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ANALYSIS OF ENERGYPLUS DAYLIGHTING MODULE RESULTS – A BRAZILIAN CASE

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ABSTRACT

This article aims to discuss the results of the EnergyPlus daylighting module – Detailed. Because of the program relevance among the brazilian researchers and the high potential for daylighting in Brazil, it is important to evaluate whether their models for calculating daylighting are appropriate for the brazilian conditions. EnergyPlus results were compared with data measured in situ, of daylit room with windows on two parallel façades. The simulation results show weak correlation between the model output and the measured data. The illuminance levels and distribution obtained in simulations were not consistent with the measured values.

INTRODUCTION

Nowadays, the thermal and energetic building performance prediction is an ordinary task because of the simulations programs. These kind of tools are very helpful because the evaluation become more precise and faster. In Brazil the most used program is EnergyPLus, developed by The Department of Energy, USA. There are a notable ~~numbers~~ of researches investigating and using this software in Brazil. Frequently they focus in thermal questions like air conditioning system behaviour, heat transfer properties, etc. However, we could find no studies in Brazil that investigate EnergyPlus potential for daylighting and electric lighting analysis and prediction. This paper therefore aims to understand the detailed daylighting module, behaviour against measured data andis part of a more extensive research cariewd ou in the Architectural School of Federal University of Minas. The main goal is develop a reliable methodology capable to reach the real potential for illumination integration and energy consumption in a country with high external illuminance levels. This article presents the first results of that research. It contains a comparison between measured and simulated data.

Discussion about validation of the model is not treated here. The focus is to evaluate the simulated outputs. The model configuration will not be adressed in this paper, as futher study is needed in this question.

Brazilian Energy Consumption in Commercial Building

The average disaggregated energy consumption in brazilian commercial building presents the profile below (figure 1). Almost one quarter of the electricity is used to artificial lighting. This percentage can be considered high because this kind of building functions mainly during the day in a country with great daylighting availability.

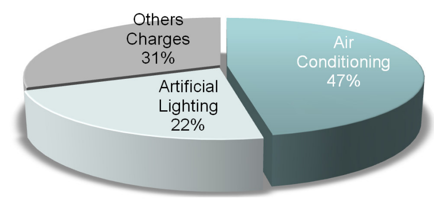

Figure 1 –Disaggregates energy consumption in commercial buildings.

On the other hand, the electric lighting can be responsible for up to 57% of the electricity consumption in commercial buildings, as shown in the figure 2. The difference in the final use of energy of the buildings shown in this figure is mainly related with the building characteristics and localization and tipology (*R. Lamberts, A.C. Mascarenhas, et AL, 1997)*. In general, is possible to identify the electric lighting as an important consumer and hopeful prospector of consumption reduction.

Concentrated efforts in this variable can contribute in improvements of buildings energy performance. The energy building simulation may help this task. Nevertheless, it is fundamental to know the programs outputs potential.

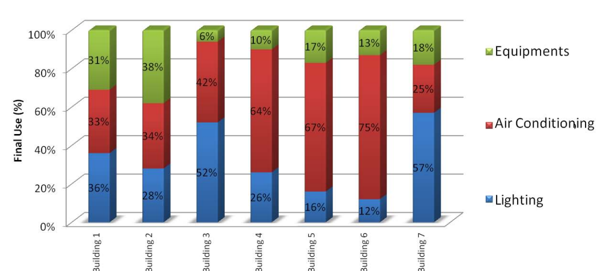

Figure 2 – Disaggregated energy consumption in seven commercial buildings.Source: L.L.B. Lomardo, R. Lamberts, A.C. Mascarenhas, et AL, 1997.

Main Aims

This article proposes to evaluate, separately, daylighting outputs of EnergyPlus. It is relevant because the daylighting data is used to calculate others important variables (outputs) as internal heat, energy consumption, economic evaluation, etc.

For this analysis the simulated output was compared with measured data. The measurements were made in August 2005 and the simulation was made using the EnergyPlus Version 2.2.

This comparison will allow a discussion about the best way to use this program to evaluate the potential of daylight and electric light integration in brazilian commercial buildings.

THE STUDY CASE – CPEI BUILDING

The measurement occurred in the Intelligent Energy Research Centre – CPEI. It is located in Belo Horizonte, Brazil. The figure 3 shows the position of Belo Horizonte and the localization of the building in the west zone of the city. The average altitude is 852,2 meters, the latitude is 19°46’35’’south and the longitude is 44°03’47’’west.

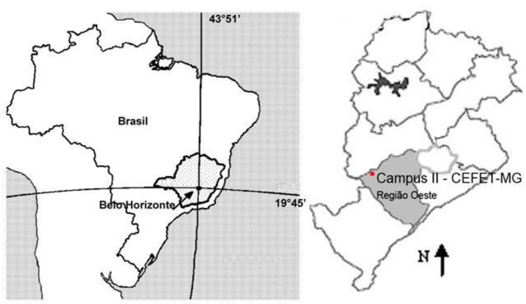

Figure 3 –Belo Horizonte and CPEI localization

According to Köppen climatic classification, the weather in Belo Horizonte is Aw – Savanna Tropical. It presents a long dry season in winter (April to September) and wet periods in the summer time. Climatologic data shows maximum temperature around 30°C in the summer and minimum mean temperature of 14°C in the winter. During the year, the average temperature varies between 18°C and 24°C. The main wind direction is east and the air velocity average oscillates between 0,5m/s and 2m/s. (INMET, 1992).

The CPEI is situated in a wooded and permeable soil area (see figure 4). The terrain is located in an urban area, where the ocupation density is not so high as the city center but is not too low as suburban. Figure 5 shows the image of CPEI building. The façades B1 and B2 belong to studied room.

The figure 6 presents the first floor plant. The grey region is the reseachers room. This area, choosen to the study area, has 58,3m² and 10 workstations with computers.

Figure 4 – Building around

Figure 5 – Façades: B1 North-Northeast and B2West-Nothrwest.

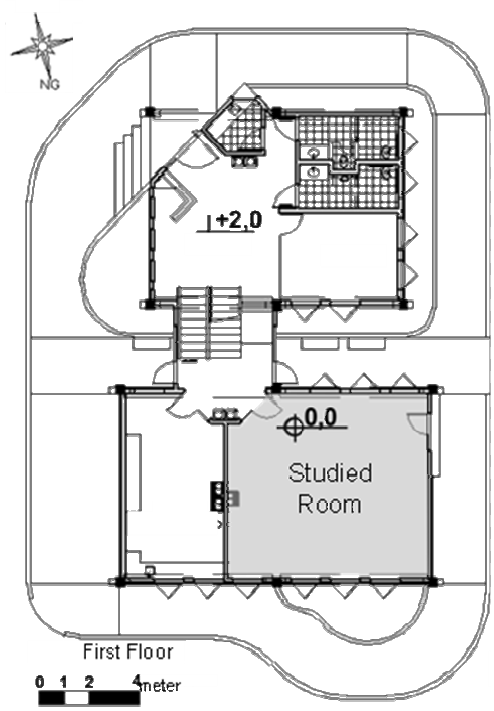

Figure 6 - First Floor Plant

There are four windows in the North-Northeast façade (8,64m²) and three in the South-Southeast (6,48m²). The internal walls are made of 15mm mortar painted in a "sand" color. The window frames are made in steel and painted dark green. The ceiling is painted white and the floor is grey.

The figure 7 below, shows the layout of the room and also the electric lighting circuits layout. The lighting fixtures are parallel with the windows façades.

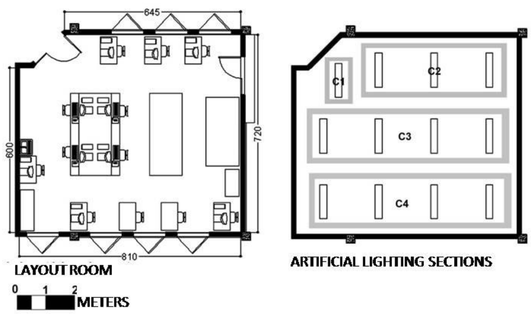

Figure 7 – Layout and electric lighting circuit.

METODOLOGY

The methodology is presented in two parts. The first is about the measurements and the second about the simulations.

Measurement

The measurements were taken continuously during two weekends in August 2005 (06, 07, 14 and 15). This procedure garanteed that there was nobody using the room during the measurements. Data from 12:00 o'clock will be analysed in this paper.

The internal arrangement of the measurement equipments was composed by nine photometers and one datalogger, both of them produced by LI-COR. The datalogger LI-1400 has three current channel inputs for LI_COR photometers. To get others inputs was necessary to connect an external plate with another current channel inputs (two inputs) and voltage channel inputs (4 inputs). Resistors were used to convert the voltage output into current outputs.

Data was read every 30 seconds and its arithmetic average of was recorded every 5 minutes. The figure 8 below shows the photometer and the datalogger.

Figura 8 – Fotometer and datalogger.

Table 1
Photometer characteristics

Absolute calibration	± 5%
Sensitivity	30µA per 100kLux
Linearity	1%*
Stability	<± 2% per year
Time Constant	10 µS
Operation temperature	-20 to 65 ° C
Relative humidity	0 to 100%

The ABNT 15215-4 – Experimental verification of natural internal ilumination in buildings – oriented the sensors positions. The data registration was taken simultaneously for the nine photometric sensosrs. All of the sensors were, at least, 50 centimeters from the walls and 80 centimeters high. The figure 9 shows the measurement points. They were distributed according to workstaion positions. The photometers connected to the voltage channel were located on places screened from solar beam radiation, because the resitors were calculated for a maximum voltage equivalent to 5 kLux.

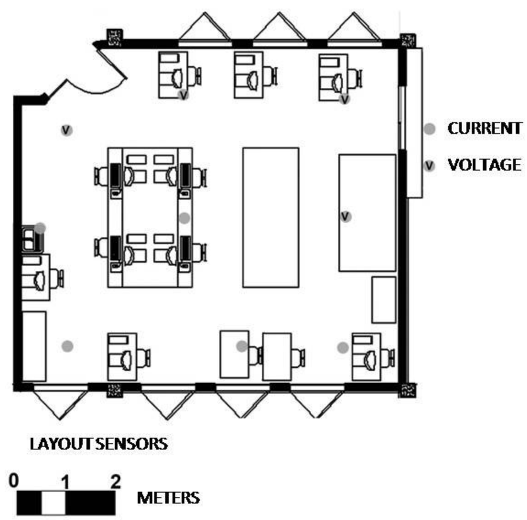

Figura 9 – Fotometers positions.

Sensor were new and calibrated from the factory, so their original multiplier were used with the current channels. New multiplier values were found to the sensosrs connected to the voltage channnels according to the resistors used.

Two external glass doors were covered with canvases in order to avoid daylight interference in the measurements.

Simulation

The first step of the second part – Simulation – was to prepare the weatherfile for EnergyPlus program. The weather data used was measured in three diferent weather stations. The WMO default station of Belo Horizonte – 5° Meteologial District – supplied the nebulisity, wet bulb temperature, atmosferic pression and precipitation; the automatic weather station located outside the building supplied dry bulb temperature, relative humidity, wind velocity and direction; and informations about horizontal radiation (beam, diffuse and global) were recieved from CDTN (Nuclear Technology Development Centre) meteorological station. The weather file is composed for the data of the measured days.

The general caracteristcs of building simulation file are presented in table 2 below. And the figure 8 shows the building model.

Table 2

General configurations of building location and simulations parameters.

Version	2.2.0
North Axis {deg}	330
Terrain	Urban
Solar distribution	Full interior and exterior with reflections
Inside convection algorithm	Detailed
Outside convection algorithm	Detailed
Solution algorithm	CTF

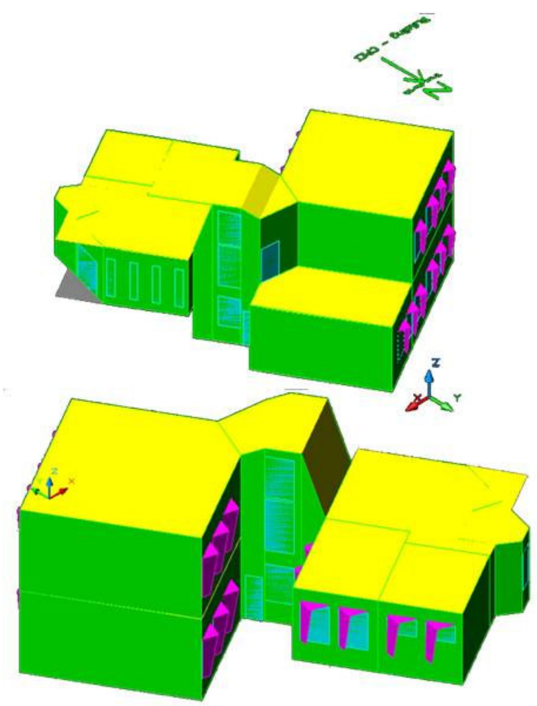

Figure 8– EnergyPlus Model.

The calculation model for internal illuminance chosen was the DAYLIGHTING: DETAILED. This is a method of analyzing daylighting from windows, skylights and complex fenestration. According to the EnergyPlus Manual, the Detailed daylighting calculation methods are derived from the daylighting calculations in DOE-2.1E and Superlite, with several key modifications (DOE, 2008). The equations are presented in the engineering documentation of EnergyPlus. Briefly, DETAILED calculates the interior daylighting illuminance at user specified reference points and then determines how much electric lighting can be reduced while still achieving a combined daylighting and electric lighting illuminance target. The results of daylight illuminance levels in a zone depends on many factors: exterior light sources, location, size, and visible light transmittance of simple and complex fenestration systems, reflectance of interior surfaces and location of reference points. The subsequent reduction of electric lighting depends on daylight illuminance level, design illuminance set point, fraction of zone controlled by reference point, and type of lighting control (DOE, 2008).

In the present study the reduction of electric lighting output was not requested as it was not the focal point of the analysis carried out. The input parameters are presented in tables 3 and 4.

Table 3

Daylighting parameters – Model DETAILED

Total Daylighting Reference Points	2
X-coordinate of first reference point {m}	8.5
Y-coordinate of first reference point {m}	2.4
Z-coordinate of first reference point {m}	0.8
X-coordinate of second reference point {m}	8.5
Y-coordinate of second reference point {m}	4.8
Z-coordinate of second reference point {m}	0.8
Fraction of zone controlled by first reference point	0.65
Fraction of zone controlled by second reference point	0.35
Illuminance set point at first reference point {lux}	5
Illuminance set point at second reference point {lux}	5
Azimuth angle of view direction clockwise from zone y-axis (for glare calculation) {deg}	90

Table 4

Illuminance map parameters

Z height {m}	0.8
X minimum coordinate {m}	0.75
X maximum coordinate {m}	7.25
Number of X grid points	3
Y minimum coordinate {m}	0.75
Y maximum coordinate {m}	7.75
Number of Y grid points	3

The datalogger outputs were converted in hourly data because the simulation outputs had this same timestep. Both outputs (measured and simulated) were used to created isoline graphics.

RESULTS

Before laying out the results, it is important to discuss some experiments realized to test the EnergyPlus outputs. The position of reference points and the impact of brise soleil in internal illumination were tested. In a first analysis some simulations with different reference points were made. And the outputs show that their position has no interference in the results. The other band test proved the model can identify attached solar protection. The illuminance levels were higher when the simulation model presented no solar protection. The geometry of the *brise soleil* is quit complex. And cause of this we suppose that the program can get along with this kind of simulation.

The outputs – measured and simulated - are presented in table 5. The analysis is focus one time: 12:00 o'clock. These data are also plotted in the isolux curves graphics. One of the measured set of data could not be considered because the photometric sensor had tribological problems during the experiment.

Table 5
Outputs data

Day	Measurement			Simulation		
06/08	264	226	149	1889	1329	1329
	2540	1292	315	2192	1574	1329
	1249	*	531	1329	1329	1329
07/08	256	198	139	1886	1329	1329
	3682	984	303	2187	1573	1329
	1096	*	498	1329	1329	1329
14/08	223	216	129	1869	1259	1259
	1035	1194	285	2030	1488	1259
	775	*	546	1259	1259	1259
15/08	216	197	122	1983	1338	1338
	861	977	272	2152	1579	1338
	616	*	504	1338	1338	1338

The same output configuration is presented in those tests and in all simulation results. The interpolation mesh has nine points but six of those points had always presented the same values. The EnergyPlus manual does not explain why daylighting is calculated in such a way. The obtained results suggest there is a limitation in the interpolation method.

All the days measured presented a similar daylight distribution behavior. The daylight distribution is coherent but the values show the illuminance doesn't offer light uniformity in the room although there are transparent surfaces in two parallel façades. The illuminance levels reduced in direction of the South – Southeast façade. There are three main reasons: the building form, the façade orientation and the inefficiency of the solar protection devices. In figure 9 there are crosswise lines in the studied room following the second line of measurement, thus show the difference of illuminance level in both window façades.

Plotting also the simulated data in the crosswise line graphics, we can see two significant variations.

The first is the illuminance level between simulated and measured data. Comparing all analyzed days, we can find weak correlation. The isolux curves graphics present the same results for completely room. The EnergyPlus simulation couldn't reproduce the level of beam radiation inside de room.

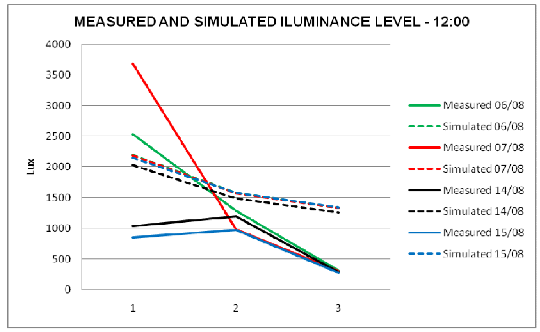

Figure 9 – Crosswise line – 12:00 o'clock

The second variation observed in the crosswise line graphics is about the decrease of the illuminance level for measured and simulated data. The simulated data present smaller difference between façades than measured data.

Continuing the evaluation of the daylighting distribution in the room, we calculated the diversity index obtained from the ratio between the maximum illuminance and minimum illuminance. Below are presented the classification and the results for measured and simulated data.

Table 6
Diversity Index Classification

Value	Concept
1,0 to 3,0	great
3,1 to 5,0	good
5,1 to 10,0	acceptable
>10,1	inadequate

Source: Souza, 2004.

Table 7
Diversity Index Analysis

Measured	6/ago	7/ago	14/ago	15/ago
12:00	17,05	26,49	8,02	7,06
Simulated	6/ago	7/ago	14/ago	15/ago
12:00	1,65	1,65	1,61	1,61

All values obtained from simulated data can be considered great. In despite of it, the diversity index from measured data presented the classification different. Two values are considered acceptable and others are considered inadequate.

The illuminance level analysis and classification was made based on the table presented in Souza (2004). Comparing the illuminance level in room, according simulated and measured data, the situation is similar as observed in diversity index.

Table 8
Illuminance Level Analysis

Criteria	Concept
Illuminance < 300 lux	Insufficient
Illuminance 300 to 1000 lux	Suitable
Illuminance 1000 to 2000 lux	Great
Illuminance 2000 to 3000 lux	Admissible
Illuminance > 3000 lux	Excessive

Source: Souza, 2004

Analyzing the figure 10, we note the simulated data are classified as great, although the measured data get the variance. The room has areas with a great illuminance level and others without enough daylighting. According the simulated data, isn't necessary to use electric lighting in this room because the illuminance level is higher than 500lux. Therefore, energy consumption can be under estimated, causing an error in building performance analysis. This inaccuracy is severity, because the measured illuminance level proved the room doesn't offer adequate visual comfort conditions for work.

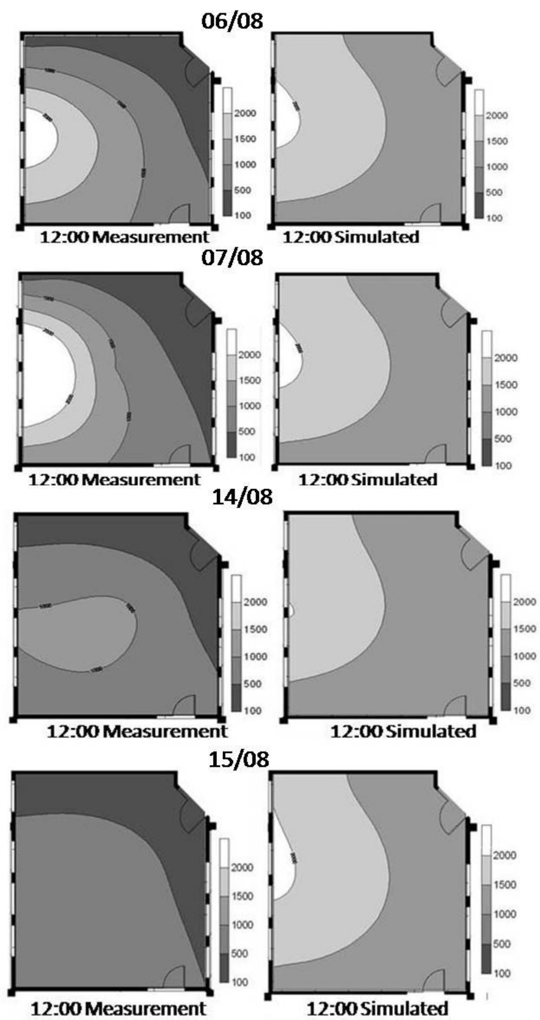

Figure 10 – Isolux Curves Graphic

CONCLUSION

It is previous to find deviations between measured and simulated data because of the characteristics of the light phenomenon. But, by the given results one can infer that the daylight output of Energy Plus is of little reliance, smaller than expected. The illuminance levels and distribution in the simulation present no correspondence with measured data. The only agreement between the measured and simulated data is the decrease of the illumination levels near the South-Southeast façade.

These results found would present a significant impact in the energy consumption because the simulated illuminance level can be considered enough to the activity that happens in this room.

This article shows that the EnergyPlus module DAYLIGHTING: DETAILED must be improved to get more fidelity with real light levels and distribution. But is important to emphasize this program is a wide and appropriate tool to energetic building performance evaluation. While there is no further development of the daylighting tools, it is important for the simulator to know the limitations of the program, so it can be better used and the results better understood.

The aim of this article was reached. It was able to analyses the capacity of EnergyPlus to reproduce daylighting. The work will be continuing. It is important to understand how to use the program faithfully, despite this limitation.

ACKNOWLEDGEMENTS

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