ANALYSIS OF THE MICROCLIMATE OF SÃO CRISTÓVÃO AND ITS INFLUENCE IN HEATING SYSTEMS, VENTILATING AND AIR CONDITIONING (HVAC)

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Abstract. Design heating, ventilation and air conditioning (HVAC) standards as ASHRAE and ANBT NBR 16401 supply only one climatic data for almost all cities listed, collected from meteorological stations located in the airports. In Rio de Janeiro, both airports are located next to the sea. It is well known that urban areas are characterized by different microclimates and the formation of heat islands, with an increase in air temperature compared to the areas of low occupancy or rural. As soon as the cost of automated meteorological stations have decreased, more suitable climatic data have become available. On the other hand, HVAC designer use commercial software for thermal load calculation where it is comfortable to pre-select climatic data ready available, usually that mentioned in the design standards. This paper aims at evaluating the effect of using meteorological data from the Santos Dumont Airport instead of the closest climatic data on the thermal load calculation of a building placed in São Cristóvão neighborhood. After choosing the design criteria and calculating the typical design day the differences in the thermal load results were analyzed.

Keywords: Heating, Ventilation, Air-Conditioning and Weather data

1. INTRODUCTION

The metropolitan region of Rio de Janeiro has a high population density and a very high degree of industrialization, and as a consequence a large concentration of pollutant emissions and heat sources. Its topographic and atmospheric peculiarities directly affect the dispersion of air pollutants and heat. Furthermore, the land use characteristics of the region with a high percentage of areas covered with asphalt and concrete are able to convert and store solar radiation into a greater extent than rural areas, promoting the onset of a horizontal temperature gradient phenomenon known as the urban heat island (Stull, 1993).

This manuscript aims to investigate the influence of urban microclimate on air conditioning designs through using climatic data from the closest meteorological station instead of those recommended by the Brazilian air conditioning design standard ABNT NBR16401. For the city of Rio de Janeiro, this standard provides climatic data from Antônio Carlos Jobim International and Santos Dumont Airports. Both are located next to the sea, so it can be supposed that they are less impacted by the urban heating.

2. MATERIAIS AND METHODS

The plant of the building used for study case is shown in Figure 1. The building has an area of 120m² and it is internally divided into administrative room, reception, security room, circulation area, information technology room, dining room and bathrooms. It is placed in the São Cristóvão neighborhood, and for this investigation, strategically located where there is a meteorological station. Figure 2 presents a map showing that it is far respectively, 6 km and 10 km, from the Santos Dumont and Antonio Carlos Jobim airports. These distances were approximately measured through straight lines using a specific tool available in the Google Maps. For any place in the Rio de Janeiro city, there is no indication in the NBR 16401 about what climatic data must be chosen. It is well known that air conditioning designers adopt the highest temperature data.

The NBR 16401 says that weather data for Santos Dumont and Antonio Carlos Jobim airports were obtained through the processing of climatic data, respectively from 1984 to 2001 and from 1982 to 2001.

The São Cristóvão meteorological station belongs to the Fundação Instituto de Geotécnica (Geo-Rio), within the Rio de Janeiro's City Hall, a department created for monitoring the rainfall in order to warn the population about risks of slope slips. It is located at the latitude of -22.896667, the longitude of -43.221667 and an elevation of 25 meters, on the top of the Geo-Rio building. This station measures and records temperature, humidity, pressure, rainfall and wind speed at 15 minute intervals. It has supplied access to download data since 2002, but the period used here is from 2003 to 2015(Alerta Rio, 2016).
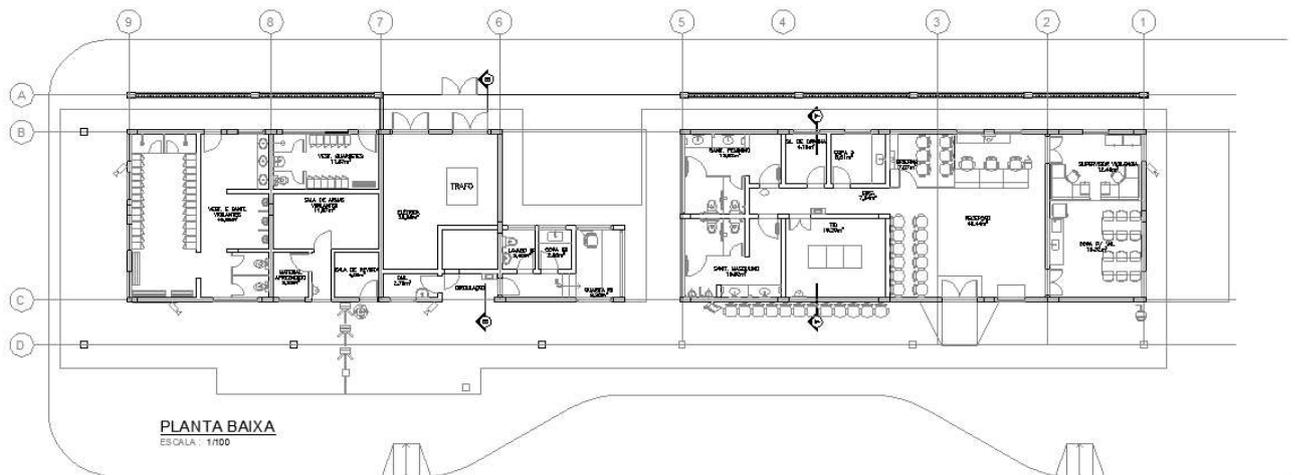
figure1.

São Cristóvão climatic data must be processed following a methodology defined by ASHRAE (2013) in order to generate a climatic data table similar to those available in the NBR 16401. It requires an extensive database obtained by direct measurement of several variables, hourly, over a period of at least eight.
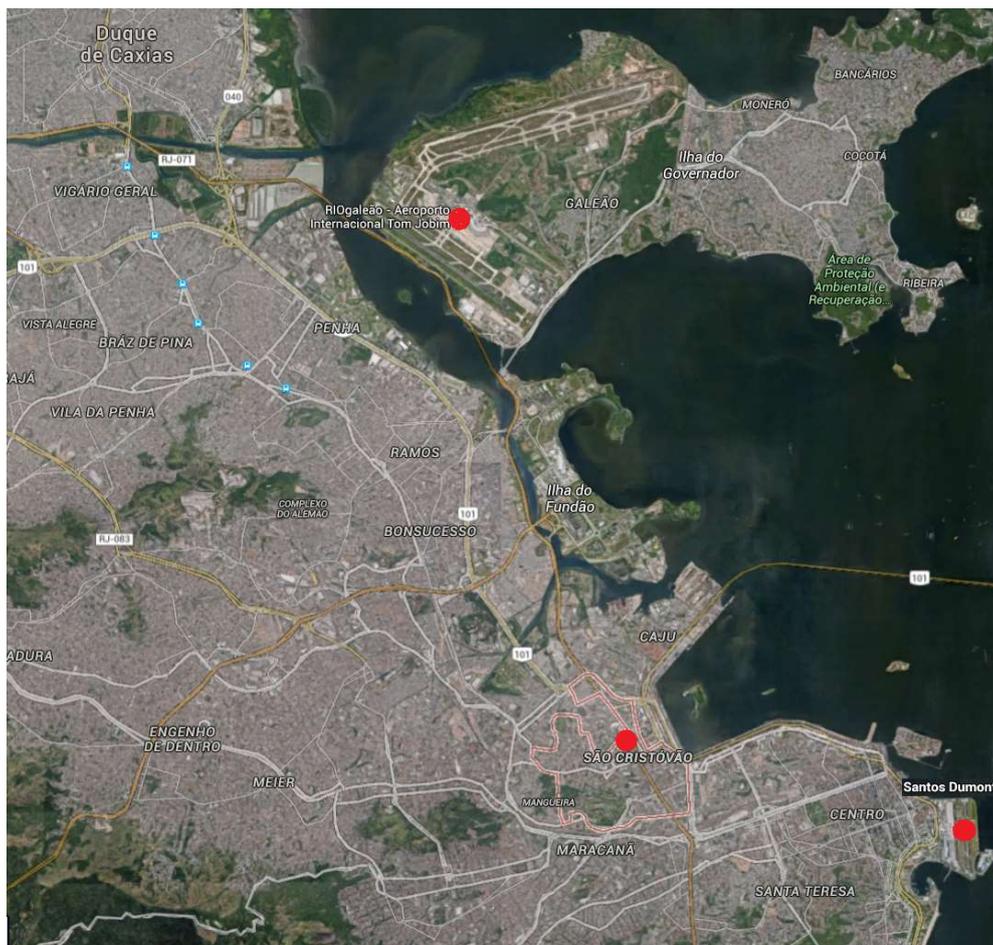

Figure2. Map with the three places by Google Maps

Among the data required is the design temperature, which for conventional cooling designs is the dry bulb temperature (DBT). This is achieved by arranging the data stored in the measurement frequency vectors, and calculating the temperature which is only equaled or exceeded by a specific percentage of the total number of times of the year. The percentages correspond to desired frequency levels (ASHRAE, 2013). The coincident wet bulb temperature (CWBT) is obtained by arranging the stored data in frequency matrices by averaging the wet bulb temperatures that occur along with the calculated DBT (ASHRAE, 2013).

The dry bulb temperature, dew point (DPT) and wet bulb temperature and wind speed corresponding to different annual percentage representing the value that is exceeded on average by the percentage indicated the total number of hours per year (8760h). The 0.4%, 1.0% and 2.0% are exceeded, on average, 35h, 88h, 175h per year, respectively, for the record period. (ASHRAE, 2013).

Meteorological data sets used for the calculations may contain missing values. Gaps up to 6 hours were filled by linear interpolation to provide the most complete possible time series. When the data at the right time are lacking, they can be replaced by data up to 0.5 hours before or after, when available (ASHRAE, 2013).

Steps have been taken to ensure that the number and distribution of data missing not introduce significant deviations in the analysis. The number of dry bulb temperature values each hour for the month, after filling by interpolation must be at least 85% of the total hours for the month and the difference between the number of temperature data observed between day and night should be less than 60 (ASHRAE, 2013).

Some months were also eliminated during the additional quality control checks. The dry bulb temperature of a station will only be used for design calculation if there was data from at least eight months that met the quality control and selection criteria from the registration period for each month of the year. For example, we must have at least eight months of January, February, March, April, May, June, July, August, September, October, November and December (ASHRAE, 2013).

Microsoft Excel was used for data processing. Downloaded climatic data are formatted with columns corresponding to climatic variables and lines to time. Only DBT, relative humidity and pressure columns were maintained, all other columns were deleted. Then, the lines corresponding to fifteen, thirty and forty five minutes were also eliminated. The lacking of DBT data was searched, and when found, data were fulfilled with the closest available, within a thirty minute interval. If not also available, data were completed using linear interpolation up to 6 hours, otherwise they have remained as DBT blank data, those must be not taken into account in the subsequent data processing. Months with lesser than 85% of the total DBT data were eliminated. So, DBT data were arranged in ascending order to find the DBTs that correspond to the frequency levels of 0.4%, 1.0% and 2.0%. Finally, the coincident relative humidity and pressure values were determined as the average ones. CWBT and DPT were read in a psychrometric chart.

The same building was used for all three cases in order to evaluate the influence of the climatic data on the thermal load calculation. The thermal load was calculated for 0.4%, 1.0% and 2.0% temperature frequency levels, as established by NBR 16401 for cooling and dehumidification designs.

Due to the complexity of the thermal load calculations, since they should take into account the simultaneity occurrence of all sources of heat loads as well as the dynamic effect of the building mass, it was necessary to use the software Energy Plus, developed by the U.S. Department of Energy Building Technologies Office. The input data in the program are DBT, wet bulb temperature, relative humidity, DPT, pressure, latitude, longitude, altitude and the mean daily temperature difference in the hottest month.

3.   RESULTS

Table 1 presents DBT, CWBT and DPT at the three frequency levels for the Santos Dumont and Antônio Carlos Jobim airports reproduced from the NBR 16401 and also those generated for São Cristóvão. The DBT for São Cristóvão was approximately a mean value between the others, accomplishing its geographical location. On the other hand, both CWBT and DBT for São Cristóvão were the lowest for all frequency levels. This was expected since São Cristóvão is more far from the sea than other stations.

Figures 3, 4 and 5 show DBT, DPT and CWBT plots at the frequency levels of 0.4%, 1.0% and 2.0%, respectively. It can be seen the same behavior for all frequency levels.

Table 1.

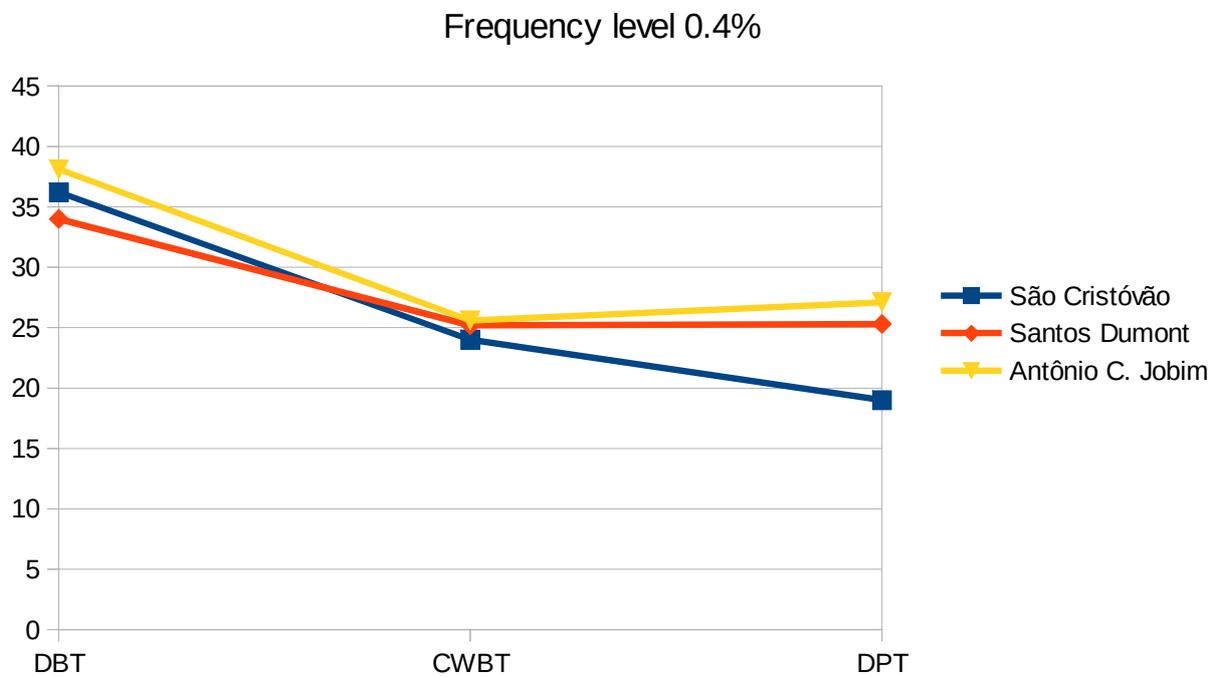| Frequency Level	Temperature	São Cristóvão	Santos Dumont	Antônio C. Jobim
0.40%	DBT	36.2	34.0	38.1
	CWBT	24.0	25.2	25.6
	DPT	19.0	25.3	27.1
1.0%	DBT	34.5	32.7	36.2
	CWBT	24.1	25.0	25.3
	DPT	19.9	25.0	26.2
2.0%	DBT	33.2	31.8	35.0
	CWBT	23.6	24.9	25.2
	DPT	19.7	24.6	26.0

Frequency level 0.4%

Figure 3. DBT, CWBT and DPT at the frequency level of 0.4%
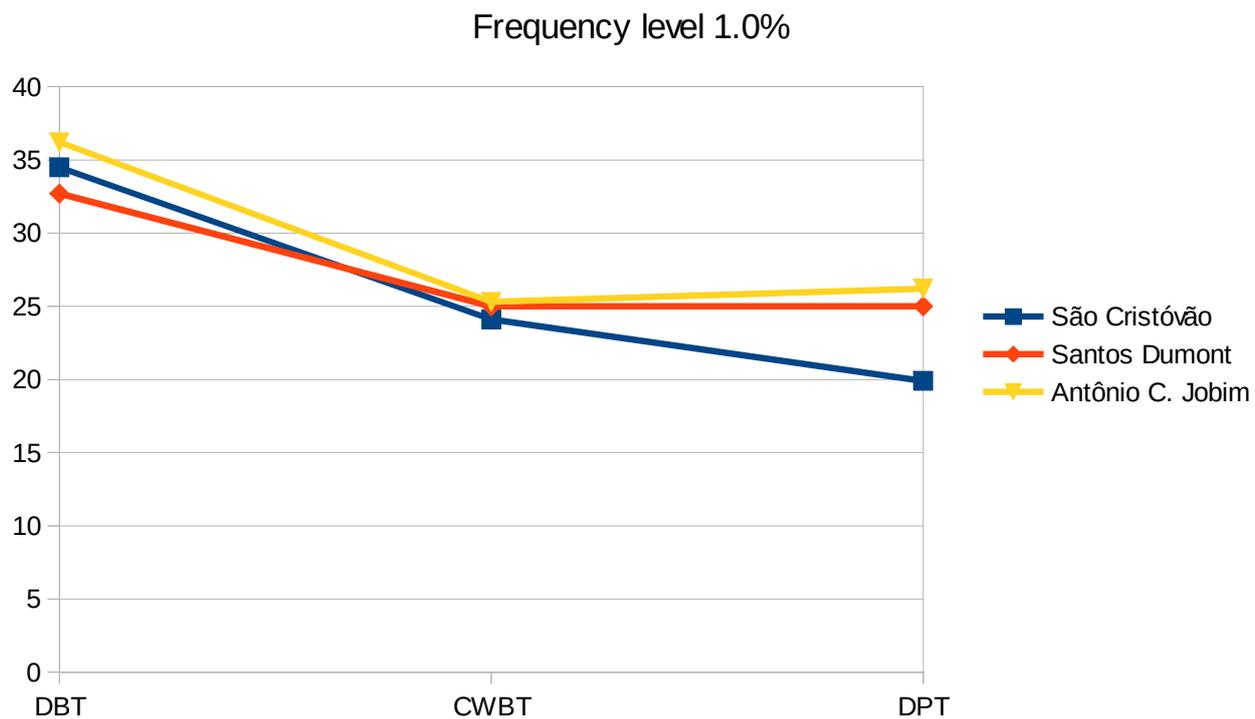
Frequency level 1.0%

Figure 4. DBT, CWBT and DPT at the frequency level of 1.0%
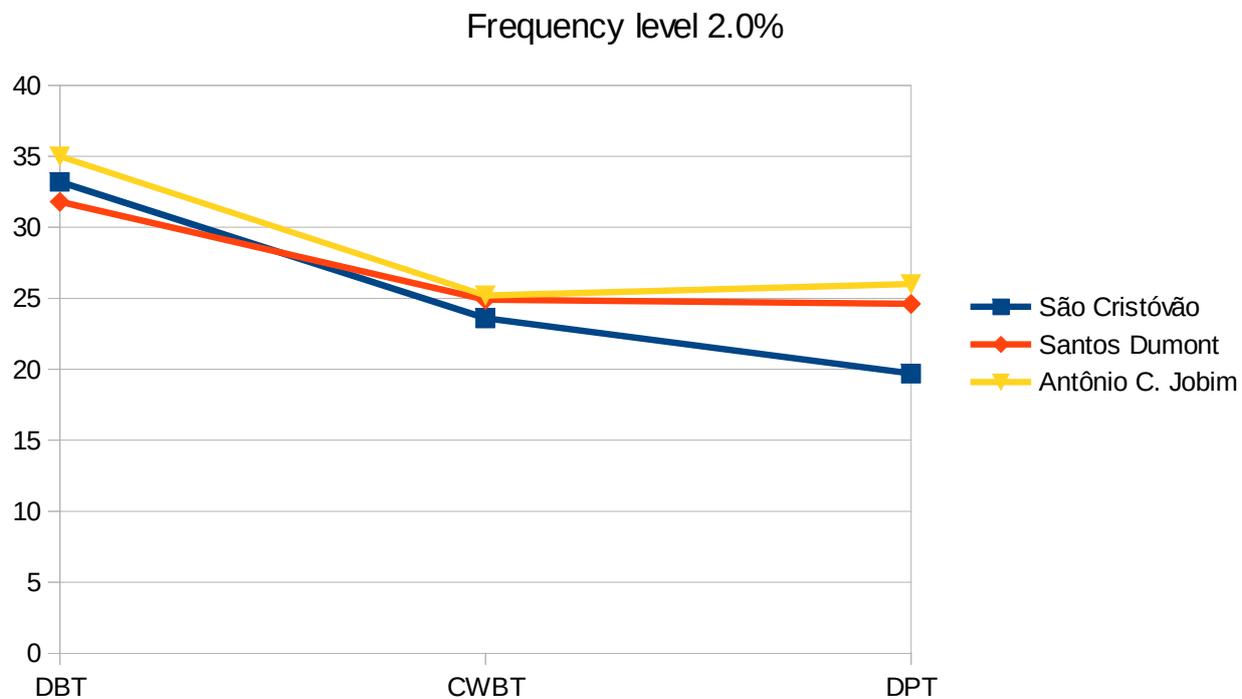
Frequency level 2.0%

Figure 5. DBT, CWBT and DPT at the frequency level of 2.0%

After defined the entry temperatures, thermal load calculations were made in order to evaluate their influence on the air conditioning design. Table 2 shows the thermal loads corresponding to the three places at the three frequency levels, with a vertical bar representation illustrated in Figure 6. The Antônio Carlos Jobim airport had the highest thermal load at all frequency levels. The thermal loads for São Cristóvão and Santos Dumont airport are very close at the frequency levels of 0.4% and 1.0%. .

Table 2. Thermal Load

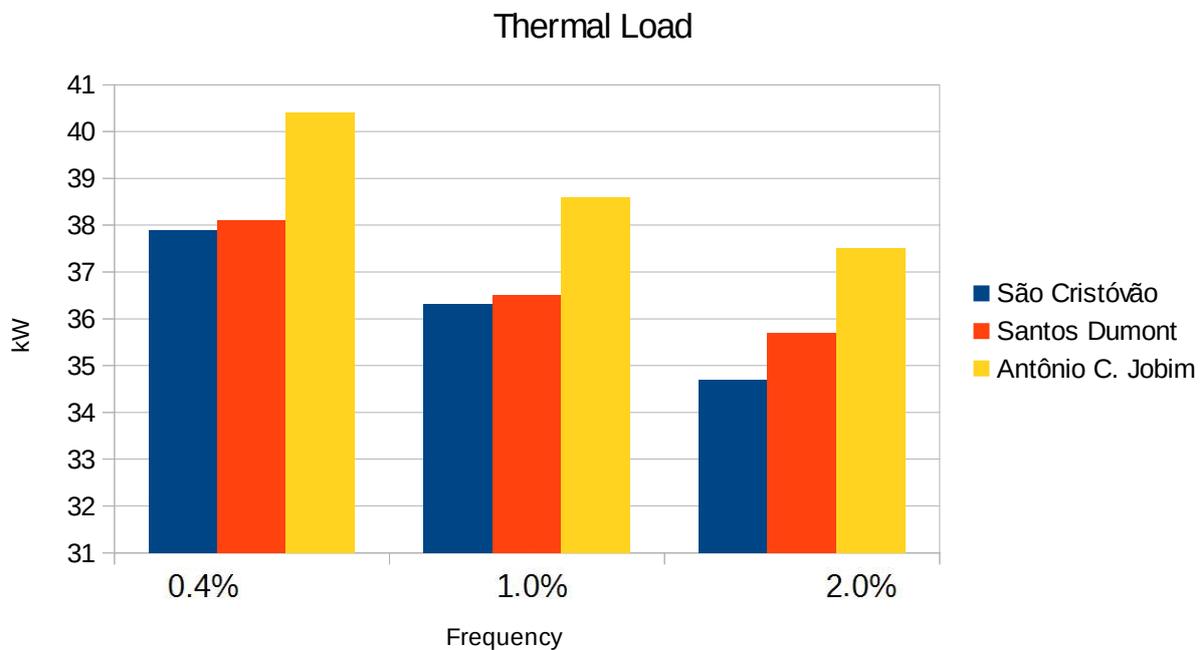| Thermal Load	0.40%	1.00%	2.00%
Antônio C. Jobim	40.4kW	38.6kW	37.5kW
Santos Dumont	38.1kW	36.5kW	35.7kW
São Cristóvão	37.9kW	36.3kW	34.7kW

Figure 6. Thermal Load

4. CONCLUSION

As soon as the costs of automated meteorological stations have decreased, more suitable climatic data have become available. On the other hand, HVAC designer use commercial software for thermal load calculation where it is comfortable to pre-select climatic data ready available, usually that presented in the design standards.

The DBTs calculated for São Cristóvão have confirmed that there is an increasing temperature gradient from the south to the north in the study region. Since São Cristóvão is a neighborhood where buildings up to 2 floors are predominant, the elevation of its meteorological station has contributed to a negligible urban heating perception.

Although the DBT for São Cristóvão is midway between the others, the thermal load for São Cristóvão was the lowest. This can be justified due to its lower air humidity.

The variations of the thermal loads among the sites chosen are around 6% for the studied construction, which does not significantly interfere in the selection of the air conditioning equipment. At first the size of the building should be higher for that percentage has a significant impact on thermal load calculation.

This research will go on encompassing other sites within the Rio de Janeiro metropolitan region.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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