfied (PPD) calculated values. The same coherence was found when the item 7 of the same norm was applied.

Coherence was also found when the methodologies proposed by prEN 15251:2005(E) [9], ANSI/ASHRAE Standard 55:2004 [11] and ATG [30] were applied, indicating that the evaluation of the thermal acceptability of ACB is possible. It is also noteworthy that the results point to no need to suit the environment so as to reach class "A" proposed by ISO/FDIS 7730:2005(E) [3] because of the levels of acceptance already achieved, especially in November, when it starts the summer season in the region.

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