Application of calibration's simplified methodology at computer simulation models in the CWA climate context

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ABSTRACT
Computer simulation tools assess environmental performance of designs from the earliest stages of a projects' life cycle. To achieve reliable readings, a preliminary step called calibration is recommended. This procedure requires a certain level of knowledge from professionals regarding thermal comfort and energy efficiency that will be required for input into the simulation software. The objective of this work is to verify the applicability of a simplified calibration methodology applied in the context of a CWA climate. As a case study, a small building located in Brasilia - Brazil was monitored during the dry period, using a digital data logger and the results were compared to a virtual model using DesignBuilder v5.0.0.137 and Energy Plus v8.0. The model calibration process consisted in changing the grounds' temperature and the thermal properties of materials, varying in -10%, 10% and 20%, in order to obtain readings equivalent to the actual buildings' performance. The results demonstrate that the softwares' algorithm produced simulated readings that were very similar to the data obtained from the monitoring of the real building. Moreover, the simulations showed that the version of the software does not recognize changes made to the input parameters related to the grounds' temperature and changes to the thermal properties of materials had little implications in the results.

KEYWORDS
Methodology, calibration, computer simulation.

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INTRODUCTION

Computer simulation allows the evaluation of the thermal-energetic performance of existing buildings, since it calculates the complex interrelationships between the building, the external environment and the buildings' systems (Trindade, Pedrini and Duarte, 2010). These tools enable the analysis of thermal performance of building components, energy efficiency, use of natural ventilation and the use of passive solar heating. (Pereira and Ghisi, 2010).

Despite the benefits from its use, computer simulation presents challenges for users that must be overcome. The complexity level of the configurations required to be input into the software and the degree of reliability of the output data often depend on the stage of the buildings' life cycle. Thus, the use of simulations to evaluate new buildings tend to be easier (Basurra, Jankovic & Hums, 2015), when compared to existing buildings, since it is difficult to identify all of the layers of constructive elements. In addition, limitations of the evidence of the physical performance of materials regarding their theoretical properties increase the degree of uncertainty (Basurra, Jankovic & Hums, 2015).

Lamberts (2005) and Oliveira *et al* (2012) point out that the understanding of the complexity of the physical phenomena and the variables that directly influence the thermal balance of buildings, require an in-depth interdisciplinary knowledge from the user.

Because of these barriers, computer simulation is rarely used by Brazilian designers in projects. However, to ensure adequate thermal-energetic performance of buildings, it is essential that tools and evaluation methodologies must be simplified to enable the dissemination of the practice in the professional ambience.

Regardless of the level of experience, Westphal and Lamberts (2010) consider that, for computer software to present reliable results, it is essential that the simulation model should be properly calibrated.

CALIBRATION AS A TOOL OF REDUCTION OF UNCERTAINTY LEVELS

Calibration is the comparison and approximation of performance data measured with those predicted by the software, in order to reduce the performance gap. This process should be conducted as a pre-established methodology to help identify, in each simulation, tweaking responsible for the variation of the outputs. Variables such as the fonts to be used, as well as the provision of the measuring period to be held, imply in the quality of the process and are considered critical by many researchers such as Sansregre and Lavigne (2015).

The level of calibration depends on the relevance of the process for the project, as well as on the availability of data, considering the different sources of data that can be evaluated: on-site information, measurements, user feedback, etc. In this sense, these would be most relevant measurement data as well as short duration measurements (Christantoni, 2015).

As previously explored, calibration depends considerably on the users experience level and some presumptions. Thus, the user's part is of high importance during the process, having a direct impact on the accuracy of the virtual model and the required calibration time (Monetti *et al*, 2015).

In this scenario, experts are able to recognize those inputs that generate greater variations in the results, since this working method requires an important period of time that sometimes implies in the limitation of the use of simulation software as a design tool (Lamberts, 2005). Monetti *et al* (2015) point out that the working methodology based on trial and error is the most widespread amongst professionals.
Oliveira *et al* (2012), Sorgato (2009) and Pereira (2009) emphasize the influence of the grounds temperature as an input for the simulation of single-storey buildings, since heat exchange between the floor and the ground are determining for the final outcome results.

Venancio (2009) suggests the inclusion of ground temperature data from the monthly averages for usage in simulation softwares. Researchers such as Sorgato (2009) suggest that the grounds temperature should be determined with the aid of softwares such as Slab*,* linked to EnergyPlus. This is due to the fact that the data obtained by the software is closer to the grounds temperatures measured at the site, compared to the monthly average temperatures of the climate file.

OBJECTIVE

The objective of the study is to calibrate a virtual model of an existing building, aiming to approximate the temperature readings with the simulation outputs. To this end, it is proposed to use a simplified method of calibration that is appropriate for professionals who do not have a deep theoretical understanding of thermal variables and softwares used in simulations. Two approaches are proposed: changes to the thermal properties of materials and grounds' temperature settings.

For the calibration model, Lamberts *et al* (2010) suggest that the calibration simulations are to be carried out by changing the thermal resistance of all construction components by -10%, 10% and 20%, which was applied in this study.

The simplified calibration, considering the systematic modification of the grounds' temperature will be explored by using the default values set in the software as a starting point.

RESEARCH OBJECT

The object of this study is a small 25m² building *(Figure 1),* built using traditional materials of the Brazilian construction industry – a wall structure of ceramic blocks and a beam-and-block floor with ceramic blocks. The building is located rear end of the plot, surrounded by vegetation characterized by tall adult species, varying between 15 to 20 meters. The proximity of the plot to the lake and the existence of dense and large vegetation, in addition to the spacing between the existing buildings on site that favor ventilation, allow the creation of a microclimate in the area.

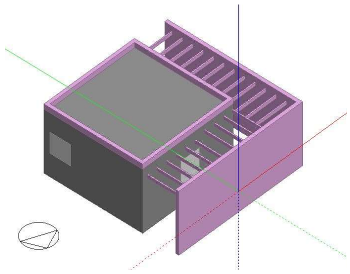

Figure 1. *Image of the computational model produced in DesignBuilder*

DATA COLLECTION

The collection of temperature data occurred within 30-minute intervals using a calibrated digital data logger, model Instrutherm HT-180, for a period of 20 days. The equipment was installed in the center of the room at 1.50m above the ground. The openings were closed and there was no movement of people throughout the period.

The buildings' modelling was performed using the DesignBuilder v5.0.0.137 and EnergyPlus v8.5 software, setting the construction materials as verified on site. The floor material was set as *"Project ground floor."*

It was observed that in the afternoon, the buildings' indoor temperature is greatly influenced by vegetation, which causes complete shading by 16 o'clock. Thus, we chose to use the data collected in the morning for the calibration of the model. Meteorological information was obtained form the National Institute of Meteorology (INMET) monitoring station, and used to compare the outdoor temperature and the temperatures provided by the climate file BRA_DF_Brasilia.867150_INMET. The information was filtered to cover the period between the 7th and 15th of July, from 6:00h to 16:00h.

Given the period to be analyzed, the information obtained from the measurement on site was compared with those of the simulation, based on the default ground temperature (14°C). Then, scenarios were simulated with ground temperatures considering the measured average and the outdoor temperatures' average. Subsequently, the softwares' default ground temperature, materials settings were tweaked by -10%, 10% and 20% regarding their thermal resistances.

RESULTS

The results obtained from the simulations showed that the change of the grounds' *Deep/Shallow Monthly Temperatures* parameters did not cause significant variation in the operating temperature of the simulated model *(Figure 2).* The result that was nearest to the measurements was that regarding day 12 *(Figure 3)* while the most dissonant result was day 9 *(Figure 4)*.

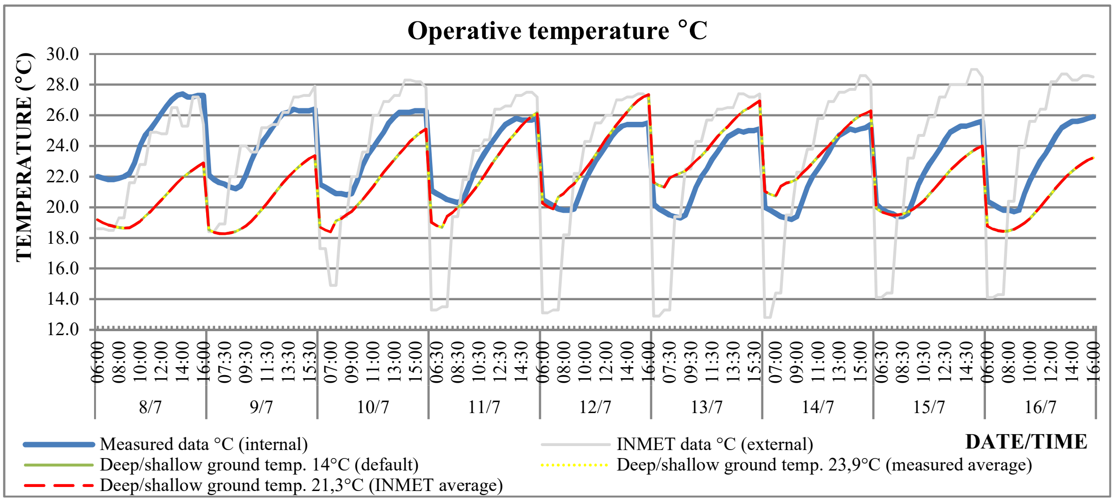

Figure 2. *Operating temperature for the different ground temperatures*

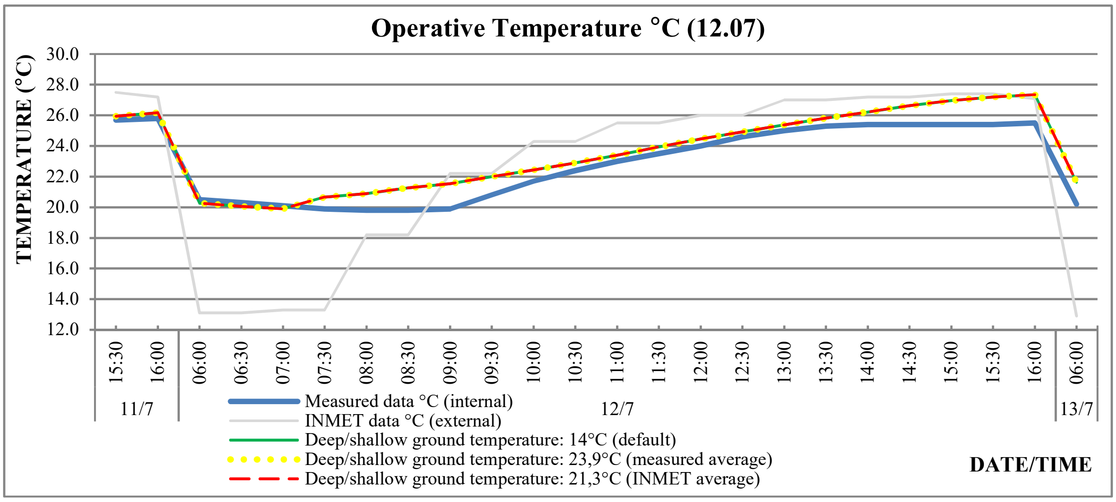

Figure 3. *Day of the most converging data for ground temperature*

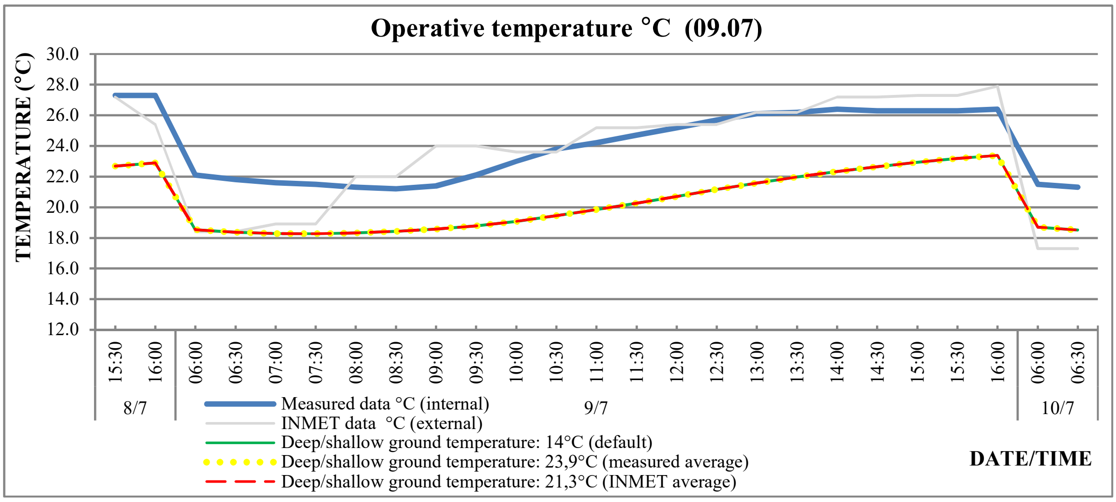

Figure 4. *Day of the most divergent data for ground temperature*

By comparing the temperature data obtained from the measurements with the temperature of the simulated model for different ground temperatures, it is evident that the simulation results present the largest differences in the first and last days while in the intervening days the results were closer.

The simulation results showed that changes in the materials thermal resistance properties as recommended by Westphal and Lamberts (2010) also did not cause significant variations in the operating temperature of the simulated model *(Figure 5*). The result with the closest measurements was the 9th day (*Figure 6*) while the most dissonant result was the 12th (*Figure 7*).

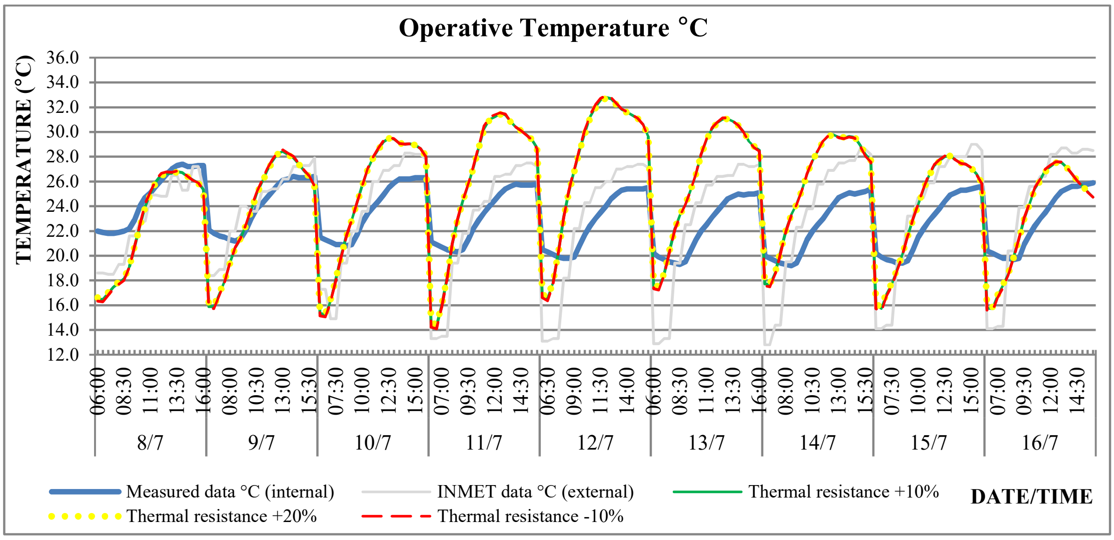

Figure 5. *Operating temperature for different thermal resistance of materials*

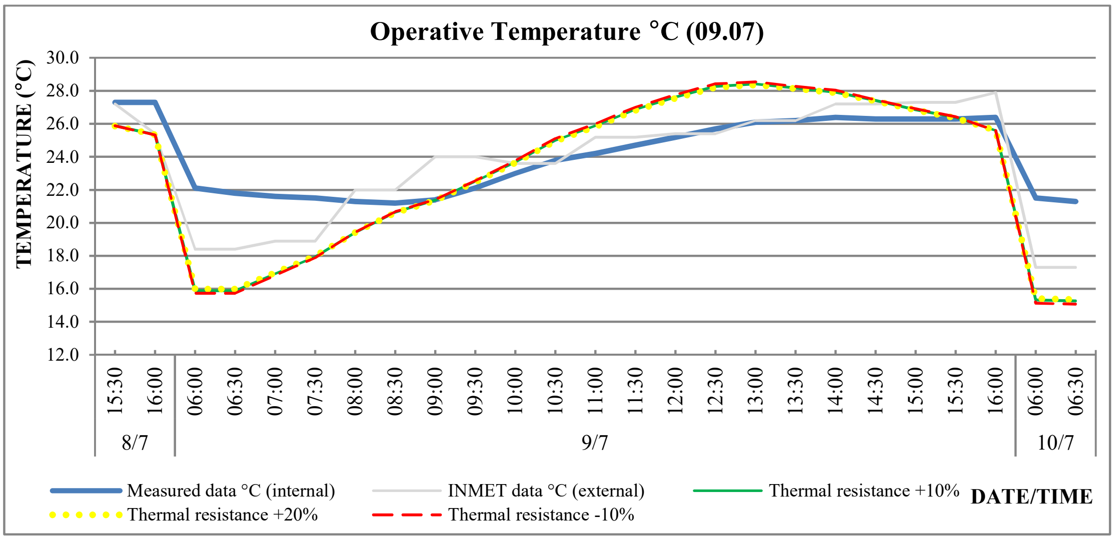

Figure 6. *Day of the most converging results for thermal resistance of materials*

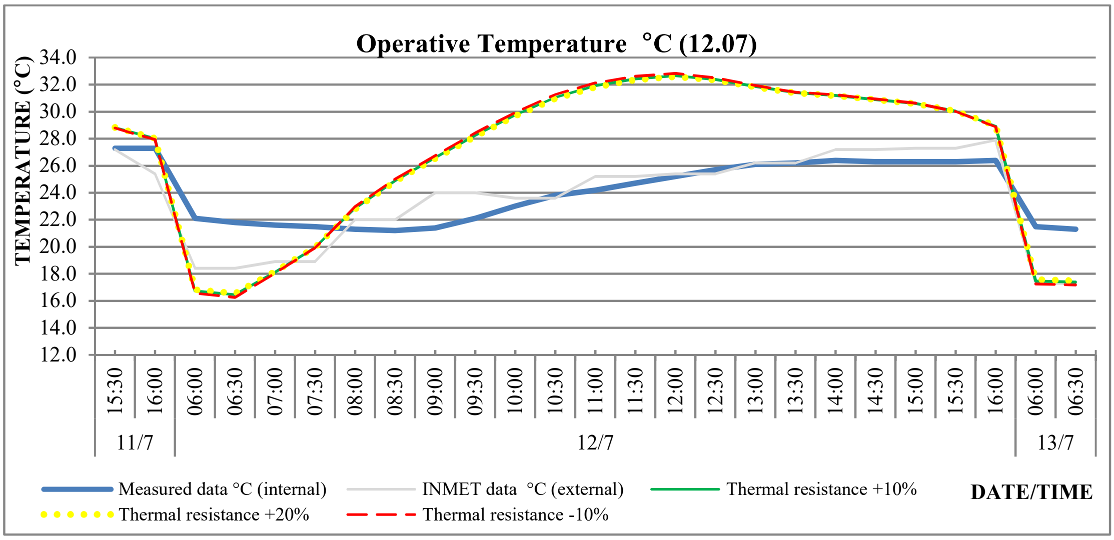

Figure 7. *Day of the most diverging results for thermal resistance of materials*

Changes made in the materials' thermal resistance parameters presented closer results of the simulation/ measurements data in the early days while in last days the results showed major differences.

CONCLUSION AND IMPLICATIONS

The results demonstrate that the softwares' algorithm generates very close results to the data obtained with the real model. The simulated model also points out that the software does not recognize changes made to parameters related to the grounds' temperature. Changes to the thermal properties of materials had little significant effect on the reported results.

Changes in the inputs of the virtual building presented no impact on operating temperatures, with data showing minimal changes, which in turn voided the calibration methodology initially proposed.

In the construction of this paper, some limitations were observed that may have interfered in some way in the final result. The first restraint concerns to the great period of shading that occurs from 2 p.m. to 4 p.m., affecting the entire building, specially considering that the afternoon period is the most critical for rising temperatures. The time interval used for the calibration exercise (from 6 a.m. to 4 p.m.) does not have such a significant temperature range (with shading from 2 p.m) compared to an entire day of solar radiation. This in turn led to greater difficulty to analyze the data regarding different scenarios, which presented small variations.

It is likely that, had the measurements occurred in September, which is considered a critical period for the region, presenting higher and larger temperature variations, differences in the simulated scenarios could have been more evident. Another point concerns the impossibility of modeling large masses of vegetation, and its actual interference on shading, using the chosen simulation software.

For future works it is indicated researching alternatives to simulate the impact of vegetation on buildings, since it is a common scenario to be found in the built environment. With this barrier overcome, it will be possible to test the assumptions previously made. Also it is indicated to run simulations and measurements during the month of September, considered the most critical period of the year.

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