Thermal Performance as a Parameter of Choice of Materials: Brazilian Antarctic Station

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ABSTRACT

In the atypical context of Antarctica, it must be considered the specific environmental conditions of the region in order to make the correct selection of more sustainable and efficient materials. Among them, there are the climatic characteristics, the isolation and the need to preserve the natural environment. The main goal of this research was to evaluate the thermal performance and the energy efficiency of new buildings of the EACF, (Comandante Ferraz Antarctic Station), expected to be finished in 2018, aiming to get and establish parameters for the new Brazilian buildings in Antarctica. To obtain the performance results of the station it was used the software Design Builder, and the study was conducted in two stages: at the first, the definition of the model, the characteristics and the properties of the materials specified in the project; and in the second stage it was determined the methodology for evaluations and the simulations.. The results demonstrated the performance of the building envelope, allowing to evaluate the materials used, pointing out possible improvements. Alternatively it was proposed to replace the galvanized steel coating specified for the envelope, for PVC (Polyvinyl Chloride), material that showed better results regarding the thermal performance and sustainability indicators.

Keywords: *antarctica, thermal performance, envelope*

1. INTRODUCTION

Performance rating systems, analysis tools and certification schemes serve to contribute to a better performance of buildings; however, there are still difficulties in establishing concrete environmental criteria for buildings, which is due to the broad interpretation of the word sustainability (Smith, 2003). In this context, the concern with sustainability becomes even more important when the place to build in Antarctica where environment, landscape and architectural impact are more critical in comparison to consolidated urban areas (Reis & Alvarez, 2015).

The first Brazilian occupation in the Antarctic occurred in 1984, with eight modules of the EACF (Secirm, 2014). The Station underwent successive reforms over time, and with no formal or environmental concern (Alvarez et al., 2004). In February 2012 a fire destroyed the main body of EACF and in the surroundings were installed the MAE (Antarctic Emergency Modules), which are serving to continue the activities of the station (Mech, 2013). After the event, a public procurement process was initiated for the project of the new permanent buildings through the development of the Terms of Reference, which were aimed at the reconstruction of the Research Station in order to meet the needs of the scientific community and to serve as reference for future buildings in Antarctica (Secirm, 2014).

Considering that the new Brazilian buildings in Antarctica were designed to use innovative techniques it is justified the need for studies on the types of materials proposed especially with regard to thermal performance, aimed at improving comfort conditions. The atypical characteristics of the region suggest systemic studies to gather with less environmental impact and materials that provide energy efficiency, especially about the reduction in fuel consumption for heating. To develop the Terms of Reference that guided the design competition for the Brazilian station, several stations were studied and, among them, the Princess Elisabeth (2007), belonging to Belgium, whose technology envelope is composed of elements in laminated wood and seals composed of a set of nine layers and clad with stainless steel blades.

The Amundsen-Scott Station (2008) belonging to the USA, was built in steel with composite panels by sealing two sheets of OSB - Oriented Strand Board, and the insulation EPS, Expanded Polystyrene (Montarroyos, 2015).

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Another reference is the Indian station, Bharati, 2012, built using prefabricated containers wrapped in a sealing structure in sandwich panels with external coating of steel (Montarroyos, 2015).

The old EACF facilities were composed of metal containers made of sealing sandwich, filled with polyurethane. Now, the new facilities will use major structures of high-strength steel (Montarroyos, 2015), to obtain favourable conditions for the improvement of performance and thermal comfort. Considering the technology adopted for the new buildings of EACF, the research aimed to evaluate the thermal performance of a room with high exposure - at the corner of the building - considering as conditioning the material proposed in the project and the possible use of PVC as outer covering of sandwich panels.

2. METHODOLOGY

The research was established from three main stages: characterization of Antarctica and the Comandante Ferraz Antarctic Station; modeling and simulations; and evaluation of thermal performance.

2.1 Characterization of antarctica and the comandante ferraz antartic station

Antarctica has unique environmental characteristics: low temperatures, strong wind gusts, isolation and preservation of the natural environment, which induce a process of human occupation in a sustainable way (Cruz et al., 2007). The Comandante Ferraz Antarctic Station was established in 1984 in the Keller Peninsula of King George Island (Alvarez, 1995). Since its settlement, the EACF passed through several expansion and modification processes, performed with the inherent concerns about the environmental impact and the possible interferences in the local ecosystem, due to poor planning of the previous design (Alvarez et al., 2007).

The new buildings of EACF are being built on the same site of the former, on Keller Peninsula (Figure 1). Its design dates from 2013 and its construction has forecast for completion in the year 2018, according to the Air Defence and Naval (Defesa Aérea e Naval, 2016). The various proposed settings for the station have a total built area of 4,500 m² formed by functional blocks and UIS - Isolated Units (Unidades Isoladas), which in its full configuration will form the basis for the operation of activities and research.

The area of laboratories was designed to meet many requirements, emphasizing the priority of the PROANTAR (Brazilian Antarctic Program) for scientific activities (Brazil, 2012). The project was developed considering the best practices of sustainability and should result in a facility of excellence, the highest quality, to promote its main goal, scientific research (Estudio 41, 2013). The set was designed from containers, which will later be covered by a system composed of insulating material with properties that mitigate the effect of salt spray and low temperatures (Figure 2).

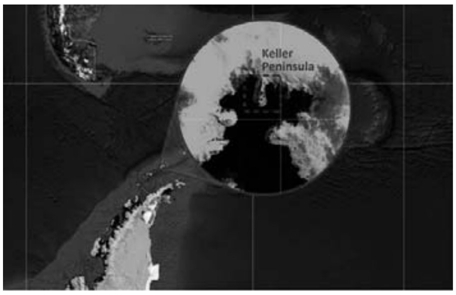

Figure 1: Scheme of keller peninsula location. Source: Brasil (2012)

Figure 2: Comandante ferraz antarctic station. Source: Comissão Interministerial para os Recursos do Mar (Interministerial Commission for Sea Resources) (2013)

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2.2 Modeling and simulations

The climatic conditions of Antarctica were obtained through the weather file EPW, *EnergyPlus Weather* for the year 2002 (Laboratório…, 2015). For the simulations, the conditions of the study area were considered, the windows do not have the any ventilation function and, thus, the model was configured as a closed space. The architectural typology adopted for the simulations was the design of the new EACF buildings of and the room, a laboratory with two external walls (worst situation). The reference values of thermal properties of building components related to the envelope, as well as the characteristics of clothing and activities performed by the laboratory users are shown in Table 1. The clothing and the activity simulate the real indoor working conditions in Antarctica, as well as the type of environment used.

The proposed design for the envelope are sandwich panels consisting of two external surfaces made from galvanized steel coil of 0.75 mm thick, each one coated with PVDF (Polivinilideo Fluoride) paint, internal layer of rigid PUR (Polyurethane) foam, with a distance of 50 cm between the wall of the container and the envelope. The panel is used to cover the outer vertical seal. The floor and has two types, one with 220mm and other with 170mm (Reis & Alvarez, 2015).

It was adopted for the comparative study an exterior coating of PVC, replacing the steel sheet while maintaining the same thermal insulation. PVC is a material consisting of 57 % of chlorine and 43% of ethylene, thermoplastic material and is the second most produced worldwide (Instituto do PVC, 2016).

The simulations were carried out for the Laboratory of Molecular Biology and its environmental conditions (Figure 3). This room is located in the functional block, 5.29 m above the ground (Figure 4). The Laboratory is located at one end of the blocks, having two of its walls exposed to the weather, one facing north and the other facing east. The simulations were carried out for the summer period (21/ Dec to 21/ Mar) and the winter period (21/ Jun to 23/ Sep).

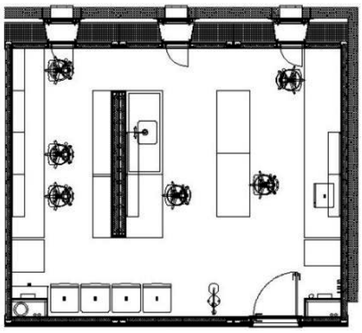

Figure 3: Floor plan of molecular biology laboratory.

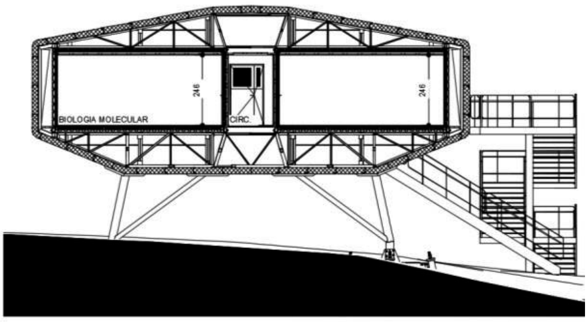

Figure 4: Section plane of the function block where the laboratory of molecular biology is located. Source: ESTÚDIO 41, 2013

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Internal walls and envelope		
Internal Walls: corrugated steel plate (container), stud "C" in galvanized steel (70 mm), rock wool 70kg / m³ (70 mm), polyethylene sleeving 2.5 kg / m³ (2 mm) , cast on 2 plates with non-combustible fiber additive (12,5 mm each)		15 cm (thickness)
Thermal transmittance floor, walls and ceiling (U)		0,185 W/(m².K)
Ceiling		12 cm (thickness)
Thermal transmittance of the triple insulating glass (U)		1,1 W/m².K
Thermal transmittance of the window aluminum frame		5,8 W/m².K
Envelope modeling (1): galvanized steel sheet (0.75 mm), polyurethane (205 mm), galvanized steel sheet (0.75 mm)		22 cm (thickness)
Envelope modeling (2): PVC (2 mm) , polyurethane (205 mm) PVC (2mm)		24,5 cm (thickness)
Occupied environment and internal loads		
Density and Occupation		0,15 person/m²
Metabolism Activity: light work of laboratory		123 W/person
Occupancy Standard: 6 people- 07h00 – 20h00		
Walls and ceilings	*Emissivity (ε)	** Absorptance (α)
Steel plate	0,30	0,30
Metal stud	0,30	0,30
Rock wool	0,90	0,60
Polyethylene sleeving	0,90	0,70
Plasterboard	0,90	0,50

Table 1: Properties of the materials of the layers of the walls, ceiling and floor. Source: Drawn from Studio 41 (2013) and Design Builder (2015)

2.3 Thermal performance evaluation

For the evaluation of thermal performance conditions it was used the hourly operating temperatures and comfort temperature defined by ISO - International Standard 7730 (International ... 2005). The criterion to define the comfort temperature was based on the type of activity involved in the laboratory work; clothing of 0.5 clo for summer and 1.0 clo for winter, considering the best category (A), and from this combination resulted a comfort temperature of 23 °C. For environmental thermal performance evaluation indicators proposed by Nico-Rodrigues (2015) were used, which made possible to analyse the hourly changes in operating temperature, for summer and winter.

2.4 Indicators

The indicators used for the systematization of data were the FDT – Frequência de Desconforto Térmico (Frequency of Thermal Discomfort) and GhDT – Graus-horas de Desconforto Térmico (Degrees-hours of thermal discomfort). These results were used as input in the buoyancy diagram.

The FDT quantifies the number of hours of discomfort, in percentage during a certain time interval, and its maximum value refers to the maximum time limit. To set this percentage of the whole time, the the percentage at which the operating temperature is above the maximum comfort temperature is used. In this study, the proposal was to analyze daily periods, of 24 hours, corresponding to a maximum frequency of 100%.

The GhDT is the difference between the hourly operating temperature and the comfort temperature when the operating temperature exceeds the defined value of the comfort temperature established for the month under study. To obtain the maximum reference value it was adopted the highest value of GhDT, considering all the features of the model and climatic conditions. For the analysis of FDT and GhDT indicators was adopted the buoyancy diagram, which considers the assessment of the frequency on two levels: temporary and frequent; and the intensity condition for the degree-hours, light and intense levels (Figure 5).

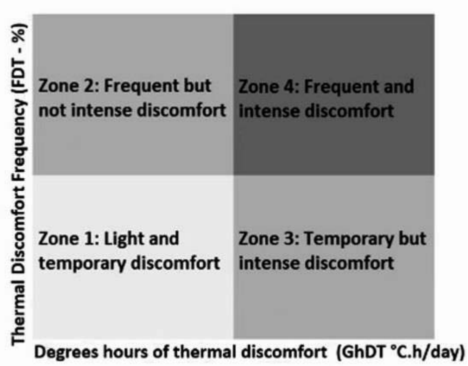

Figure 5. Buoyancy diagram FDT and GhDT indicators. Source: Nico-Rodrigues, 2015

3. RESULTS AND DISCUSSIONS

3.4 Determination of conditions

The results defined the internal hourly air temperature of the Molecular Biology Laboratory aiming to determine the environmental thermal performance with emphasis on thermal comfort using in your envelope galvanized steel and PVC. The results were subjected to statistical treatment to set the maximum amounts of daily GhDT, which is the reference value used for laboratory analysis with the two materials (Table 2).

Seasons	Material	GhDT
Winter	Galvanized Steel	170,20 ºC.h/day
	PVC	170,15 ºC.h/day
Summer	Galvanized Steel	166,4 ºC.h/day
	PVC	300,5 ºC.h/day

Table 2: Maximum reference values for GhDT at each station. Source: Authors

3.5 Simulations

The simulations made possible to assess the environmental thermal performance according to the materials used in the envelope, especially the use of artificial heating as a strategy for thermal comfort. The first series of results showed the internal conditions of the Molecular Biology Laboratory with the use of galvanized steel in the envelope and, afterwards, the results that would be achieved with the PVC replacement.

The values of FDT and GhDT obtained for each day are shown in the buoyancy diagram, characterizing the conditions for thermal comfort (Figure 6). It should be noted that the buoyancy diagram relates the values of FDT with the highest value of GhDT of each season of the year, demonstrating the daily situations, being the best condition that converges to the origin.

The results of performance simulations have shown that the use of galvanized steel in the envelope, partially meets the conditions for thermal comfort determined by the ISO 7730 standard as well as the use of PVC, using a comfort temperature of 23°C. The ISO standard allows some temperature variations, being temperatures of 19 °C be still within the norm, which increases the amount of hours within the comfort limit. And with the use of PVC obtained better performance results compared to the previous situation, especially in the summer season. It was observed that the results of the FDT and GhDT indicated two levels of discomfort for the simulations with the steel - being them levels (A) and (B) - and three levels for the simulations with PVC - which are (A), (B) and (C) - where (A) means days of frequent and slight discomfort; (B) days of frequent and intense discomfort; and (C) days of temporary and mild discomfort.

The results showed both for summer and winter an uncomfortable environment, but the comparative analysis between the two simulated materials showed that a better indoor environment is achieved if the PVC is used in the envelope. Observing the analyzis of materials separately in both seasons, it was found that in the envelopment with galvanized layers, the temperature values remained constantly below the comfort threshold, classifying the discomfort as intense, and a FDT common in winter. In summer the temperatures remained below the limit, but the discomfort is rated as mild to intense, and the FDT remained intense.

In the simulations with layers of PVC, temperature values remained below the comfort limit in winter, with a few days with some hours within the limit, classifying discomfort as frequent, and an often FDT. In summer there was an improvement in the results, almost all days are presenting all hours within the comfort limit, but with a few days still below the threshold, being the discomfort classified as intense or temporary, and FDT ranging from heavy and light.

The adoption of PVC, as an alternative material, would improve the results; however, it is not enough to achieve the optimal results. It is suggested that the wall exposed to the weather also has a spacing of approximately 50 cm, already adopted in the other external wall, serving as attenuator space, which holds a layer with temperature at 10 °C, since this construction proposal has proved effective in other situations analyzed. It is possible to obtain better results using different types of thermal insulation defined according to the physical and thermal properties, greater or lesser thermal inertia. It is noteworthy that the Belgium station , for example, is classified as the most efficient among the studied station due to, between other factors, the adoption of nine insulation layers with properties that potentiated the thermal efficiency of building.

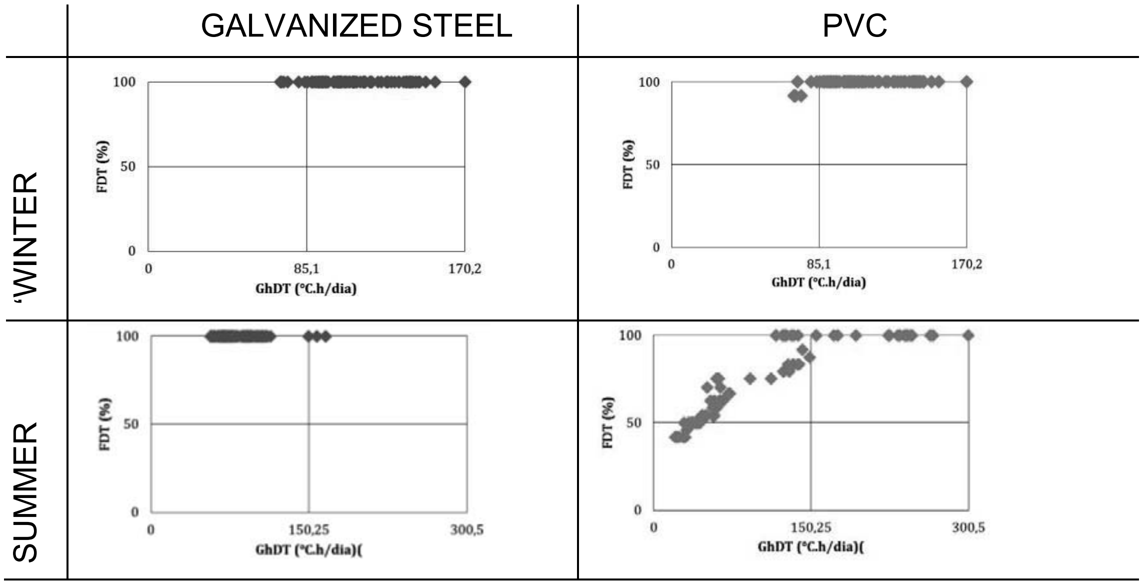

Figure 6: Buoyancy diagrams of the summer and winter seasons. Source: Authors

Another likely factor responsible for improving internal conditions is the incidence of solar radiation and the different behaviour of steel and PVC in the outer layer. In the summer period, the amount of solar radiation is much bigger and keeps the temperature in the space between the panels heated a lot longer. Although the PVC is thinner, its performance is better than the steel plate, as it can be observed in the Spanish station Juan Carlos in which was used a similar material in the form of modular rings of plastic fiber.

4. CONCLUSIONS

From the analysis made with the methodology adopted, it was possible to understand the environmental performance for the buildings in Antarctica, focusing on thermal comfort. The daily fluctuations in the operating temperature guided to solutions aimed at improving the thermal comfort and the indicators allowed the understanding of the internal conditions of the environment.

It is important to know that the building system from containers surrounded by a second outer layer coating on the sandwiches panels is a technique whose maintenance activities may be carried out by the Navy in Rio de Janeiro, which has a lot of experience in such activities in Antarctica. Studies with the use of PVC in the Antarctica environment are still in the initial process, and those results are an incentive for continuity, because it was realized that the model with PVC had an improvement in the results when compared to model that used steel. However, it should be noted that the two construction solutions still require further developments to meet the requirements of the adopted standard.

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