A Review of the Brazilian NBR 15575 Standard: Applying the Simulation and Simplified Methods for Evaluating a Social House Thermal Performance

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Abstract

The new Brazilian ABNT NBR 15575 Standard (the "Standard") recommends two methods for analyzing housing thermal performance: a simplified and a computational simulation method. The aim of this paper is to evaluate both methods and the coherence between each. For this, the thermal performance of a low-cost single-family house was evaluated through the application of the procedures prescribed by the Standard. To accomplish this study, the *EnergyPlus* software was selected. Comparative analyses of the house with varying envelope U-values and solar absorptance of external walls were performed in order to evaluate the influence of these parameters on the results. The results have shown limitations in the current Standard computational simulation method, due to different aspects: weather files, lack of consideration of passive strategies, and inconsistency with the simplified method. Therefore, this research indicates that there are some aspects to be improved in this Standard, so it could better represent the real thermal performance of social housing in Brazil.

1. INTRODUCTION

The Brazilian NBR 15575 Standard - Residential buildings - Performance (ABNT 2012), establishes performance requirements for residential buildings. Among the requirements to be met, one of them refers specifically to the thermal performance of buildings. It is worth mentioning that this Standard is expected to be approved by March 2013.

In general, the thermal performance as established by the NBR 15575 Standard seeks to meet the comfort needs of residents in their homes. There is not any mention of heating or cooling systems. It considers that the housing thermal performance depends only on the interactive behavior between external walls, roof and floor. It allows the thermal performance to be evaluated for external walls and roof independently, or for the building as a whole, defining requirements according to the bioclimatic zone where the building is located. The eight Brazilian bioclimatic zones are prescribed by ABNT NBR 15220 (ABNT 2005).

The Standard establishes two procedures: simplified normative—list of pre-requirements to be fulfilled—and the evaluation method through computer simulation, offered as an alternative, in case the building does not meet the requirements by the simplified method. Figure 1 below outlines the evaluation of thermal performance recommended by the Standard.

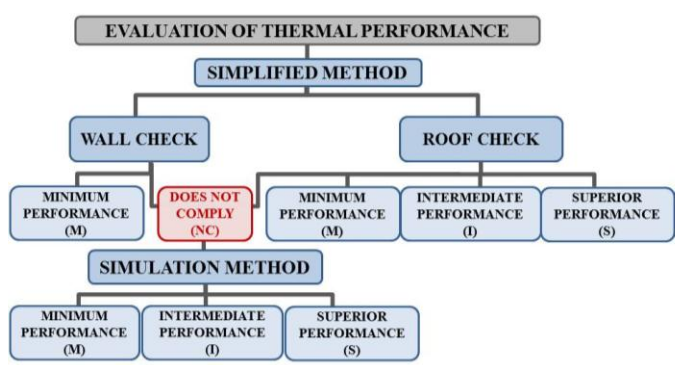

Figure 1: Thermal performance evaluation procedure according to the NBR 15575 Standard.

In the simplified procedure, the sole requirement is that thermal transmittance (U), solar absorptance (α) and heat capacity (C) of external walls and roof have to be below certain limits. Values corresponding to the bioclimatic zone 4, where the city analyzed in this paper is located, are placed in Table 1. It can be noted that according to the Standard's logic, better performance levels are related to lower U-values and solar absorptance (α).

			$\alpha \leq 0.6$	$\alpha > 0.6$
Walls (Minimum Performance/M)	U (W/m².K)	M	≤ 3.7	≤ 2.5
	C (KJ/m².K)		≥ 130	
Roofs (Minimum/M, Intermediate/I or Superior/S Performance)	U (W/m².K)	M	≤ 2.3	≤ 1.5
		I	≤ 1.5	≤ 1.0
		S	≤ 1.0	≤ 0.5
Notes: Walls are classified just as minimum performance/M or it does not comply/NC				

Table 1: Thermal properties of walls and roofs according to NBR 15575 Standard.

The method of evaluation by simulation recommends using software validated by ASHRAE Standard 140 (ASHRAE 2004). The building should be modeled following the guidelines shown in Table 2. Basically, the simulation has to be performed for the house with no occupation and windows and doors closed.

Climate file	Summer and Winter design days
Solar Orientation	According to the project, or: a) Summer: bedroom or living room window to the west (another wall to the north, if possible) b) Winter: bedroom or living room window to the south (another wall to the east, if possible)
Internal gains	No internal gains
Infiltration	1 air change / hour (ACH)
Shading	Consider shading elements, if they are provided in the building
Envelope absorptance	Walls and roof color specified in the project. If wall color is not defined, use three absorptance values 0.3, 0.5 and 0.7
General observations	Each room has to be considered as one thermal zone If the building does not meet the minimum performance in the summer, consider one of the options below: a) adoption of external or internal solar protection, reducing at least 50% of the direct solar radiation b) ventilation rate of 5 ACH c) Combination of the two previous strategies

Table 2: Guidelines for simulations according to NBR 15575 Standard.

Comparisons are made between the outdoor air temperature and the maximum or minimum indoor air temperatures in longer permanence rooms (bedrooms and living rooms) for Summer and Winter design days, based on the following performance levels (Table 3).

	Performance level	Temperatures required for Bioclimatic Zone 4
Summer	Minimum/M	$T_{i, max} \leq T_{o, max}$
	Intermediate/I	$T_{i, max} \leq (T_{o, max} - 2\ °C)$
	Superior/S	$T_{i, max} \leq (T_{o, max} - 4\ °C)$
Winter	Minimum/M	$T_{i, min} \geq (T_{o, min} + 3\ °C)$
	Intermediate/I	$T_{i, min} \geq (T_{o, min} + 5\ °C)$
	Superior/S	$T_{i, min} \geq (T_{o, min} + 7\ °C)$
Notes $T_{i, max}$ is the indoor maximum air temperature, in degrees Celsius, during the Summer design day $T_{o, max}$ is the outdoor maximum air temperature, in degrees Celsius, during the Summer design day $T_{i, min}$ is the indoor minimum air temperature, in degrees Celsius, during the Winter design day $T_{o, min}$ is the outdoor minimum air temperature, in degrees Celsius, during the Winter design day		

Table 3: Minimum, intermediate and superior thermal performance according to NBR 15575 Standard.

This Standard has been causing a great impact in the national civil construction industry. Considering its significance in the actual scenario, it is worth analyzing if its procedures would really lead to better residential building thermal performance. There are still few studies that analyze the NBR 15575. Loura, Assis e Bastos (2011) compare this Standard with other Brazilian housing energy efficiency regulation; Brito et al (2012) analyze the limits prescribed by the simplified method for one bioclimatic zone (the hot and humid zone number 8) and Sorgato et al (2012) analyze some aspects of the Standard text and justify the need for a better consideration of the effect of shading and ventilation. Thus, this paper aims to evaluate the simplified and simulation methods prescribed by the Standard and the coherence between each other. This paper focuses on social housing, due to the general lack of quality usually found in this type of building and the large housing deficit in Brazil.

2. METHODS

The thermal performance of a social housing model was analyzed. The analyses were performed according to the simplified and simulation procedures as described in the Standard, regardless of whether the building had fulfilled the simplified method requirements or not. The simulations followed the recommendations shown in Table 2. The selected computer program for simulating thermal-energy performance was the *Energy Plus* (EERE, 2012). To evaluate the coherence between the two methods, the simulations were accomplished considering different external walls and roof thermal transmittance and solar absorptance, and the same thermal capacity. The values were chosen to cover all ranges considered in Table 1.

The analyzed model corresponds to a single-family and single-storey two-bedroom residence (Figure 2). It represents a typical model of social housing, obtained from a major housing funding agency in Brazil. The simulations were performed for the city of São Carlos, State of São Paulo, latitude 22°01'S and longitude 47°53'W, which represents a subtropical climate, with mild and dry winters and hot and humid summers (Table 4). This city belongs to Brazilian bioclimatic zone four.

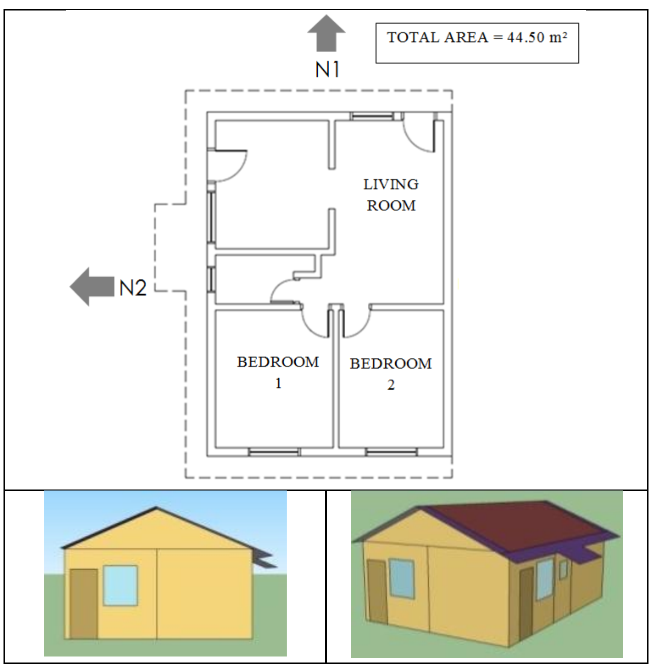

Figure 2: Housing floor plan view, indicating the considered north orientations; housing main façade and perspective.

In addition to the verification of design days, recommended by the NBR 15575 Standard, an analysis was carried out based on the building's annual performance. The EPW climate file was obtained from a national database (Roriz 2012). Annual heating and cooling degree-hours were obtained for the rooms of longer stay (living-room and two bedrooms). The limits of 18 °C for heating and 26 °C for cooling were considered.

Month	Max T (°C)	Min T (°C)	AverUR (%)
January	26.3	18.3	76.6
February	27.5	18.5	74.5
March	26.5	17.6	73.7
April	25.5	16.6	75.7
May	22.7	12.7	71.1
June	23.1	13.1	70.5
July	24.4	12.0	53.2
August	26.1	14.8	57.9
September	26.0	13.8	59.0
October	27.9	17.6	65.2
November	27.8	17.0	68.5
December	27.4	17.4	70.7
Average	25.9	15.8	68.1

Max T- monthly average maximum air temperature
Min T- monthly average minimum air temperature
AverUr- monthly average relative humidity

Table 4: Climate data for Sao Carlos, SP.

Table 5 summarizes the main input data for the simulations and their variations. With the exception of solutions defined for walls and roofs, the other fixed parameters correspond to the most common values for this type of housing in Brazil.

3. RESULTS

3.1. Comparison between Simulation and Simplified Procedures

In the analysis corresponding to the simplified procedure, the U-value, the absorptance and the heat capacity of the walls and roof must comply with certain limits (Table 1). That is, by the simplified procedure only the requirements for walls and roofs are evaluated. In the studied cases (Table 6), it can be noted that if the walls or the roof show absorptance above 0.6 (dark colors) and that the thermal transmittance is above 2.5 (for the walls) or 1.5 (for the roofs), the minimum performance is not met. These three cases are highlighted in the two first columns of Table 6. When this occurs, the simulation procedure has to be done, when the performance of housing is evaluated as a whole. Otherwise, it is not necessary to simulate the building.

Variable parameters			
Solar Orientation (Figure 2)	N1 - analysis of the Winter design day and by the degree-hour method[1] N2 - analysis of the Summer design day		
α_w[2]	$\alpha_w1 = 0.30$	$\alpha_w2 = 0.56$	$\alpha_w3 = 0.72$
α_r[3]	$\alpha_r1 = 0.30$	$\alpha_r2 = 0.90$	
Construction solutions for the external walls (W) (Material order from outside to inside)	W1 Solid brick (10cm) uncoated U = 3.70 W / m². K and C = 149 kJ / m². K		
	W2 Mortar (2.5 cm) + expanded polystyrene insulation (0.5 cm) + solid brick (10cm) U = 2.40 W / m². K and C = 149 kJ / m². K		
	W3 Mortar (2.5 cm) + expanded polystyrene insulation (1cm) + solid brick (10cm) U = 1.85 W / m². K and C = 149 kJ / m². K		
Construction solutions for the roof (R) (Material order from outside to inside)	R1 Mortar (2.5 cm) + insulation (expanded polystyrene) 0.5 cm + concrete slab 10cm + mortar 2.5cm U = 2.30 W / m². K and C = 270 kJ / m². K		
	R2 Fiber cement tile (slab and cover) (0.8cm) + expanded polystyrene insulation (0.5 cm) + concrete slab (12cm) U = 1.61 W / m². K and C = 264 kJ / m². K		
	R3 Fiber cement tile (slab and roof) (0.8cm) + expanded polystyrene insulation (1cm) + concrete slab (12cm) U = 1.34 W / m². K and C = 264 kJ / m². K		
Fixed parameters			
Window glass type	Clear glass 4 mm Solar transmittance at normal incidence: 0.84		
Percentage of window area	window area/ wall area bedrooms: 19.3% living room: 16.3%		
Construction solution for the internal walls	Mortar (2.5 cm) + hollow concrete block 9 cm + mortar (2.5 cm) U = 2.27 W / m². K, C = 206 kJ / m². K		
Internal gains	No internal gains		
Air infiltration	1 ACH in each room and in the attic		

Notes
[1] A reference house, with usual walls and roof constructions was simulated in various solar orientations and the N1 orientation resulted in the maximum heating plus cooling degree-hours (considering the sum of the three rooms).
[2] α_w= Solar absorptance of the external surface of the walls
[3] α_r = Solar absorptance of the roof

Table 5: Main parameters of the simulations.

Alternative simplified methods to simulation can be pointed to by standards in order to facilitate the analyses of building models that have typical features. Thus, the performance of less elaborate buildings can be quickly evaluated. The simulation analysis, a way to assess more accurately the housing performance, could be used only when necessary. Therefore, coherence between these methods is expected, so that the simplified method represents a reliable building performance. Or, if the model is simulated, its performance has to be equal or superior to the evaluation provided by the simplified method. This consistency between both methods was always observed when the building performance did not comply with the simplified procedure requirements (highlighted cases in Table 6: (g), (m) and (n)). It can be noted that in these three cases, when the buildings were simulated, two distinct situations were found:

1) in the Summer, the performance continued to not meet the criteria and in the Winter, minimum performance was achieved. This happened in cases (g) and (m);

2) minimum performance was achieved both in the Summer and Winter. This happened in case (n).

Moreover, there are other situations in which the coherence between the methods was not observed. In such cases, highlighted in Table 6 (cases (d), (h), (l) and (o)), the performance requirements were met according to the simplified method, and later it was shown that the performance requirements were lower or unmet according to the simulation method. This type of result, also observed in other situations (Brito et al. 2008), indicates that there are problems in the Standard's simplified method. It is believed that the evaluation of a home building solely by the thermal properties of its environment, without considering other factors influencing the thermal performance is, in principle, one form of flawed analysis. Even in the case of social interest housing, which meet very limited standards and have very similar architectural features. After all, these results regarding very simple low-cost housing, show that the limits set by the simplified method do not consistently represent what happens in the simulation. Furthermore, it is important to highlight that the NBR 15575 Standard is valid for any type of residential building, in which the performance differences due to other factors, such as the percentage of glass area, could lead to greater inconsistencies.

	Evaluation by Simplified Procedure		Evaluation by Computer Simulation Procedure	
Envelope thermal properties Walls and Roof (U, α)	Performance		Performance	
	Walls[1]	Roofs	Winter	Summer
(a) W1, α_{w1} + R2, α_r1 (3.7, 0.3) + (1.61, 0.3)	M	M	M	M
(b) W2, α_w1 + R2, α_r1 (2.4, 0.3) + (1.61, 0.3)	M	M	M	M
(c) W3, α_w1 + R2, α_r1 (1.85, 0.3) + (1.61, 0.3)	M	M	M	I
(d) W1, α_w2 + R2, α_r1 (3.7, 0.56) + (1.61, 0.3)	M	M	M	NC
(e) W2, α_w2 + R2, α_r1 (2.4, 0.56) + (1.61, 0.3)	M	M	M	M
(f) W3, α_w2 + R2, α_r1 (1.85, 0.56) + (1.61, 0.3)	M	M	M	M
(g) W1, α_w3 + R2, α_r1 (3.7, 0.72) + (1.61, 0.3)	NC	M	M	NC
(h) W2, α_w3 + R2, α_r1 (2.4, 0.72) + (1.61, 0.3)	M	M	M	NC
(i) W3, α_w3 + R2, α_r1 (1.85, 0.72) + (1.61, 0.3)	M	M	M	M
(j) W2, α_w1 + R1, α_r1 (2.4, 0.3) + (2.3, 0.3)	M	M	M	M
(k) W2, α_w1 + R2, α_r1 (2.4, 0.3) + (1.61, 0.3)	M	M	M	M
(l) W2, α_w1 + R3, α_r1 (2.4, 0.3) + (1.34, 0.3)	M	I	M	M
(m) W2, α_w1 + R1, α_r2 (2.4, 0.3) + (2.3, 0.9)	M	NC	M	NC
(n) W2, α_w1 + R2, α_r2 (2.4, 0.3) + (1.61, 0.9)	M	NC	M	M
(o) W2, α_w1 + R3, α_r2 (2.4, 0.3) + (1.34, 0.9)	M	M	M	NC

[1] According to the Standard, in the simplified procedure, walls are classified just as minimum performance or it does not comply (NC).

(grey cell) Minimum performance not achieved by the simplified method or the simulation method

(bold border) Performance by simplified method superior to performance by simulation

Table 6: Compliance to the simplified and simulation methods according to NBR 15575 Standard.

3.2. Evaluation by the NBR 15575 Standard Simulation Procedure (Design Days) and by the Annual Simulation

3.2.1. Walls with different U-values and absorptances

Figures 3 and 5 show the results according to the Standard simulation procedure, which considers the Summer (Figure 3) and Winter (Figure 5) design days. Figure 3 shows in the y-axis the $T_{i,\ max}$ in bedroom 1 during the Summer design day (warmest room in the summer, with the worst sun exposure). Figure 5, the $T_{i,\ min}$ in bedroom 2 during the Winter design day (the coolest room in the winter, also with the worst sun exposure). The U-value of the external walls is shown in the x-axis and each line corresponds to distinct solar absorptances of the house walls. In all combinations shown in these graphs, the roof was maintained with U = 1.61 W / m². K and α = 0.3. The performance levels that the house would have according to the Standard's criteria, presented in the Introduction, are indicated on the graph.

Figures 4 and 6 show the results for the same simulations, run for a typical year. The annual cooling (Figure 4) and heating (Figure 6) degree-hours are represented on the y-axis. They are the sum of the annual degree-hours of the longer permanence rooms. In this case, there are no performance levels, as this is not a method regulated by the Standard.

Figure 3 shows that the minimum performance was not reached in the case of higher values of absorptance and U-value. These results follow the same pattern of the simplified method table (Table 1), where only walls with a U-value below certain limits are accepted and these limits decrease as the solar absorptance increases. However, the limits found for this situation differ somewhat from those established by the Standard, which led to the incompatibility between the simplified and the simulation methods presented in the previous item (Table 6). The results for the typical year simulation (Figure 4) present the same graphic pattern.

In Figure 5 it was found that the minimum performance was reached in all cases analyzed. Similar to the Summer, walls with higher U-value show the worst performance (lower temperatures in the Winter). Nevertheless, with respect to solar absorptance, the result was the opposite of that observed for the Summer: the higher the absorptance, the better the performance. That is, for the situations above, it is more difficult to achieve minimum performance in the Summer than in the Winter. Similar results were obtained by the annual analysis method (Figure 6).

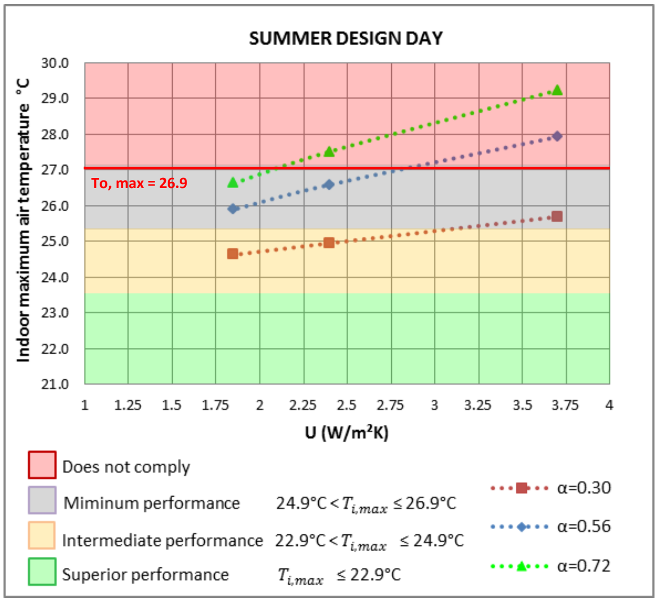

Figure 3: Indoor maximum air temperature during the Summer design day, for the house with various external walls U-value and solar absorptance. Roof with U = 1.61 W / m². K and α = 0.3.

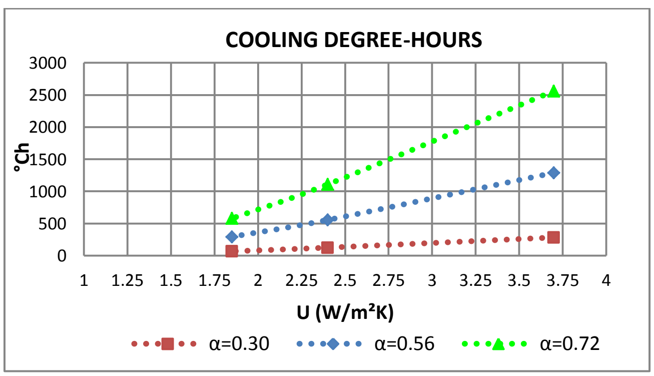

Figure 4: Cooling degree-hours during a typical year for the house with various external walls U-value and solar absorptance. Roof with U = 1.61 W / m². K and α = 0.3.

3.2.2. Roofs with different U-values and absorptances

Similarly to the walls, Figures 7, 8, 9 and 10 refer to the results for Summer and Winter design days (Figures 7 and 9) and for the annual simulation (Figures 8 and 10), considering distinct roof U-values and solar absorptances. In such cases, the wall was maintained with U=2.4 W / m². K and α = 0.3 for all combinations.

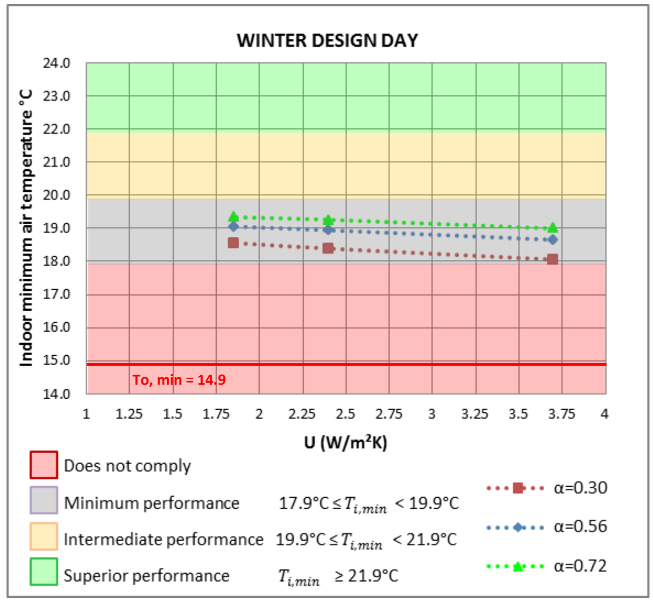

Figure 5: Indoor minimum air temperature during the Winter design day, for the house with various external walls U-value and solar absorptance. Roof with U = 1.61 W / m². K and α = 0.3.

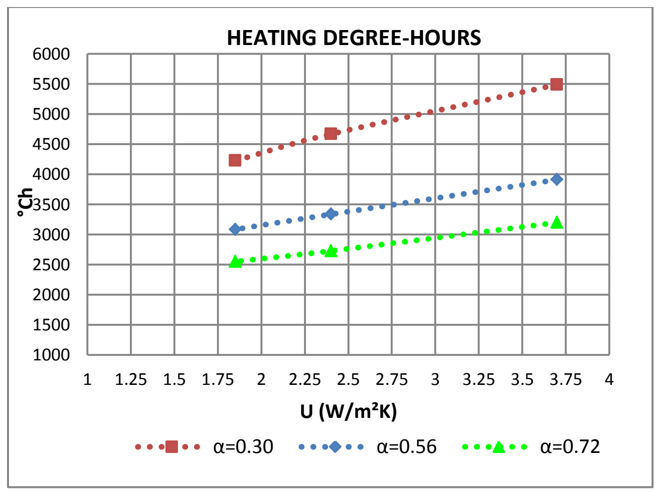

Figure 6: Heating degree-hours during a typical year for the house with various external walls U-value and solar absorptance. Roof with U = 1.61 W / m². K and α = 0.3.

The results for the Summer design day (Figure 7) are very similar to the ones previously shown in Figure 3: the higher the absorptance and the U-value, the worse the performance. Also, in a similar way, these results follow the same logic of the simplified method (Table 1), but the limits do not correspond exactly to those established by the Standard, resulting in the incompatibilities already mentioned in the previous items (3.1 and 3.2.1). The typical year simulation (Figure 8) shows the same pattern of results.

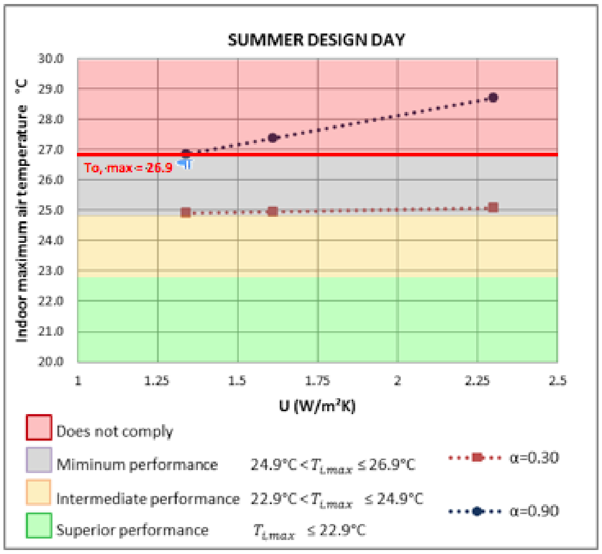

Figure **7:** Indoor maximum air temperature during the Summer design day, for the house with various roof U-value and solar absorptance. External walls with U = 2.40W / m². K and α = 0.3.

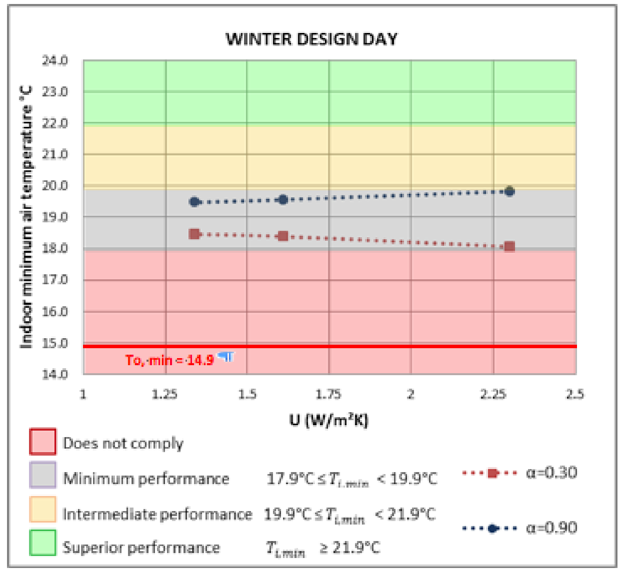

Figure 9: Indoor minimum air temperature during the Winter design day, for the house with various roof U-value and solar absorptance. External walls with U = 2.40W / m². K and α = 0.3.

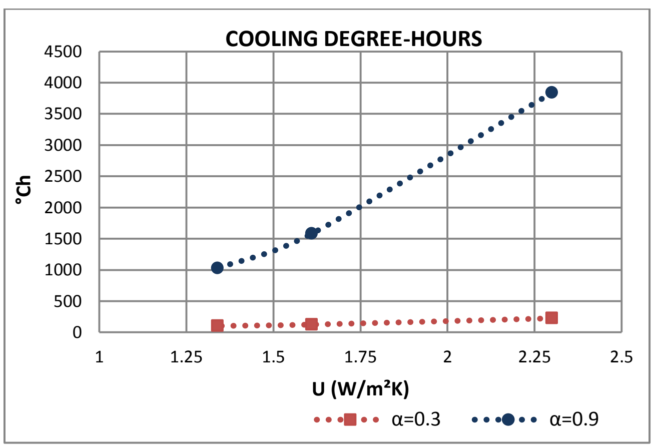

Figure 8: Cooling degree-hours during a typical year for the house with various roof U-value and solar absorptance. External walls with U = 2.40W / m². K and α = 0.3.

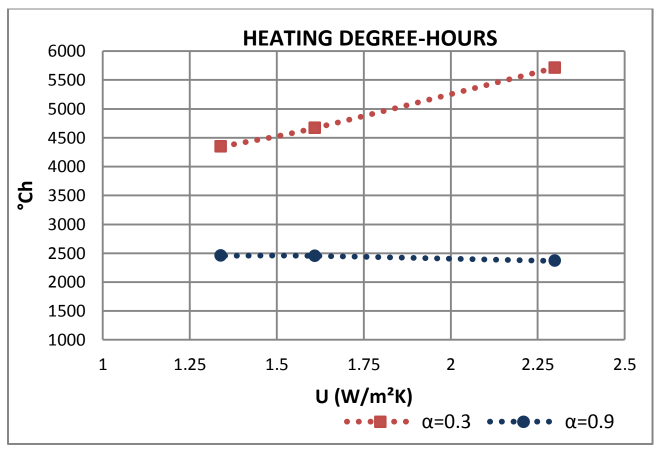

Figure 10: Heating degree-hours during a typical year for the house with various roof U-value and solar absorptance. External walls with U = 2.40W / m². K and α = 0.3.

Regarding the Winter, all cases are classified with the minimum performance (Figure 9). Again, the results follow the same pattern already mentioned in 3.2.1, when thermal properties of walls were varied. And also, achieving the desired performance for Summer requires more of the envelope than for Winter. The typical year simulation showed the same type of results (Figure 10).

3.3. General Remarks on the Simulation Method

When applying the simulation procedure, some aspects that could be improved were observed and they are listed in the sequence.

1) Definition of Summer and Winter design days. Climate data for these days have to be based on the Standard, which provides this information only for state capitals, and even then the data is incomplete. This indicates the need of interpretation by the user, which may lead to misunderstandings.
2) Lack of consideration of important aspects that influence the building performance and may change its final evaluation. The simulation procedure does not consider the building with internal gains—people, equipment, lighting—

which would change the results, and better reflect the thermal performance of the housing in interaction with its users (as it occurs, for example, in another national standard that assesses home energy efficiency, the RTQ-R (INMETRO 2010)). Also, the NBR 15575 Standard disregards the use of passive strategies for thermal comfort, such as natural ventilation and shading. These resources are widely used in this type of building in Brazil, where the use of artificial conditioning systems has a high cost. As evidenced by Sorgato et al. (2012), these aspects significantly influence the building performance and should be considered more thoroughly by the Standard.

4. CONCLUSION

The NBR 15575 Standard has been widely discussed in the academy and civil construction industry. With its approval, a great impact in the construction market is expected. However, this research indicates that there are some aspects to be improved. This Standard presents simplified and simulation procedures to verify the thermal behavior of buildings. The simplified method is important because it provides general guidelines for easy verification, requiring no special knowledge, as in the case of the simulation method. Nevertheless, in the results analyzed in this research, incoherence was found between the two methods presented in the Standard. In four studied situations, performance requirements were met according to the simplified method, and later it was shown that they were lower or unmet according to the simulation method. In addition, the simplified method sets limits for the envelope thermal properties that do not take into account the equilibrium between different needs for Summer and Winter. Moreover, evaluating a building only by its opaque surface is a limited assessment. There are other aspects, such as the glass area, that should also be considered. It is also important to highlight that these results are limited to Sao Carlos (Brazilian bioclimatic zone number four). The analysis of other climate zones would contribute to improving NBR 15575.

Acknowledgements

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