Referência

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Adaptive Thermal Comfort in Brazilian Schools by Building Performance Simulation (BPS)

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Abstract: Building performance simulation (BPS) is a crucial tool towards the design of projects better adapted its climatic context. In this sense, the objective of this research is to evaluate a method of thermal comfort analysis of schools in three Brazilian cities using BPS. The methodological procedures involved a literature review, in which the simulation tool and analysis method were chosen. Following simulations with the software DesignBuilder were performed using as study case a standard school typology designed by the General Coordination of Educational Infrastructure (CODIN/FNDE). This article evaluates its percentage occupied comfort hours in 3 reference cities: Cuiabá-MT, Brasília-DF, and Curitiba-PR. The results show respectively, for the cities of Curitiba, Brasília and Cuiabá, percentages of comfort hours of 76%, 70%, and 23%. The research states that the project must have different strategies for different climates. Finally, this article recommends this method should be applied to other cities and buildings.

Key words: Building performance simulation, thermal comfort, standard design, protocol, schools.

1. Introduction

The Building Performance Simulation (BPS) is an essential method of supporting the architectural design process. The project designed and supported by computer simulations tends to be better adapted to its climate context, mainly because the computer simulation programs use specific climate files that broadly characterize the climate of the project—loci city. In this sense, computer simulation provides adequate apprehension of the impact of specific design variables on the building's final energy consumption and environmental thermal comfort [1-3].

The representation of thermodynamic phenomena through virtual models simplifies the environmental understanding in which the building is inserted, thus contributing to the architect's design process [4, 5].

From a historical perspective, in the 1970s, as a result of the oil crisis, European countries and the US alarmed about the need for rational energy use in buildings set out to formulate the first policies focusing on energy efficiency [6-9]. This context has led to the development of methods for building performance evaluation and mechanical system design and the evolution of early simulation software, still limited to analytical calculations, to more robust tools capable of performing dynamic calculations [3, 7, 10].

Today it is clear that computer simulation has improved the design process [9, 11-13]. Its use allows to carefully investigate the impact of different architectural aspects on the environmental performance of buildings [14], providing a better understanding of the impact of specific design decisions on their thermo-energetic behavior [6, 15].

Thermal comfort analysis methods advanced in 2004 when the American ASHRAE Standard 55-Thermal Comfort Environment for Occupancy [16] began to include an adaptive approach for assessing thermal comfort in not artificially unconditioned environments. The standard restricts the method presented to the assessment of the thermal performance of naturally ventilated buildings and establishes the concept of thermal acceptability, which has acceptable thermal conditions for 80% and 90% of occupants. This

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approach establishes that the user is not inert to their environment, interacting with them in order to improve their thermal comfort conditions. Humphreys [17] refers to the user-centered adaptive approach as a parameter to reformulate conventional temperature standards so that there is an empirical relationship between climate and thermal comfort. In this sense, the main objective for this article is to analyze adaptive thermal comfort in school buildings using BPS for different climates in Brazil.

2. Method

Through DesignBuilder v5.3 software, it is possible to manage a series of thermal simulations from EnergyPlus v8.9. For this, it is using genetic algorithms to approach the defined goal. In this sense, starting from the percentage of the number of hours occupied (POC) obtained by the standard design in its original characterization, some variables were parameterized: vertical sealing transmittance, type of coverage, percentage of opening area, glass type, shading, and natural ventilation. The determination of acceptable thermal conditions in naturally conditioned spaces according to ASHRAE 55 applies, however, only in climates whose maximum outdoor temperature varies between 10 ℃ and 33 ℃.

The metabolic rate of users, ranging from 1.0 met to 1.3 met, and acceptable clothing limits between 1 and 0.5 clo, is also established. Environments that meet these requirements are calculated as the internal operating temperature. This temperature must not exceed the determined limits calculated for an acceptability percentage of 80%. The outdoor temperature reported by Standard 55 represents the average predominant outdoor air of a set of days (between 7 and 30 subsequent days and preceding the analyzed day), which defines the thermal amplitude of the environment, whose users had to adapt physically, psychologically, and physiologically.

For each of the representative cities, their respective psychometric chart was then constructed as an instrument for understanding the local climate with the use of ClimateConsultant v6.0 software, which allows the insertion of EPW (Energyplus Weather Data). The 8,760 hours are evaluated according to three available comfort models: California Energy Code, ASHRAE Fundamental, and ASHRAE Standard 55-2004, the latter including the adaptive approach valid only for naturally ventilated environments.

In this research it was employed the adaptive comfort model of Standard 55 [16]. The normative limit of acceptability of 80% was adopted to define the comfort zone on the psychometric chart and plotted at all hours of the year. In the ClimateConsultant application, then it can observe several parameters determined for the elaboration of the psychometric chart and representation of each of the 8760 hours of the year. The points indicated in green represent the hours within the adaptive comfort limit.

It is performed a comfort diagnosis of the standard school typology designed by the General Coordination of Educational Infrastructure (CODIN/FNDE for three cities: Curitiba (Fig. 1), Brasília (Fig. 2), and Cuiabá (Fig. 3). The envelope characterization of Thermal Transmittance, Thermal Capacity, and Reflectance was following the current Brazilian Bioclimatic Zoning—NBR 15220-3 [18]. Thus, once the envelope parameters were extracted, they were released in the Consumption Indicator calculation formulas, resulting in both climate zones equivalent to Level A, after using the index from Dear and Brager [19]. After verifying the POC within the comfort zone and its respective Numerical Equivalent, the area of each simulated environment is weighted to determine the Pedagogical Block Numeric Equivalent as a whole.

3. Results

The following graphs are presenting the three representative cities, where the hourly operating temperature profiles for the three rooms of the pedagogical block.

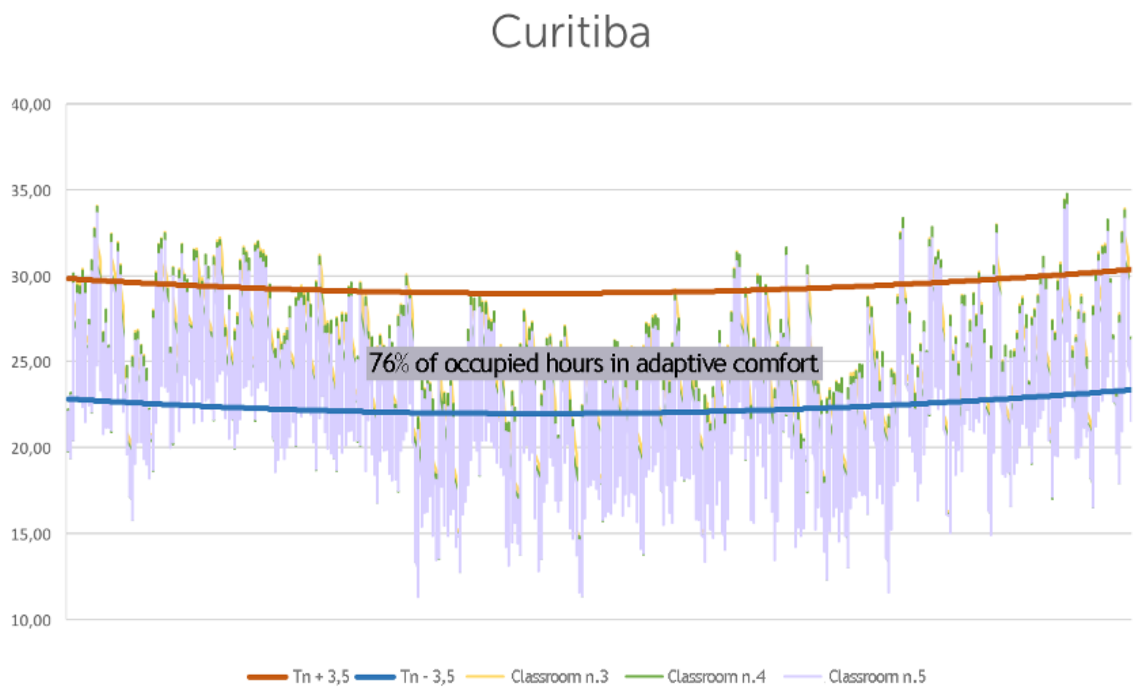

Fig. 1 Annual operating temperature profile for the city of Curitiba.

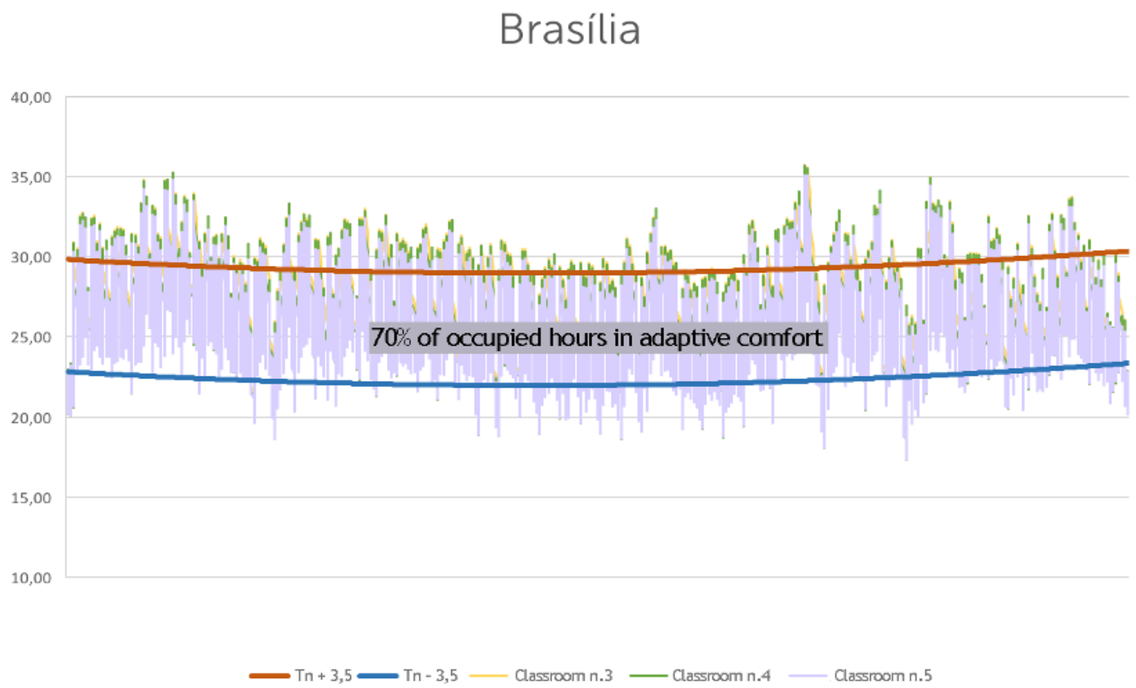

Fig. 2 Annual operating temperature profile for the city of Brasilia.

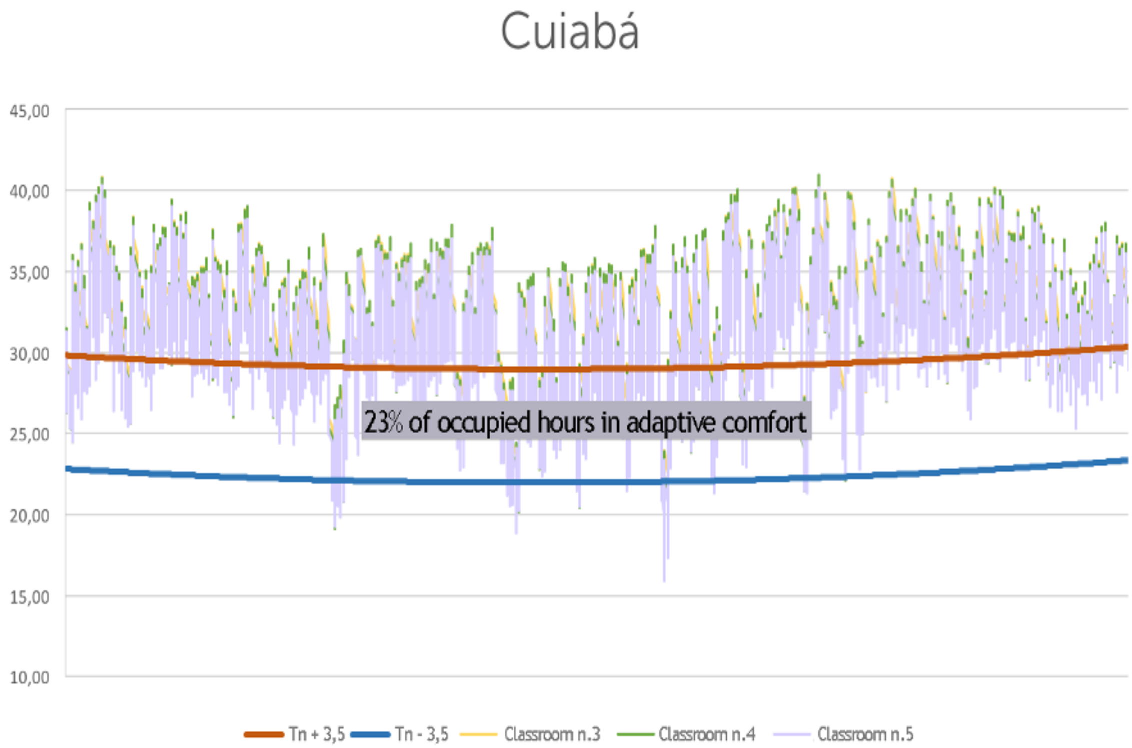

Fig. 3 Annual operating temperature profile for the city of Cuiabá.

For the city of Curitiba, there is a higher POC in comparession to the psychometric chart, with a POC od 76%. Once the primary design characteristics were considered, it is understood that the internal loads represented by the occupancy density and power density and equipment contribute significantly to the achievement of this result.

Differently, Cuiabá and Brasilia held results relatively similar to the data indicated by their psychometric charts. On the one hand, in Brasília the hottest hours do not differ considerably from the limits of adaptive comfort, and there is a smaller number of uncomfortable cold hours compared to the psychometric chart, with an overall POC of 70%. On the other hand, in Cuiabá only 23% of the hours occupied are within the adaptive comfort zone, and most of the year, there is expressed heat discomfort.

4. Conclusions

By diagnosing the comfort indices of the school rooms for each city analyzed, the study states essential differences in the necessary thermal comfort levels between the different climates, showing the importance of the design adapted to the place.

The article states that the use of computer simulation is one of the most effective ways to inform public policies regarding the differentiation of designs from bioclimatic zones. In this sense, future studies point to new analyses for other Brazilian cities, and it is recommended that a school building possibly could be monitored in one of the cities case studies of this article for data collection in a real situation. Futhermore, this article recommends that this method should be applied to another context, such as different cities and distinct typologies of buildings.

Ultimalely, the use of DesginBuilder software proves to be adequate. However, there is a lack of methods and protocols that guide adaptive thermal comfort analysis in tropical climates with the use of computer simulation, where the use of natural potential can be explored so well regarding the use of air conditioning.

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