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Surface condensation risk evaluation in light steel framing walls using ISO 13788:2012

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Abstract: In recent years, Light Steel Framing (LSF) system has been increasing in Brazil. Despite numerous advantages when compared with the conventional construction system, such as the agility of the construction process, when inadequately designed, buildings can have their hygrothermal behavior penalized. Pathologies, such as surface condensation, can lead to degradation of the building envelope, and compromise indoor air quality. Thus, the objective of this paper is to evaluate the risk of surface condensation in a specific type of LSF system envelope, in an artificially conditioned environment, in bioclimatic zones 1 and 2 of Brazil. The evaluation uses the methodology described in the ISO 13788 (2012) standard. The methodology employed in this study consists of the conduction of computational simulations of a vertical enclosure within the LSF system using the THERM software. The evaluated configuration presented a risk of surface condensation in both regions. Among the strategies to reduce the effects of thermal bridges and the consequent risk of condensation in the panels, the one that presented the best results is the application of EPS thermal break strips.
Keywords: Surface condensation; ISO 13788; Light Steel Framing; vertical enclosure; Brazilian bioclimatic zones.

1 Introduction

The construction industry in Brazil, even today, is predominantly characterized by the conventional construction system, employing masonry and reinforced concrete structures. It is marked by workforce informality, high rates of waste and improvisation (Gomes, Souza and Tribess, 2012). However, the LSF system has gained significant popularity in the Brazilian market, particularly as an alternative for housing construction in social programs, schools, and shopping malls (ABCEM, 2021).

LSF constructions offer several advantages over conventional construction methods, including high architectural adaptability, high structural strength-to-weight ratio, faster execution time, reduced on-site space requirements, superior manufacturing quality, reduced material waste and high potential for steel recycling (Santos, 2017). Given the current global context, there is a growing focus on sustainable construction solutions to mitigate environmental impacts. Consequently, systems like LSF are emerging as favorable alternatives to traditional construction approaches.

However, despite the mentioned advantages, poorly designed LSF buildings can present certain drawbacks, such as low thermal inertia and the occurrence of thermal bridges. Thermal bridges refer to areas within the building envelope where concentrated phenomena of heat transfer take place, adversely affecting the energy efficiency of the structure (Santos, 2017). One of the outcomes of these effects is the occurrence of surface condensation (Roque and Santos, 2017).

Internal surface condensation occurs when the temperature of the inner face of the envelope is lower than the dew point temperature (Bellia and Minichiello, 2003). The risk of surface condensation tends to be higher in areas with greater heat transfer between the interior and exterior environment (Barreira, 2013). In LSF buildings this effect typically occurs along the alignment of the metal studs and can lead to the development of mold and the phenomenon known as "ghost marking", which involves dark-colored marks caused by surface condensation and the accumulation of dust on the alignment of the studs within the internal vertical panels (Gomes, 2012).

Brazilian standards, despite evaluating and providing criteria for the performance of residential buildings, currently do not address the effects of condensation. Furthermore, studies on LSF buildings predominantly focus on the load-bearing structure, with limited research conducted on the hygrothermal behavior of the building's envelopes. Given the increasing adoption of this construction technique, it is imperative to consider other performance parameters of buildings to ensure extended durability and improved indoor environmental quality for occupants.

Thus, the aim of this study is to evaluate the risk of surface condensation in a specific type of vertical enclosure within the LSF system, using the methodology outlined in the ISO 13788 (2012) standard for bioclimatic zones 1 and 2 of Brazil. Through this performance evaluation, it is expected that this work will contribute to the consolidation of LSF in Brazil as a consistent alternative to the traditional construction system.

2 Literature review

2.1 LSF system

The LSF system is characterized by a dry construction method that uses prefabricated and assembly-based materials, with cold-formed galvanized steel profiles as the primary construction element. These profiles are responsible for composing the structural and non-structural panels, beams, roof trusses, and other components of a building (Santiago, Freitas and Crasto, 2012). Vertical and horizontal enclosure panels, on the other hand, serve to cover the structure and to provide support for thermal and acoustic insulation materials, finishes, and waterproofing (Santos, 2018).

Due to the increasing utilization of LSF, a wide variety of materials are now available for vertical closing. The NBR 16970-1 (2022) mentions gypsum plasterboard, cement boards, Oriented Strand Board (OSB) panels, and vinyl siding as the most used vertical enclosure in Brazil. Additionally, thermal insulation materials such as glass wool and EPS panels can also be mentioned.

The LSF system offers numerous advantages compared to conventional construction methods. These include the high-quality production of raw materials, fast execution, high mechanical strength relative to its weight, organized construction sites, and waste reduction (Santos, 2018). Despite these clear advantages, there are still limitations related to this system, such as height restrictions and, when poorly designed, inefficient thermal performance of the buildings (Roque and Santos, 2017).

2.2 LSF thermal performance

To evaluate the thermal performance of LSF buildings, it is important to determine the type of construction system in relation to the position of the thermal insulation. There are three types of systems: cold construction, hybrid construction and warm construction (Santos, Martins and Silva, 2014). Cold construction is characterized by having all insulation located inside the wall, hybrid construction combines insulation both on the exterior and interior of the wall, and warm construction has all insulation located on the exterior of the wall, as shown in Figure 1 (Roque and Santos, 2017).

In cold construction, the insulation located inside the wall is interrupted by the presence of metal profiles. According to Santos, Martins and Silva (2014), this type of system is not recommended for regions with cold climates, as the effects of thermal bridges are more pronounced in this type of construction, increasing the chances of surface condensation and other pathologies. Hybrid construction, in turn, combines both solutions. Part of the insulation is inserted inside the wall and part is located on the outside in a continuous manner (Santos, Martins and Silva, 2014). In order to reduce the risk of condensation, it is recommended that at least one third of the insulation be positioned continuously (Martins, Santos and Silva, 2015). Finally, warm construction has the thermal insulation fully positioned on the outside and without interruption. This is the most suitable system for cold climates, as it reduces the risk of condensation in the envelope and reduces the effects of thermal bridges. However, this configuration has thicker walls, which can reduce the area of internal environments.

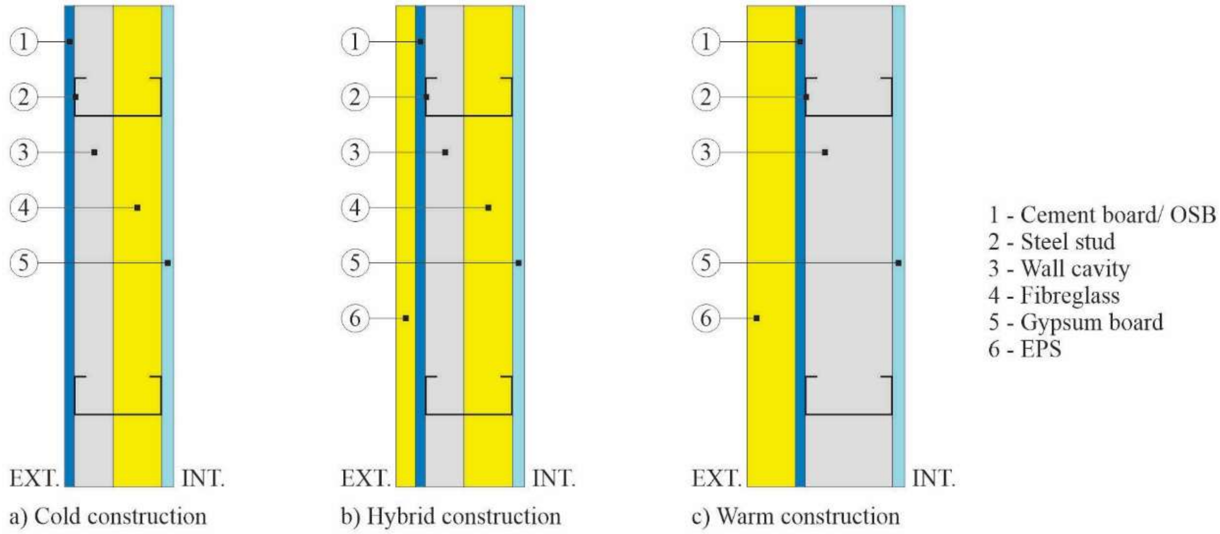


Figure 1. LSF construction classification according to the insulation material position. Adapted from Santos, Martins and Silva (2014).

2.3 Surface condensation and ISO 13788 (2012) standard

Condensation can be defined as the conversion of water vapor into liquid water (BS 5250, 2016). It is a common phenomenon in buildings and is associated with relative humidity, occurring primarily in two ways: interstitial condensation and surface condensation. The first occurs between layers within the building envelope, while the latter occurs on the surface of the enclosure (Pires, González and Tutikian, 2021).

According to Barreira (2013), the assessment of surface condensation considers the surface temperature and the dew point temperature of the air. Whenever the surface temperature is lower than the dew point temperature, surface condensation occurs. The study of this phenomenon is of great importance as surface condensation promotes the development of mold, compromises indoor quality, and leads to the degradation of finishes. In addition, condensation also increases the thermal conductivity of the building envelope.

According to Guerra et al., (2012), a combination of low external air temperatures, high indoor relative humidity, high internal air temperature, and ventilation set up favorable conditions for the occurrence of surface condensation. Additionally, the materials used in the building envelope also play a role in the development of this phenomenon (Silveira, Pinto and Whestphal, 2019).

In Brazil, the NBR 15575 standard (ABNT, 2013) addresses the performance of residential buildings with the aim of ensuring safety, occupants' comfort, and the longevity of the property. However, despite the impact of condensation on the durability of building elements and indoor air quality, this standard does not specifically address its effects (Pires, González and Tutikian, 2021). International codes, such as the "Code of practice for control of condensation in building", (BS 5250, 2016), refer to the method described in ISO 13788 (2012), (Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation), for calculating the risk of surface condensation.

ISO 13788 (2012) has been used to provide a simplified criterion to analyze surface and interstitial condensation and the risk of mold development, while also offering recommendations to mitigate these phenomena. Nevertheless, this standard has certain limitations, such as the omission of moisture originating from the ground and building elements, as well as the failure to account for climatic and environmental variations during the analysis (Mumovic et al., 2006).

3 Materials and methods

The methodology employed in this study consists of the conduction of computational simulations of a vertical enclosure within the LSF system using the THERM software (Berkeley LAB, 2022). Subsequently, based on the obtained results, an assessment of the risk of surface condensation in the enclosure will be carried out, following the guidelines outlined in ISO 13788 (2012) standard. The thermal behavior of the cold system's construction configuration was also evaluated after adopting strategies that minimize the effects of thermal bridges in the panel and consequently reduce the risk of surface condensation.

3.1 The object of study definition

To evaluate the surface condensation risk in a vertical LSF enclosure, it is necessary to define a representative envelope model. According to ISO 10211 (2017) standard, the geometric model should be defined using a section plane to accurately represent the entire wall. Figure 2 represents the geometry of the model along with its dimensions in millimeters. This study evaluates an external LSF enclosure with insulation located inside the wall (cold construction). This is the most widely used type of enclosure in Brazil. Additionally, Table 1 provides the configuration of the panel and the thermophysical properties of the respective materials used.

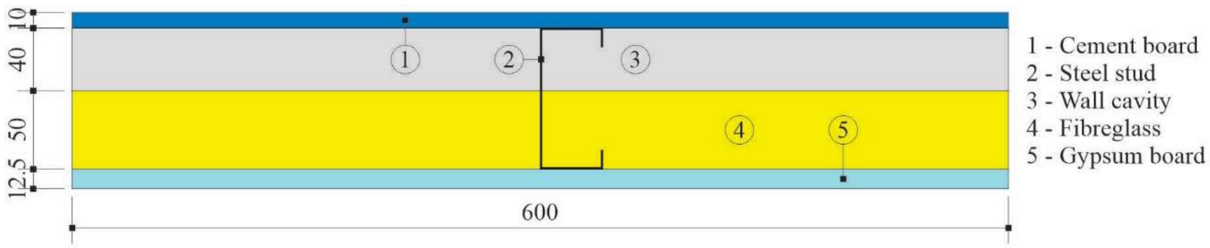


Figure 2. Panel cross section for modeling in THERM software (dimensions in millimeters).

Table 1. Summary of the construction configuration adopted for simulation model. Adapted from Clarke (2001).

Material	Thickness (mm)	Density (kg/m³)	Thermal conductivity (W/mK)
Cement board (external environment)	10	1800	0.65
Steel studs (90x40x12x0,8mm)	90	7800	55
Fibreglass	50	12	0.04
Gypsum board (internal environment)	12.5	800	0.17

3.2 Modeling in THERM software

THERM is a downloadable for free computational program developed by Lawrence Berkeley National Laboratory (LBNL), designed for modeling two-dimensional heat transfer effects in building components, such as windows, walls, roofs, and others (Berkeley LAB, 2022). The heat transfer analysis conducted by the software is based on the finite element method, providing results such as surface temperature values, heat transfer coefficients, thermal resistance, heat flow vectors, and isotherm lines (Berkeley LAB, 2022). In this study, THERM software is used to obtain surface temperature values along the building envelope (Figure 3). In addition, visualizing the heat flow through the steel stud also contributes to understanding the effects of thermal bridges across the panel (Figure 4).

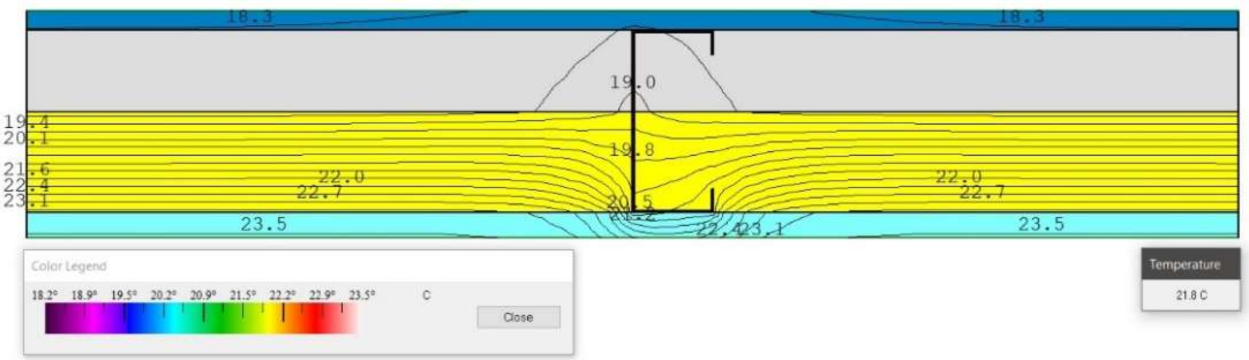


Figure 3. Example of Isotherms generated by the THERM program.

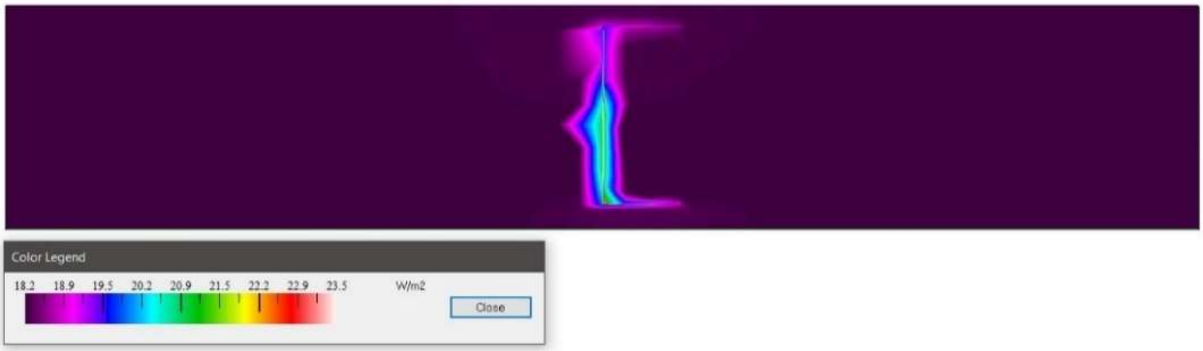


Figure 4. Graphical example of heat flow through the steel stud generated by the THERM program.

To achieve this, it is essential to construct the model to be simulated in the program's interface, apply materials thermal properties, and define boundary conditions for the evaluated situation, including temperature. Once all the input data has been provided, the simulation can be executed, and necessary results for assessing the surface condensation risk can be obtained.

THERM's steady-state conduction algorithm is a derivative of the computer program TOPAZ2D (Shapiro, 1986). THERM's radiation view-factor algorithm is a derivative of the computer program FACET (Shapiro, 1983). The governing equation for two-dimensional heat conduction is derived from the general energy equation and is given by the partial differential equation shown in Eq. (1).

$$k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)+q_g=0 \tag{1}$$

where: q_g = internal heat generation; subject to the following set of boundary conditions: $q_f = 0$ adiabatic boundary condition; T = f (x, y) temperature boundary condition; $q_f = q$ known heat flux boundary condition; $q_r = h(T - T_\infty)$ convection/linearized radiation boundary condition; $q_r = \varepsilon_i \sigma T_i^4 - \alpha_i H_i$ radiation boundary condition.

The magnitude of the heat flux vector normal to the boundary, $q = q_f + q_c + q_r$ is given by Fourier's law in Eq. (2).

$$q_f+q_c+q_r=-k\left(\frac{\partial T}{\partial x}n_x+\frac{\partial T}{\partial y}n_y\right) \tag{2}$$

where: k = thermal conductivity; n_x, n_y = vector components of the outward facing normal to the boundary; T = temperature.

Details of the automatic mesh generator algorithm, error estimation algorithm and other calculation routines can be obtained in the program manual (THERM, 1998).

3.3 Domain and bondary conditions definition

For the simulations runed on THERM software, two bioclimatic zones (BZ) were chosen for analysis: BZ1 and BZ2. The selection of these two relatively homogeneous regions in terms of climatic aims to encompass a temperate climatic zone, where the thermal bridges effects are more critical, which represents a significant portion of the Brazilian territory. To represent zones 1 and 2, the cities of Curitiba – PR and Santa Maria – RS were selected, respectively. The choice of these cities was determined by the availability of climate data provided by "Instituto Nacional de Meteorologia" (INMET – Brazilian National Institute of Meteorology).

In this study, the simulation of the geometric model is limited to the assumption of an artificially conditioned environment at the minimum temperature condition. The minimum temperature condition is defined as the average of daily minimum temperature recorded over a period of ten years for the considered bioclimatic zones. The definition of seasons was not adopted, thus, due to the vast Brazilian territory extent, the behavior of seasons varies significantly from region to region. Therefore, the average of the lowest daily temperature recorded between the years 2011 and 2021, as available from INMET for Curitiba and Santa Maria, was determined, as presented on Table 2.

Table 2. Average minimum temperatures – period between 2011 -2021. Adapted from INMET, (2023).

Data		Average Monthly temperatures (°C)											
BZ	City	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dez
1	Curitiba	18.1	18.1	16.8	15.2	12.7	11.2	10.5	11.0	12.8	14.6	15.1	17.4
2	S. Maria	20.1	19.5	17.4	15.3	12.1	10.3	9.4	11.3	12.7	15.5	17.3	18.9

For the development of the computational simulations, the outside air temperature was determined by the minimum temperature condition, the internal air temperature was determined to be 24.0°C, and the relative humidity was set at 65% for the indoor environment, and the lateral faces of the object of study were considered adiabatic. The selection of the internal cooling temperature limit was based on the ranges specified in the NBR 16401 (2008) standard, while the relative humidity was determined considering that surface condensation risk is higher in more humid environments, i.e., in environments with values above 60% (Santos, 2017).

3.4 Surface condensation risk evaluation according to ISO 13788 (2012) standard

To assess the surface condensation risk, the ISO 13788 (2012) standard employs the parameter called temperature factor at the internal surface (f_{Rsi}) as a criterion. The f_{Rsi} is defined as shown in Eq. (3). In this section, all equations presented for calculating the surface condensation risk were obtained from ISO 13788 (2012).

$$f_{Rsi} = \frac{T_{si} - T_e}{T_i - T_e} \tag{3}$$

where: T_{si} = Internal surface temperature (°C); T_e = External air temperature (°C); T_i = Internal air temperature (°C).

The f_{Rsi} varies according to the relative humidity of the internal and external air, as higher humidity levels increase the risk of condensation (Bellia and Minichiello, 2003). To assess the condensation risk, f_{Rsi} is compared with the critical or minimum temperature factor ($f_{Rsi,min}$), as shown in Eq. (4), given by:

$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} \tag{4}$$

where: $T_{si,min}$ = Minimum internal surface temperature (°C); T_e = External air temperature (°C); T_i = Internal air temperature (°C).

Thus, if f_{Rsi} is lower than $f_{Rsi,min}$, it indicates condensation surface risk. The process to obtain these parameters is outlined in the following steps:

1. Define values of external temperature (T_e), external relative humidity (φ_e), internal temperature (T_i), and internal relative humidity (φ_i);

2. From these values, determine saturation vapor pressure (p_{sat}) using one of two empirical formulas: Eq. (5) and Eq. (6).

$$p_{sat} = 610{,}5 \times e^{\frac{17{,}269 \times T_i}{237{,}3 + T_i}} \text{ para } T_i \geq 0°C \tag{5}$$

$$p_{sat} = 610{,}5 \times e^{\frac{21{,}875 \times T_i}{265{,}5 + T_i}} \text{ para } T_i < 0°C \tag{6}$$

where: p_{sat} = Saturation vapor pressure (Pa); T_i = Internal air temperature (°C).

3. Determine indoor air pressure (p_i) according to Eq. (7):

$$p_i = p_{sat} \times \varphi_i \tag{7}$$

where: p_i = Indoor air pressure (Pa); p_{sat} = Saturation vapor pressure (Pa); φ_i = Internal relative humidity.

4. Calculate minimum saturation pressure (psat,min) according to Eq. (8):

$$p_{sat,min} = \frac{p_i}{\varphi_{cr}} \tag{8}$$

where: $p_{sat,min}$ = Minimum saturation pressure (Pa); p_i = Indoor air pressure (Pa); φ_{cr} = Critical air relative humidity.
ISO 13788 (2012) standard defines the critical relative humidity (φ_{cr}) as 0.8 (80%) for cases in which specific definition is provided.

5. Define critical surface temperature (Tsi,min) using the empirical formulas Eq. (9) and Eq. (10):

$$T_{si,min} = \frac{237{,}3 \times \log_e\left(\frac{p_{sat,min}}{610{,}5}\right)}{17{,}269 - \log_e\left(\frac{p_{sat,min}}{610{,}5}\right)} \text{ para } p_{sat,min} \geq 610.5\text{Pa} \tag{9}$$

$$T_{si,min} = \frac{265{,}5 \times \log_e\left(\frac{p_{sat,min}}{610{,}5}\right)}{21{,}875 - \log_e\left(\frac{p_{sat,min}}{610{,}5}\right)} \text{ para } p_{sat,min} < 610.5\text{Pa} \tag{10}$$

where: $T_{si,min}$ = Minimum internal surface temperature (°C); $p_{sat,min}$ = Minimum saturation pressure (Pa).

6. Calculate the parameters f_{Rsi} and $f_{Rsi,min}$ according to Eq. (1) and Eq. (2), respectively, and perform the necessary analyses.

4 Results and discussion

Based on the geometric model simulation and the data obtained for the surface temperatures, the condensation risk on the enclosure internal surface was assessed for each representative city, following the method described in ISO 13788 (2012) standard. For the evaluated condition with an internal air temperature (Ti) of 24.0°C, internal relative humidity (φi) of 65%, and external relative humidity (φe) of 80%, the minimum surface temperature was found to be 20.6°C. If the model internal surface exhibits a temperature below this value at any point, there is a risk of condensation occurrence. It is important to note that the method used involves comparing the temperature factor (fRsi) with the minimum temperature factor (fRsi,min). When fRsi is lower than fRsi,min, it indicates the potential for surface condensation. The results obtained for BZ1 and BZ2 are represented in Table 3 and Table 4, respectively.

Table 3. Surface condensation risk analysis for Curitiba (BZ1) – according to ISO 13788 (2012)

Mon.	T_e (°C)	T_i (°C)	φ_i (%)	p_{sat} (Pa)	p_i (Pa)	$P_{sat,min}$ (Pa)	$T_{si,min}$ (°C)	$f_{Rsi,min}$	T_{si} (°C)	f_{Rsi}	RISK
JAN	18.1	24.0	65	2982	1938	2423	20.6	0.42	22.0	0.66	NO
FEB	18.1	24.0	65	2982	1938	2423	20.6	0.42	22.0	0.66	NO
MAR	16.8	24.0	65	2982	1938	2423	20.6	0.53	21.6	0.67	NO
APR	15.2	24.0	65	2982	1938	2423	20.6	0.61	21.1	0.67	NO
MAY	12.7	24.0	65	2982	1938	2423	20.6	0.70	20.3	0.67	YES
JUN	11.2	24.0	65	2982	1938	2423	20.6	0.73	19.7	0.66	YES
JUL	10.5	24.0	65	2982	1938	2423	20.6	0.75	19.5	0.67	YES
AGO	11.0	24.0	65	2982	1938	2423	20.6	0.74	19.7	0.67	YES
SEP	12.8	24.0	65	2982	1938	2423	20.6	0.70	20.3	0.67	YES
OCT	14.6	24.0	65	2982	1938	2423	20.6	0.64	20.9	0.67	NO
NOV	15.1	24.0	65	2982	1938	2423	20.6	0.62	21.1	0.67	NO
DEZ	17.4	24.0	65	2982	1938	2423	20.6	0.48	21.8	0.67	NO

Table 4. Surface condensation risk analysis for Santa Maria (BZ2) – according to ISO 13788 (2012)

Mon.	T_e (°C)	T_i (°C)	φ_i (%)	p_{sat} (Pa)	p_i (Pa)	$P_{sat,min}$ (Pa)	$T_{si,min}$ (°C)	$f_{Rsi,min}$	T_{si} (°C)	f_{Rsi}	RISK
JAN	20.1	24.0	65	2982	1938	2423	20.6	0.12	22.7	0.67	NO
FEB	19.5	24.0	65	2982	1938	2423	20.6	0.24	22.5	0.67	NO
MAR	17.4	24.0	65	2982	1938	2423	20.6	0.48	21.8	0.67	NO
APR	15.3	24.0	65	2982	1938	2423	20.6	0.61	21.1	0.67	NO
MAY	12.1	24.0	65	2982	1938	2423	20.6	0.71	20.1	0.67	YES
JUN	10.3	24.0	65	2982	1938	2423	20.6	0.75	19.5	0.67	YES
JUL	9.4	24.0	65	2982	1938	2423	20.6	0.77	19.2	0.67	YES
AGO	11.3	24.0	65	2982	1938	2423	20.6	0.73	19.8	0.67	YES
SEP	12.7	24.0	65	2982	1938	2423	20.6	0.70	20.2	0.66	YES
OCT	15.5	24.0	65	2982	1938	2423	20.6	0.60	21.1	0.67	NO
NOV	17.3	24.0	65	2982	1938	2423	20.6	0.49	21.8	0.67	NO
DEZ	18.9	24.0	65	2982	1938	2423	20.6	0.33	22.3	0.67	NO

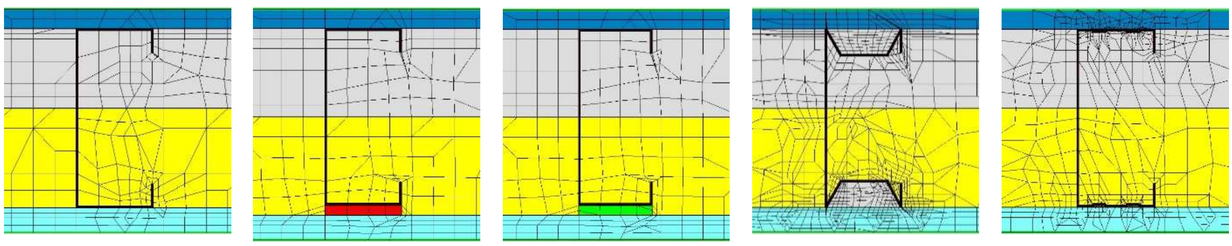
In both bioclimatic zones, the adopted construction configuration used as the model showed a surface condensation risk between the months of May to September. These months experience the lowest recorded temperatures, leading to grater temperature differentials between the internal and external environments. The larger temperature gradients facilitate increased heat exchange through the studs, thereby increasing the risk of surface condensation occurrence.

Thus, it can be inferred that the evaluated construction configuration of the LSF system is not recommended for BZ1 and BZ2 concerning surface condensation according to ISO 13788 (2012) criteria. According to Roque and Santos (2017), the cold construction system is the least suitable for cold climate regions, where the effects of thermal bridges are more significant, given the greater heat exchange through the envelope. Therefore, for bioclimatic zones 1 and 2, the most suitable configurations are the warm and hybrid systems. Thus, aiming to achieve better thermal performance for the construction system using the cold system, which is the most widely used in Brazil, strategies to mitigate the effects of thermal bridges were applied in cases where there was a possibility of the envelope condensing.

In this stage, the thermal behavior of the cold system construction configuration was evaluated after adopting strategies that minimize the effects of thermal bridges. Strategies ranging from thermal break strips to steel studs with modified flanges were considered (Table 5). Figure 5 presents the panel cross-section detail with finite element mesh of the base case and the strategies adopted in this study.

Tabela 5: Information on thermal break strategies. Adapted from Clarke (2001).

Type	Strategy	Thickness (mm)	Thermal conductivity (W/mK)
Thermal breaks	Rubber strip	5.0	0.3
	EPS strip	5.0	0.035
Modified profiles	Vertical ridges (1/4")	12.7	---
	Dimples	0.8	---



(a) Base case (b) Rubber Strip - rectangle in red (c) EPS Strip - rectangle in green (d) Vertical Ridges (e) Dimples

Figure 5. Panel cross-section detail: strategies analyzed to reduce the effects of thermal bridges..

The simulations were performed using the THERM software and the temperatures measured on the internal surface of the construction element were computed for bioclimatic zones 1 and 2, as described in

Table 6 and Table 7. The values highlighted in the tables indicate the configurations in which there is still a risk of condensation occurring, as temperatures lower than Tsi,min = 20.6°C were obtained.

Table 6. Temperatura superficial interna (Tsi °C) obtida para cada configuração na ZB1 - Curitiba

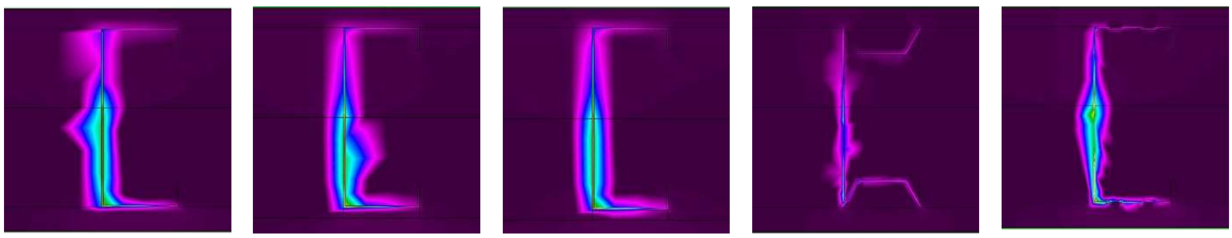
Mon.	Base case	Rubber Strip	EPS Strip	Vertical Ridges	Dimples
MAI	20.3	20.5	21.5	20.7	20.4
JUN	19.7	20.0	21.2	20.3	19.9
JUL	19.5	19.8	21.1	20.1	19.6
AGO	19.7	20.0	21.2	20.3	19.9
SET	20.3	20.5	21.5	20.7	20.4

Table 7. Temperatura superficial interna (Tsi °C) obtida para cada configuração na ZB2 – Santa Maria

Mon.	Base case	Rubber Strip	EPS Strip	Vertical Ridges	Dimples
MAI	20.1	20.3	21.4	20.5	20.2
JUN	19.5	19.8	21.0	19.9	19.6
JUL	19.2	19.5	20.8	19.7	19.3
AGO	19.8	20.1	21.2	20.2	19.9
SET	20.2	20.5	21.5	20.6	20.3

Modifying the flanges of steel studs is one of the most commonly used strategies to create a thermal break between the steel studs and the cold side of the enclosure. The application of dimples on the flanges is an option widely used in temperate countries to reduce the contact of the structure with the enclosure plates. However, in this study, this strategy did not prevent condensation from occurring on the steel studs, since the heat flux through the structure did not decrease considerably in relation to the base case (Figure 6a and Figure 6e).

Another way to reduce the negative effect of the structure on the overall thermal performance of the system is to consider steel studs with vertical ridges, which reduce the contact between the structure and the panels by inserting a layer of stagnant air. This thermal break strategy considerably reduces the heat flow through the steel stud (Figure 6d), increasing the thermal resistance of the enclosure. The steel stud with vertical ridges presented results superior to profile with dimples for the analyzed configuration. However, these values are still very close to the critical limit of 20.6°C in both climatic conditions. Considering that this study evaluated the average of the lowest external temperatures, this strategy may present unsatisfactory results in situations with temperatures lower than those considered in this work.



(a) Base case (b) Rubber Strip (c) EPS Strip (d) Vertical Ridges (e) Dimples

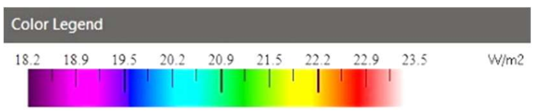


Figure 6. Detail of the heat flow through the steel stud for Curitiba (BZ1) in January.

On the other hand, among the strategies analyzed, the one that presented the best results is the application of EPS thermal break strips. By fitting rigid EPS insulation between the structural elements and the closing plates (Break Strips), condensation on the inner face of the panels was avoided. Compared to the thermal performance of the panel obtained with the application of rubber strips (Figure 7b), EPS reduces excessive heat loss through the steel studs, maintaining a higher surface temperature close to the panel structure (Figure 7c).

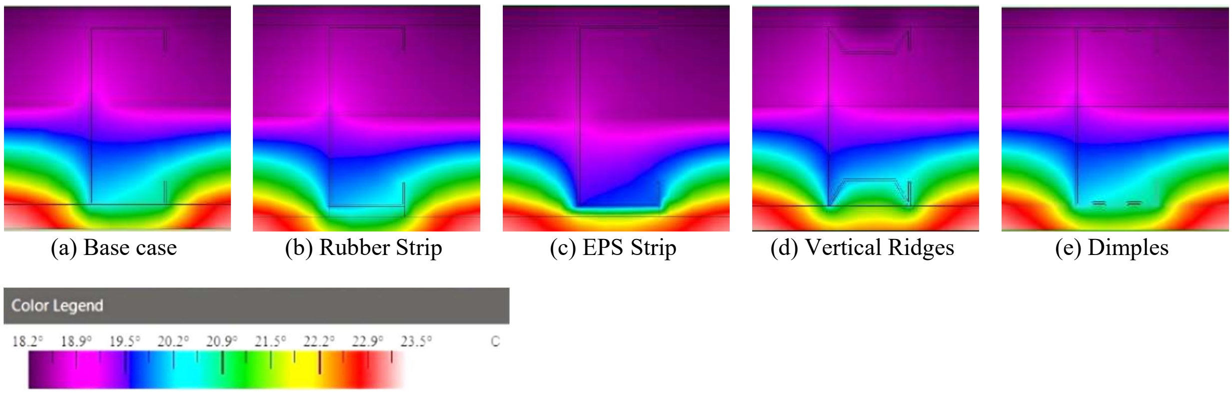


Figure 7. Detail of thermal infrared on the steel stud for Curitiba (BZ1) in January.

5 Conclusions

The aim of this study was to evaluate the thermal performance of a vertical enclosure in a LSF system and analyze the surface condensation risk, considering bioclimatic zones 1 and 2, along with the minimum temperature condition for these regions. The study was conducted using THERM software for constructive element modeling, and ISO 13788 (2012) standard was employed for assessing the surface condensation risk on the internal face of the building envelope, under the assumption of an artificially conditioned environment.

Based on the obtained results, the evaluated configuration presented a risk of surface condensation in both regions. The construction configuration with all the thermal insulation inside the wall, as simulated, is less suitable for temperate climate regions. In most climates, it is necessary to create a thermal break between the steel profiles and the cold side of the enclosure. In this study, it was observed that an improvement in the thermal efficiency of LSF panels can be obtained by inserting an insulating coating on the flange of the uprights.

Therefore, based on the analysis of the results, the evaluation method for surface condensation risk in ISO 13788 (2012) standard is recognized as suitable for analyses in cold climate regions or in cases where the internal air temperature is higher than the external air temperature.

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