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Energy Efficiency Assessment of the Involvement of an Educational Building using the Prescription Method (RTQ-C).

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***Abstract*— *For a building to be considered sustainable, it is essential that it be energy efficient and assess the impact that its implementation and use will have on the environment. The evaluation of the energy efficiency of the systems that make up a building becomes fundamental. For this, the analysis of the envelope, its materiality, its conductivity indices and thermal transmittance directly influence the energy consumption of a building. Based on the Technical Quality Regulation for the Energy Efficiency Level of Commercial, Service and Public Buildings (RTQ-C), it was possible to evaluate and classify the efficiency levels of an educational building located in the municipality of Lajeado, Rio de Janeiro state. Grande do Sul, Brazil, applying natural and innovative materials for thermal insulation of wraps. The original rating of Level D goes to levels A and B, depending on the amount of insulating material applied. It is noteworthy that for the building to be classified as Level A, it is necessary to reduce the energy consumption of the artificial lighting system by 65%.*
***Keywords*— Energy efficiency; Wrapper; Thermal insulation; RTQ-C.**

I. INTRODUCTION

For a building to be considered sustainable, it is essential that it be energy efficient. The impact it will have on the environment should always be considered, always aiming at its reduction, aiming at a reduction in water and energy consumption if purchased from conventional constructions (YUDELSON, 2013).

So, energy efficiency,

> "Can be understood as obtaining a service with low energy expenditure. Therefore, one building is more energy efficient than another when it provides the same environmental conditions with lower energy consumption."(LAMBERTS et al., 2004, p. 14)

For these cases, concepts related to the study of the physics and thermal behavior of materials, mainly related to heat transfer, and the potentiality of a given material to conduct heat apply. Understanding the basic concepts of heat transfer in buildings tends to improve the thermal comfort of environments and optimize costs related to electricity consumption. ASDRUBALI et al. (2015a) mentions that "thermal insulation systems and materials aim to reduce heat flow transmission. The thermal insulation performance of single or combined homogeneous materials is generally assessed, respectively, by thermal conductivity and thermal transmittance" (ASDRUBALI et al., 2015, p. 2).

1.1 STANDARDIZATION AND CERTIFICATIONS

According to NBR 15220 (ABNT, 2005), which presents the method for calculating the Thermal Performance of Buildings. The fundamental index is the thermal conductivity (λ) of the materials, which, as described in the first part of NBR 15220, is the "physical property of a homogeneous and isotropic material, which has a constant heat flux, with a density of 1 ° C. W / m² when subjected to a uniform temperature gradient of 1 Kelvin per meter ", and its unit of measurement is W / (mK) (ABNT, 2005, p. 1). A material may be considered as a thermal insulator if its thermal conductivity index is less than 0,07 W / m.K. (ASDRUBALI et al., 2005).

According to NBR 15220 (ABNT, 2005), the thermal conductivity for conventional materials such as Styrofoam (EPS), glass wool and rock wool, with indexes (λ) of approximately 0.038 W / m.K. Wiebeck et al. (2005)

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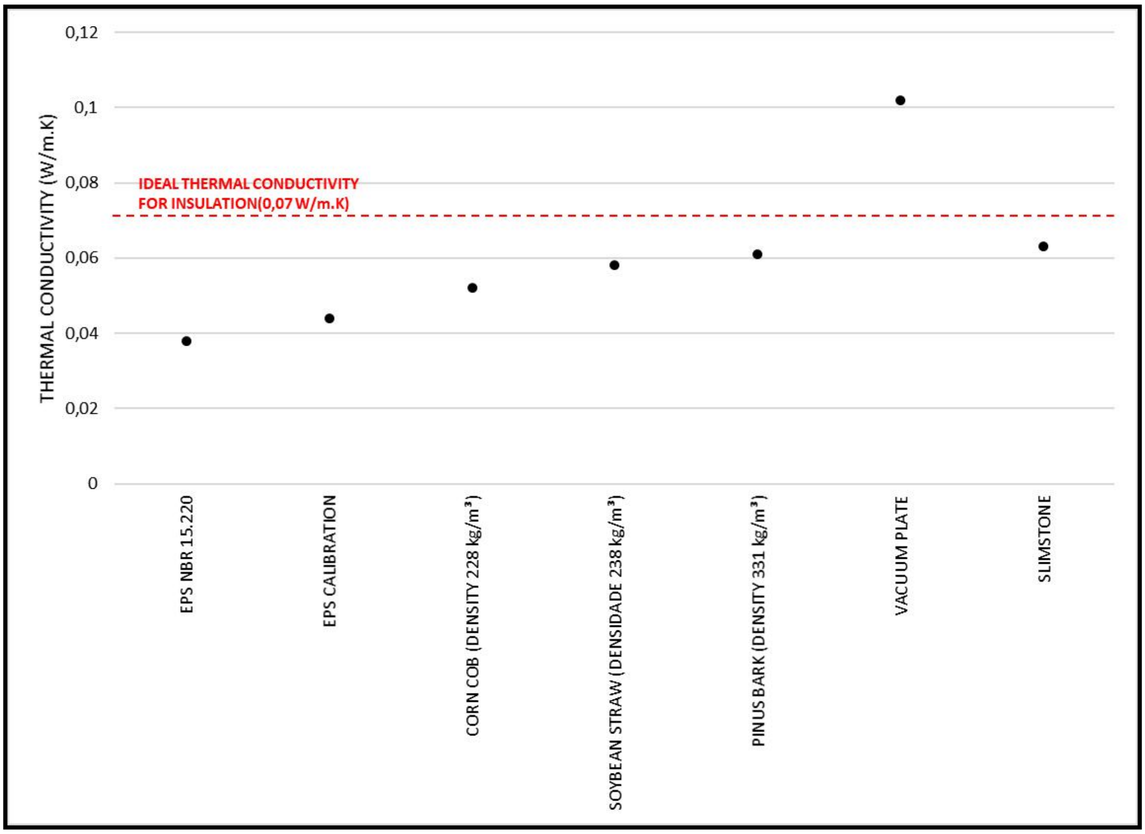
presents data related to synthetic polymers (EPS and XPS), as being materials with good fire resistance, acoustic insulators, and do not propagate fungi. In their composition, polymers (PU) have isocyanates, being volatile substances, pose a risk to the health of the people who inhale them.

Spinelli et al. (2019, forthcoming), presents thermal conductivity results with the use of vegetable raw materials such as corncob, soybean straw and pine bark, together with innovative materials such as vacuum layer and waste insulation board SlimStone Industrial. It is noteworthy that when comparing materials developed with natural elements, they have thermal conductivity indexes similar to the industrialized and standardized materials, as shown in graph 1 (Spinelli et al., 2019, forthcoming).

Graph 1: Comparative Thermal Conductivity



Source: Spinelli et al., 2019, forthcoming.

The second part of the standard presents the thermal conductivity of several conventional materials (ABNT, 2005, p. 13). In the fourth part, NBR 15220 details the method for determining thermal resistance and thermal conductivity using the protected hot plate principle (ABNT, 2005). By determining the Thermal Conductivity of a material, it becomes possible to calculate the Thermal Resistance (R) of elements and components, the Thermal Transmittance. (U)[1], Heat Flow Density (q)[2]of an opaque closure, and the Heat Flow (Q)[3]. The determination of these variables directly influence the thermal behavior of buildings, especially with regard to Thermal Capacity[4]and Thermal Delay[5]. Also noteworthy is the Solar Heat Gain Factor for buildings, which can be distinguished as solar gain for opaque elements. (F_{So}) and for transparent and translucent elements (F_{St}). This Solar Factor is directly related to solar radiation (I) that affects building components, especially transparent ones, and how much of this radiation is absorbed, reflected and relayed to indoor environments (ABNT, 2005).

[1] "The inverse of the total thermal resistance of a component" (ABNT, 2005)."

[2] "Quotient of the heat flux that crosses a surface by the surface area" (ABNT, 2005)."

[3] "Quotient of the amount of heat that crosses a surface over a period of time" (ABNT, 2005)."

[4] "Amount of heat required to vary the temperature of a system by one unit" (ABNT, 2005)."

[5] "Time elapsed between a thermal variation in a medium and its manifestation on the opposite surface of a constructive component subjected to a periodic heat transmission regime" (ABNT, 2005)."

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Thus, considering the importance of energy performance for the quality of buildings, NBR 15575 was prepared to meet the requirements of users of housing buildings, a behavior related to the period of their use. It is a set of standards that stipulates performance according to requirements (qualitative), criteria (quantitative or assumptions) and evaluation methods that provide the construction of safer and more efficient buildings. It also highlights the demands of residential building users by presenting an overall list divided into safety, livability and sustainability. This performance standard complements pre-existing standards, not replacing them, where performance and prescriptive standards are to be used together (ABNT, 2013).

Cambeiro et al. (2016) describes that buildings are consequently one of the main sources of pollution worldwide. International certification models that attest to the environmental sustainability of buildings adopt the environmental impact of construction on their life cycle as a key feature. These certificates currently meet local criteria (BREEAM, created in the UK, HQE in France, LIDERA in Portugal) or have universal reach, such as the American certification known as LEED. These certificates take into account the energy performance of the building as a fundamental characteristic, based on the construction process, building materials and their origin (being a long distance transportation concern, and amount of gas emissions generated, among others), as well as as energy uses for the execution and maintenance of the building.

1.2RTQ-C Building Classification

Aiming at the energy classification of buildings based on the energy efficiency law (nº 10.295 / 2001), the National Institute of Metrology, Quality and Technology (INMETRO) presented revisions in 2010 the Technical Quality Regulation for the Energy Efficiency Level of Commercial, Service and Public Buildings (RTQ-C) (BRASIL, 2013; BRASIL, 2012). RTQ-C has a similar purpose as LEED and is applicable for certification of three types of buildings: I) conditioned buildings; II) partially conditioned; and II) unconditioned; these may be and mixed use, commercial, service and public (Ordinance No. 372, 2010).

Energy level labeling for a building by the RTQ-C system is based on prescriptive method analysis of simulations of a limited number of cases by regression or by the simulation method. Thus, RTQ specifies three levels of efficiency for buildings, ranging from level A (most efficient) to E (least efficient), presented in ENCE (National Energy Conservation Label), and are divided into three individual systems: Envelope, Artificial lighting system and air conditioning system (Ordinance No. 372, 2010).

Based on the information provided in NBR 15220 and NBR 15515, RTQ "creates conditions for energy efficiency level labeling" for buildings, as shown in Figure 1 (BRASIL, 2013).

Fig.1 - RTQ-C National Energy Conservation Label

Source: Brasil (2010).

The evaluation of the individual systems, results in a final classification, which, for this,

> "Points are assigned to each individual system and, according to the final score, a rating that also ranges from A (most efficient) to E (least efficient) presented on the ENCE - National Energy Conservation Label" is obtained (BRAZIL, 2013).

The development of RTQ analyzes can be developed using two methods: prescriptive and simulation. The Prescriptive Method is an analytical method based on a limited number of data. The Simulation Method uses a computer program to add the project variables, and based on the results, to classify the systems that make up the building (BRASIL, 2013).

Bavaresco et al. (2017), developed a metamodel for the thermal load calculation of five different commercial buildings, and the design of the thermal loads for comparison in the EnergyPlus program, comparing the two results in RTQ-C. The data presented by the metamodel presented satisfactory results and can be applied in RTQ-C in order to classify buildings (BAVARESCO et al., 2017).

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Quevedo et al. (2017) analyzed by the prescriptive method, according to RTQ-C, a building for public use, located in the city of Florianopolis (Bioclimatic Zone 3). Entering the parameters resulted in an analysis of 12,000 cases, and a result in which 39% of cases achieved an "A" rating level. However, according to the authors;

> Ease of achieving the highest level of energy efficiency is understood to be an incentive policy for labeling, especially during the implementation of a voluntary labeling program. It is suggested that the RTQ-C scale be adapted to provide a distribution closer to the normal distribution where "C" would represent most of the constructed buildings (QUEVEDO et al., 2017).

II. MATERIALS AND METHODS

2.1Energy Efficiency Simulation

Based on the study developed by Spinelli et al. (2019, forthcoming), the study proposes to analyze the energy efficiency of educational buildings located in the city of Lajeado / RS (Figure 2).

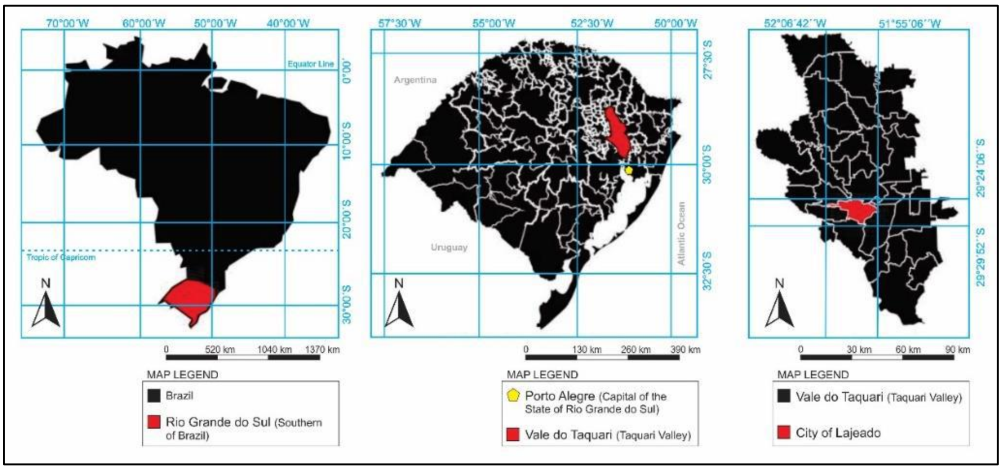

Fig.2 – Localization of the State Rio Grande do Sul in Brazil, of Vale do Taquari in the state Rio Grande do Sul, and the municipal area of Lajeado in Vale of Taquari.
Source: Spinelli et al., 2017.

By analyzing the bioclimatic chart (Figure 3) for the city of Lajeado / RS (Spinelli et al., 2017), it is observed that in 45.26% of the typical days of the year, the built environment is in thermal comfort. , if the building meets NBR 15.575 (2013). For 36.5% of the typical days of the year, the thermal inertia strategy should be used, using thermal insulation to keep indoor environments at a comfortable temperature. By properly using bioclimatic strategies, together with the appropriate materiality for building execution, the possibilities for saving energy are increased, making them more energy efficient.

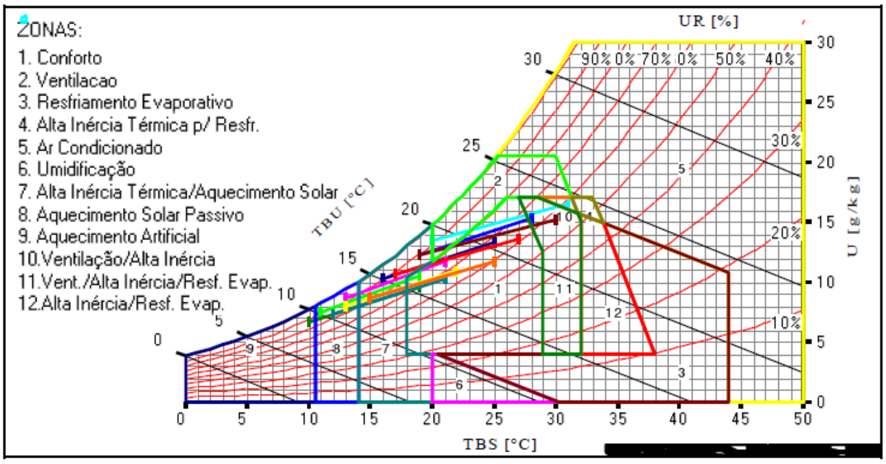

Fig.3 – Bioclimatic chart of the city of Lajeado-RS
Source: SPINELLI et al. (2017, p. 470).

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The building selected for the development of the energy efficiency study is located on the campus of the University of Taquari Valley - Univates (51 ° 95´77´´ W / 29 ° 25´37´´S). First building built at Univates, it began construction in 1964 and was completed in 1969 (Figure 4). The building has 3,563,55m² of built area, distributed in three floors.

Fig.4 – Building selected for the study.

Fig.4 – Floor Plans of the Building.

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This was selected for the development of the study because it is the oldest building of the institution and its building system is the most conventional, similar to most buildings built locally, with the constructive characteristics: I) masonry executed in solid ceramic block; II) use of simple glass in the frames; and III) covering in fiber cement tiles.

The floors of the building are made up of classrooms, offices, toilets, teachers' rooms, computer labs, circulation, among other spaces (Figure 5). Regarding equipment, all environments have a Split System for artificial climate control, elevator connecting the floors, and artificial lighting system using fluorescent tube lamps.

2.2Prescription Method Energy Efficiency Simulation (RTQ-C)

Using the RTQ-C prescriptive method as a basis (BRAZIL, 2013), simulations with data insertion in a spreadsheet were developed, and the results converted to the indices determined by the RTQ-C. The development of the simulations will take place by the following steps:

- Analysis of the building envelope efficiency, calculating the thermal transmittance (U) for envelope, roof and glass, as determined by NBR 15220 (ABNT, 2005);
- Development of calculations for Height Factor (FA), Form Factor (FF), Percentage of Facade Openings (PAF), and Vertical (ASV) and Horizontal (ASH) Shading Angles;
- Calculation of the Consumption Index (CI) of the building, which relates the data presented in the Chart and local Bioclimatic Zone, with the indexes calculated in the previous step;
- Determination of the efficiency level of artificial lighting, calculating the installed power and illuminated area of the building, determination of threshold power and determination of the efficiency level related to the activity developed in the building (according to tabulated indexes in RTQ-C);
- Determining the efficiency level of the air conditioning system, analyzing from the weighting of equipment classification (Efficiency Seal) by their capacity (BRASIL, 2013);
- Bonus calculation for the energy efficiency index, determining the building elevator efficiency index, as specified in the VDI4707 standard (BRAZIL, 2013);

The first stage of the simulation for the building studied, evaluated and analyzed the data for energy efficiency classification according to the original materials in which the building was executed. According to the requirements defined in the regulation, the efficiency level of the envelope, the artificial lighting system and the air conditioning system were calculated.

At the end of the pre-existence analysis, in a second moment new simulations were developed with the application of the characteristics of the materialities developed in the study by Spinelli et al. (2019, forthcoming). Thus, a set of materiality combinations was elaborated for the simulation in the building envelope, using as thermal insulation material air layer, Styrofoam, pine bark, soybean straw, corncob, slimstone and vacuum plate.

Regarding artificial lighting and air conditioning systems, the original characteristics were maintained and considered for analysis of the artificial lighting system: typology of lamps, model, power and quantity of lamps. For the HVAC system, the information for the development of the analysis were: manufacturer, system typology, capacity (BTU's), power and consumption (w / w).

After the simulations were completed by the prescriptive method, the Energy Efficiency Level of the Building was determined, classifying each system with index “A” for more efficient, until “E” for more inefficient, concluding with the determination of a general index for the building (BRAZIL, 2013).

III. RESULTS AND DISCUSSIONS

3.1. WRAP

The classification of the building envelope was analyzed and presented by the Thermal Transmittance Index (U) of the masonry and roof, so that each part of the building can be identified in the composition of an appropriate envelope classification to add the final classification. When the original building and its characteristics were analyzed, unsatisfactory results were obtained in relation to the original materials when compared to the classification parameters of the RTQ-C.

Table 2 shows the results of the analyzed building data according to their original envelope composition. The materiality of the masonry is external plaster, solid ceramic block and internal plaster. In the roof the original materiality is concrete slab, air bed and fiber cement tile. It is noteworthy that when analyzing the thermal transmittance (U) of masonry and roofing materiality compositions, and comparing the classification according to RTQ-C, Brazil (2013), both are classified as Level C and D for energy efficiency, in which For these cases the level D will be considered in the final calculation.

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Table 2: Wrap classification of original building.

ENVELOPE COMPOSITION	THERMAL TRANSMITANCE COMPOSITION (U)	TYPE	RTQ-C CLASSIFICATION LEVEL
ORIGINAL MASONRY (PLASTER+ MASSIVE CERAMIC BLOCK +PLASTER)	**3,34 W/m²K**	Wall transmittance	Level D U ≤ 3,7W/m²K
ORIGINAL COVERAGE (CONCRETE SLAB + AIR LAYER + FIBER TILE)	**1,83 W/m²K**	Coverage transmittance (air-conditioned)	Level C e D U ≤ 2,0W/m²K

To achieve better wrap classification levels in the RTQ-C, adjustments to the existing masonry were proposed. The option of complete replacement of the masonry was discarded due to the high cost, and its structural impossibility, since the building has structural walls without pillar, increasing the cost. Thus, it was decided to add internally in the masonry that have contact with the exterior, the application of a drywall partition, flush with the wall. The simulations continued with the application of insulation between the plasterboard and the existing masonry. The compositions were simulated with the thermal insulation materials researched by Spinelli et al. (2019, forthcoming) such as Styrofoam (EPS), pine bark, soybean straw, corn cob, slimstone and vacuum plate.

As described in Table 3, it is observed that the most outstanding materials were Styrofoam, pine bark, soybean straw and corncob, obtaining A and / or B classification for wall and roof. When comparing the Thermal Transmittance indices, the composition containing Styrofoam had the best performance; however, the Thermal Transmittance results of the compositions with natural elements for thermal insulation, in relation to the RTQ-C index, stand out.

Table 3:Adaptedbuilding envelope classification (R1).

ENVELOPMENT COMPOSITION	THERMAL TRANSMITTANCE COMPOSITION(U)	Envelopment Type	LEVEL RATING RTQ-C
Original masonry + 5cm airlayer + internaldrywall	**1,75 W/m²K**	Wall transmittance	Level B U≤2W/m²K
Original cover (concrete slab + airlayer + fibercement tile)	**1,83 W/m²K**	Coverage transmittance (air-conditioned)	LevelC e D U≤2,0W/m²K
Original masonry + Styrofoam (EPS) + 2cm airlayer + internaldrywall	**0,74 W/m²K**	Wall transmittance	LevelA U≤1W/m²K
Original Cover + Styrofoam (EPS)	**0,78 W/m²K**	Coverage transmittance (air-conditioned)	LevelB U≤ 1 W/m²K
Original masonry + Pinus bark 3cm + Layer Air 2cm + inner drywall	**0,95 W/m²K**	Wall transmittance	LevelA U≤1W/m²K
Original cover + Pinus bark 3cm	**1,02 W/m²K**	Transmitância da cobertura (climatizado)	LevelB U≤1W/m²K
Original masonry + soybean straw 3cm + layer air 2cm + inner Drywall	**0,93 W/m²K**	Transmitância da parede	LevelA U≤1W/m²K
Original cover + soy straw 3cm	**1,00 W/m²K**	Coverage transmittance (air-conditioned)	LevelB U≤1W/m²K
Original masonry + Corn COB 3CM +	**0,88 W/m²K**	Wall	LevelA

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layer Air 2cm + inner Drywall		transmittance	U≤1W/m²K
Original cover + cob Corn 3cm	**0,94 W/m²K**	Coverage transmittance (air-conditioned)	LevelB U≤1W/m²K
Original masonry + Slimstone + Air layer + inner Drywall	**1,39 W/m²K**	Wall transmittance	LevelB U≤ 2 W/m²K
Original coverage + slimstone	**1,55 W/m²K**	Coverage transmittance (air-conditioned)	LevelC U≤ 2 W/m²K
Original Masonry + Vacuum plate + air Layer + inner Drywall	**1,05 W/m²K**	Wall transmittance	LevelB U≤ 2 W/m²K
Original cover + Vacuum plate	**1,83 W/m²K**	Coverage transmittance (air-conditioned)	LevelC U≤ 2 W/m²K

Thus, it was proposed to adapt them asonry compositions with natural elements of thermalinsulation, sizing the Thermal Transmittance without the air layer, but with expanding the thermalinsulation layer from 3cm to 5 cm. For the insulation of the roof, there vision is proposed by applying a double layer of insulating material, from 3cm to 6cm and 9cm, according toTable 4.

Table 4: Classificationofthebuilding envelope with natural materials (R2).

ENVELOPMENT COMPOSITION	THERMAL TRANSMITTANCE COMPOSITION (U)	Envelopment Type	LEVEL RATING RTQ-C
Original masonry + pine bark 5cm + Internal drywall	**0,82 W/m²K**	Wall transmittance	LevelA U≤1W/m²K
Original cover + Pinus bark 10cm	**0,47 W/m²K**	Coverage transmittance (air-conditioned)	LevelA U≤0,5W/m²K
Original masonry + soybean straw 5cm + Internal drywall	**0,79 W/m²K**	Wall transmittance	LevelA U≤1W/m²K
Original cover + soybean straw 9cm	**0,49 W/m²K**	Coverage transmittance (air-conditioned)	LevelA U≤0,5 W/m²K
Original masonry + Corn cob 5cm + Internal drywall	**0,73 W/m²K**	Wall transmittance	LevelA U≤1W/m²K
Original cover + Corn cob 9cm	**0,45 W/m²K**	Coverage transmittance (air-conditioned)	LevelA U≤0,5W/m²K
Original masonry + slimstone 3cm + layer air + inner drywall	**0,98 W/m²K**	Wall transmittance	LevelA U≤ 1 W/m²K
Original coverage + slimstone 10cm	**0,48 W/m²K**	Coverage transmittance (air-conditioned)	LevelA U≤0,5W/m²K
Original masonry + 5cm Vacuum plate + Air layer + inner drywall	**0,95 W/m²K**	Wall transmittance	LevelA U≤ 1 W/m²K
Original cover + Vacuum plate 16cm	**0,49 W/m²K**	Coverage transmittance (air-conditioned)	LevelA U≤ 0,5 W/m²K

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It is verified in the presented results that the revision of the thickness of the insulating material layer represents in a new classification in the energy efficiency level of RTQ-C, but with very thick layers which can make the production of insulating material unfeasible. We highlight the results for the roof, which receives the most radiation, and the need for larger insulation layers, reaching 10cm thick for recycled material, and 16cm for vacuum plate, which can lead to under load of the building structure. For these cases, heat reflective material below the tile may be used and the air layer thermal resistance increased from 0.21 m.K / W to 0.61 m.K / W.

3.2. ARTIFICIAL LIGHTING

Based on the information in table 4.2 of the RTQ-C manual, which describes the acceptable maximum illumination power density - DPIL limits for the desired efficiency level (Brazil, 2013), the lighting system analysis was developed. of the building, for the main activity of the building. In the survey developed in the environments, the artificial lighting components were verified and follows a standard for all spaces, being 40 W Fluorescent lamps. Thus, to measure the installed Power, the total number of lamps in each environment was quantified. their respective installed power.

Calculating the values of limiting artificial lighting power density (DPI) and their respective areas, we obtained the activity limiting power for each classification level according to the RTQ-C manual (BRAZIL, 2013), observing the classification of each room for Artificial Lighting, as shown in Table 5.

Table 5: Classification of the environments according to their artificial lighting.

		A	B	C	D
Auditorium	Totalinstalled (w)	24400			
	Area (m²)	1350,66			
	DPI Limit (W/m²)	8,5	10,2	11,9	13,6
	Area X DPI Limit (W)	11481	13777	16073	18369
Environment Classification		E			
Office – open Plan	Total installed (w)	21880			
	Area (m²)	1256,29			
	DPI Limit (W/m²)	10,5	12,6	14,7	16,8
	Area X DPI Limit (W)	13191	15829	18467	21106
Environment Classification		E			
Restroom	Total installed (w)	1440			
	Area (m²)	128,24			
	DPI Limit (W/m²)	5	6	7	8
	Area X DPI Limit (W)	641	769	898	1026
Environment Classification		E			
Restroom	Total installed (W)	1440			
	Area (m²)	128,24			
	DPI Limit (W/m²)	5	6	7	8
	Area X DPI Limit (W)	641	769	898	1026
Environment Classification		E			
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	Area X DPI Limit (W)	641	769	898	1026
Environment Classification		E			
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	Area (m²)	128,24			

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	DPI Limit (W/m²)	5	6	7	8
	Area X DPI Limit (W)	641	769	898	1026
Environment Classification		E			
Stairs	Total installed (W)	320			
	Area (m²)	80,46			
	DPI Limit (W/m²)	7,4	8,88	10,36	11,84
	Area X DPI Limit (W)	595,404	714,4848	833,5656	952,6464
Environment Classification		A			

Having developed the individual classification of each environment, it is verified that only the ladder has classification level A, not because of the type of lamp used, but because of the poor lighting installed. The other environments had a high installed load, and all were classified as E. This information was compiled in a table to classify the lighting system of the building according to the manual RTQ-C. Taking into consideration the purpose of the environment to be classified, the comparative data took as reference the school / university data. When calculated, the values obtained a general classification for artificial lighting systems E (Table 6), exceeding the lower limits for classification D.

Table 6: Final classification of the building for the artificial lighting system.

		A	B	C	D
School/ University	Total installed (W)	50680			
	Area (m²)	3449			
	DPI Limit (W/m²)	8,5	10,2	11,9	13,6
	Area X DPI Limit (W)	29318	35182	41046	46909
Classification		E			

After the analysis of the original artificial lighting system, it was found that it is necessary to update the models of lamps used in the building, and reduce the installed power from 50,680 W to 22,806 W, thus providing a 65% saving in energy consumption, and achieving level A rating.

3.3. ARTIFICIAL CLIMATIZATION

The determination of the efficiency level of the artificial HVAC system should be considered the classification and rating of the equipment energy efficiency label performed by INMETRO, together with data and energy specifications of each of the models present in the building. For the building, there are a total of 48 equipment, distributed in five different models, described in Table 7, along with the weighting coefficient of each air conditioning system.

Table 7: Air Conditioning Equipment Information.

Floor	Level	EqNum	Numberofequipments	Unit power (Btu / h)	Total power	Weighting	WeightingEqNum
1	B	4	13	42000	546000	0,25490196	1,019607843
2	B	4	7	60000	420000	0,19607843	0,784313725
2	B	4	9	36000	324000	0,1512605	0,605042017
3	B	4	7	60000	420000	0,19607843	0,784313725
3	B	4	12	36000	432000	0,20168067	0,806722689
Total			**48**	**234000**	**2142000**	**1**	**4**

When calculating the weighting, the numerical equivalent 4 was obtained, where this result was analyzed and classified according to RTQ-C. Therefore, the system obtained level B for the Artificial Climatization System.

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The standard of installed equipment was maintained, according to INMETRO's certification seal indicating B for all equipment.

3.4. FINAL EFFICIENCY LEVEL

At the conclusion of the analysis and individual classification of the systems, the final efficiency level for the building (Table 8), maintaining the original materiality, the classification level according to RTQ-C was D, maintaining the original levels of classification of lighting and air conditioning systems, respectively E and B. When proposing the materiality changes in the envelope (R1), the simulated classification for the building was C, even though there was a significant improvement in the envelope classification for each of the simulations.

Table 8 - Final efficiency rating of Building 1.

Materials	Envelopment level R1	Final energy efficiency levelR1	Envelopment level R2	Final energy efficiency level R2
CONVENTIONAL MATERIAL	D	D	D	D
MATERIAL CONV. + AIR LAYER + INTERNAL DRYWALL	B* D**	C	B* D**	C
MATERIAL CONV. + STYROFOAM + AIR LAYER + INTERNAL DRYWALL	A* B**	C	A* A**	C
MATERIAL CONV. + PINUS BARK + AIR LAYER + INTERNAL DRYWALL	A* B**	C	A* A**	C
MATERIAL CONV. + SOYBEAN STRAW + AIR LAYER + INTERNAL DRYWALL	A* B**	C	A* A**	C
MATERIAL CONV. + CORN COB + AIR LAYER + INTERNAL DRYWALL	A* B**	C	A* A**	C
MATERIAL CONV. + SLIMSTONE + AIR LAYER + INTERNAL DRYWALL	B* C**	C	A* A**	C
MATERIAL CONV. + VACUUM PLATE + AIR LAYER + INTERNAL DRYWALL	B* C**	C	A* A**	C

OBS.: * Level of envelopment efficiency: walls; * * Level of envelopment efficiency: coverage.

When developing revised simulations (R2) for insulation materials, the final classification of the building was maintained at C. It is noteworthy here that the original classification level of the artificial lighting system (E) has a large participation in the final classification. of the building. By modifying the lighting classification level to level A, the final classification of the building would obtain Seal A for the simulations performed (R1 and R2).

IV. CONCLUSIONS

The evaluation of energy efficiency and the application of constructive elements that make it possible for a new or refurbished building to become sustainable has been one of the fundamental alternatives in the construction sector. The development of new construction materials, in which production processes provide low energy consumption and reduction of polluting elements, has been increasingly viable (SPINELLI et al., 2019, forthcoming).

The application of innovative materiality in the building envelope proposed in this research, simulating from the use of the RTQ-C prescriptive method for efficiency classification, highlights new possibilities for reduction in energy consumption. Analyzing the building in its original composition, the classification according to RTQ-C presents level D for the envelope, E for artificial lighting system and B for climate system.

The natural materials (tree bark, soybean straw and corn cob) were efficient when applied to the walls (Level A) and roof (Level B), for use as thermal insulation material. The innovative materials (slimstone and vacuum plate) were less efficient compared to natural materials, but with significant advance compared to the original materiality of the building, respectively Level B and C. However, maintaining the original efficiency levels of the artificial lighting and air conditioning system, the overall level of the building remained at C.

Even with a review of the thickness of the thermal insulation layers, the overall level of the building classification remained at C, highlighting that the lighting and artificial air conditioning systems have a high percentage of influence on the final classification of the building, so that this level A, the building's lighting system needs to be modernized, reducing current consumption by 65%. Thus, it is emphasized that the insulation insulation treatment should be considered in conjunction with all other systems, starting at the design stage. It is also proposed that the energy efficiency evaluations be developed using a computer simulation program to compare results between studies.

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