Analysis and comparison of thermal lag in material of finishes type in dwellings of social interest in the city of Mexicali, Baja California

Análisis y comparación de retraso térmico en material tipo acabado en viviendas de interés social en la ciudad de Mexicali, Baja California

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Abstract

The global temperatures have shown the tendency of global warming and climate change continues, that is why, the need is to search alternatives that are effective inthe thermic reinforcement of the envelope of the dwelling. In consequence, the objective of the present investigation was to analyze the thermal behavior of a material that promises thermal lag qualities effective in comparison to the traditional finishes. This text was worked under a monitoring scheme and analysis of the results through a unit difference. The results indicate that the material of finishes studied favors the thermal lag between superficial temperatures and stability in thermal oscillation from the interior side of the wall and the roof analized. This article works as a divulgation and invitation to other investigations that share the objective to analyze materials that favor the thermal lag and energetic efficiency in the envelopes of the buildings.

Finish material, Thermic lag, Surface temperature

Resumen

Las temperaturas globales demuestran que la tendencia de calentamiento global y cambio climático continúan, por ello, se ve la necesidad de buscar alternativas que sean eficaces en el reforzamiento térmicode la envolvente de las viviendas. Por tanto, el objetivo de la presente investigación fue analizar el comportamiento térmico de un material que promete cualidades de retardo térmico eficaces en comparación con los acabados tradicionales. Se trabajó bajo un esquema de monitoreo y análisis de resultados mediante diferencia de unidades. Los resultados indican que el material de acabado estudiado favorece el retraso térmico entre temperaturas superficiales y estabilidad en la oscilación térmica del lado interior del muro y cubierta analizado. Este extenso sirve como divulgación e invitación a otras investigaciones que compartan el objetivo de analizar materiales que favorezcan el retraso térmico y eficiencia energética en las envolventes de las edificaciones.

Material de acabado, Retraso térmico, Temperatura superficial

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Introduction

Global temperatures show a growing tendency for global warming and climatic change; a recent article states that 2021 was the sixth year with the highest temperature at global level; it increased its temperature 1.5 Fahrenheit degrees or 0.85°C above the average NASA's reference period (Potter, 2022).

Also, it's expected a rise in temperature up to 1.5°C in the beginning of 2030 and 2,0 °C more for 2050 worldwide (López-Suárez, 2022).

Derivative of the distinct human activities, in the last years the increase of gasses emitted to the atmosphere has slightly changed the atmosphere composition, ergo the concentrations of the Greenhouse Gas has increased, according to a recent study, CO2 is one of the gasses that has increased the most since industrial revolution, principally due to fuel burning; contributing to the development of global warming and temperature increase (Coppini, 2019).

Furthermore, it's relevant to make emphasis that 38% of greenhouse gas is directly related to the construction sector, which 25% represents new edifications and 75% operational (Souza, 2022).

Otherwise, if the climate context is considered, the environmental conditions, the basic need that is architecture and in punctual manner the dwelling; it is characterized for being the main instrument to satisfy thermal comfort to whoever habits it. This does not only create harm from its realization, if not in its use and maintenance, that is to say; to supply basic needs, like the use and waste of electric energy, natural or LP gas, potable water, drainage, inter alia (Espinosa-Guerrero, 2017).

In addition, several investigations affirmed that dwellings's constructive methods lack of thermal benefits for their users, despite that human beings are distinguished for having homeothermic qualities, that is to say, they have the ability to keep their internal temperatures independent to any climatic conditions; nevertheless, exists a constant thermal change between man the environment (Schackow et al., 2018).

Additionally, also the difference between internal and external temperatures, which reflects the user's efforts effectiveness not just to adapt to external thermal conditions if not also to interior temperatures (Andreoni & Ganem, 2017).

Nevertheless, investigations focused on internal thermal comfort and housing habitability, affirms that, at least in Mexico, dwellings has problems of not being properly adequate for extreme climatic conditions, due to the popularity of certains construction systems distinguished in the country; as it is the masonry block, which has maintained itself valid, because its practicality and easy use in construction; nonetheless, these characteristics do not justify the lack of comfort in the majority of dwellings in the country (Sánchez-Terán et al., 2018).

Furthermore, one of the main alternatives the users of this kind of dwellings appeal to are the use of active cooling systems viz all electromechanic air conditioners, however, its use directly resents global warming to a global scale and in an economic level of those who use it.

That's the reason, there's a need to search for efficients alternatives that contribute to a thermal reinforcement of house facades. There are a great number of researches that study walls and roofs materials, all of them keep a relation with thermal comfort and conclude that the application of thermal insulators or thermal retardants in facades are one of the most efficient alternatives in reducing the thermal transmittance, consequently, these insulators became the intermediates of the energetic exchanges between two complex environments: inside and outside (Andreoni & Ganem, 2017).

With the intention to solve the presented problematic, several companies continue a constant innovation and development of materials and construction systems, committed to the environment, thus to increase the users' life quality, nevertheless, it is required to prove and analyze that the materials fulfill the necessary characteristics to provide a thermal support, in this case the envelope.

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Thus, the objective of the present investigation was to analyze the thermal behavior of a material which pledges efficient thermal lag qualities in comparison with traditional plastering. The object of study was the city of Mexicali, Baja California where two cases of study were compared, under traditional construction systems of the region as it is the concrete block, nonetheless, one of them bears the thermal retardant (Thermorock ®). The investigation was realized under the method of monitoring and comparison of unit differences between temperatures: exteriors and interiors, through thermocouples. The methodology mentioned was applied in two Social Interest Level Dwelling (VIS in Spanish), where the monitoring was done in a defined period; it is highlighted the month of November as transient and January as cold.

It is important to emphasize that during the process of investigation and application the following normatives were consulted; ISO-9869-1:2014 "Thermal insulation - Building elements - In-situ measurement of thermal resistance and thermal transmittance" to guarantee the level of trust of the measurement and the norm ASTM C 168-97 "Standard Terminology Relating to Thermal Insulating Materials" as reference to establish the optimal nomenclatures.

The results demonstrate that the finish material studied (Thermorock®) in the construction systems supports the thermal lag and the reduction of superficial temperature, which is reflected in a positive way in the disminution of its thermal amplitude, furthermore it succeeded to achieve the reduction of heat earning and heat loss inside the living space.

Antecedents

Some studies that have contributed to knowledge of the topic through scientific tests are presented.

Sobaler-Rodríguez et al. (2019), in Madrid, Spain, through his investigation stated that despite the best option to keep an interior space in optimal thermal conditions are insulators, wide thicknesses are not necessary to compliance with the normatitative requirements, because, the increase of thickness works in high transmittance parameters, therefore, in the case of dwellings is not essential.

Likewise, Azqueta (2018), in Buenos Aires, Argentina, affirms that, the contribution of the thermal isolation or thermal retardants in the surroundings, produces an enhancement in the comfort of buildings and decreases the use of thermal conditioning equipment, additionally mentions that the energetic saving that this produces and proposes to reorient to productive proceedings, besides the reduction of emissions.

Simultaneously, Briones & Jacobo (2018), in Chaco, Argentina, confirm that the hygrothermal control of the constructions depends of the materials used in the envelopes, for instance, thermal retardants, as well to the right application, in other words the required thickness and the physical characteristics of it, for the reason that its simply use does not guarantees positive results.

Bienvenido-Huertas, et al (2019), in Sevilla, Spain, in their research concerning the revision of methods for the evaluation of thermal transmittance in walls, certify that is key to understand wall's thermic transition in a heat loss perspective, through the following methods; theoric method, heat flow meters, simple hot box heat meter, thermometric method and infrared thermography.

Theoretical considerations

The theoretical considerations presented in this section will facilitate the understanding of the concepts used in this article. The main objective of a dwelling is to provide an adequate interior ambient for the user's necessities. In these requirements there's thermal resistance, which indicates the quantity of heat that traspasses an enclosure for time, surface, and heat difference (Álvarez, 2019). Otherwise, we can define thermal resistance as the capacity of a material to retain heat (Schackow *et al*., 2018).

In studies focused on a determinated space temperature, thermal isolation is defined as the capacity of materials to conduct heat to the opposite side (Ayarquispe, 2019). Thermal lag is when the exterior surface increases its temperature due to the solar radiation, which initiates a progressive heating through conduction until it reaches the interior face. The delay time of the thermal wave to get past the wall is conditioned to the thermal conductivity of the material, density, thickness and specific heat (Cárdenas, 2019).

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Furthermore, an isolating material is understood as those which have been evaluated by the transitory method of linear heat source, by the resultant coefficients contrasted with conventional materials (Guillén *et al*., 2018).

It is known as specific heat to the amount of required heat for a volume sample temperature constantly increase a degree (Gordillo et al, 2019).

Each material possesses different capacities to reflect the solar radiation received, thus we can describe the reflectance as the result of the alteration of the absorbed solar radiation (Alchapar y Correa, 2015). Likewise, thermal bridges can be defined as the surrounded thermal zone of a building where evidences a variation of the uniformity of construction, which can be due to a change in thickness of the enclosure, the penetration of constructive elements with a different conductivity, along others, that entails a reduction of the thermal resistance respecting the rest of the enclosure (Sancho, 2015).

When the user's necessities are satisfied in a room, it has to fulfill an energetic saving, so energetic efficiency can be described as a mechanism to assure the energetic supply, based in the implementation of new technologies and good consumption habits, to optimize the handling and use of the energetic resources available (Ministerio de Minas y Energía [MME], 2016).

Methodology, materials and method

This research is developed following a thermal logger monitoring method. We considered other similar papers as references to elaborate the methodology of this article, which it is described in the following chapters.

Investigation design

This research was carried out with a monitoring scheme and comparison of unit differences of both external and internal surface temperature register through a thermal logger. This scheme was applied in two model houses located in an economic level division, both of them were constructed with the city's traditional system. The monitoring was done on a specific period, therefore its classification allowed an analysis and conclusions in well determinated periods.

Area of study

This study was realized in Mexicali, Baja California, Mexico (Figure 1), this city has a BW climate (Koppen-Garcia categorize), which indicates that is an arid, dry climate, it has rainy winters and an annual very extreme temperature oscillation (Ley *et al*., 2011).

Figure 1 Location of Mexicali, Baja California.
Source: Mapbox

The annual average temperature is 22.4°C, the warmest season is june to september whose average temperature is 33.1°C and it can get to a maximum of 42.2°C; meanwhile the coldest seasons correspond from December to January, in this period the monthly average temperature is 12.4°C (Ley et al, 2011). The precipitation is poor, 75 mm in a year, during summer there are plenty of insolation hours, from 2,400 up to 2,500 hours per year with a uniform distribution. Wind velocity can reach 100 km&h (Ley et al, 2011)

The monitoring was done in two houses located in Ángeles de Puebla (Figure 2) a division placed in the southeast side of Mexicali.

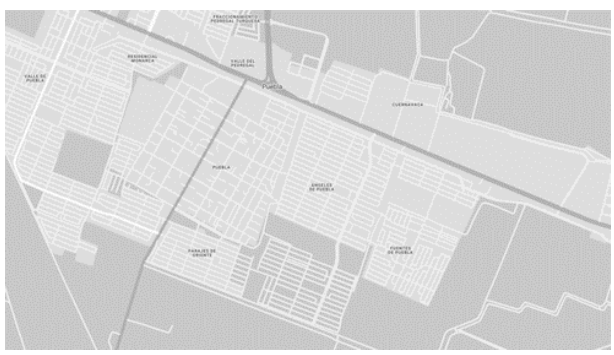

Figure 2 Location Ángeles de Puebla, Mexicali Baja California
Source: Google Map style

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June 2022, Vol.6 No.15 17-28

Cases of study

Two economic level adjacent houses were chosen for this research, both of them constructed with a region's conventional system, that consist in masonry blocks reinforced with a rebar and filled with concrete at every three cells. There is a difference between the wall's finish material of the houses, in the Case 1 it's applied in a textured plaster.

Period of study

We made an observation of the subjects of study on the final period of warm, transition period and the beginning of the cold period, which corresponds from September 2021 to February 2022. For purposes of this paper, the months of November and January stood out and were categorized as transition and cold periods respectively.

Measurement instruments

Two kinds of temperature loggers were used in this research, for environment temperature we used a thermal stress sensor RC-51H model that has a EN12830 certificate, CE, RoHS, for surface temperature we used a four channel logger thermometer (4 channel K thermometer SD Logger). Both sensors were programmaded on fields.

Installation strategy

In both cases two 4 channels were placed in the same location, whose log interior and exterior roof's surface and the walls oriented at west, south and east.

It's truly important to point out we consulted the followings standards ISO-9869-1:2014 "Thermal insulation - Building elements - In-situ measurement of thermal resistance and thermal transmittance" to warranty the log's level of confidence and the standard ASTM C 168-97 "Standard Terminology Relating to Thermal Insulating Materials" as guide to determine propers nomenclatures.

The following plan (Figure 3) shows the location of each code in case 1, the nomenclature can be consulted in the list:

- C1-R Ext: External side Roof.
- C1-R Int: Internal side Roof.
- C1-WW Ext: External side West Wall.
- C1-WW Int: Internal side West Wall.
- C1-WS Ext: External side South Wall.
- C1-WS Int: Internal side South Wall.
- C1-WE Ext: External side West Wall.
- C1-WE Int: Internal side West Wall.

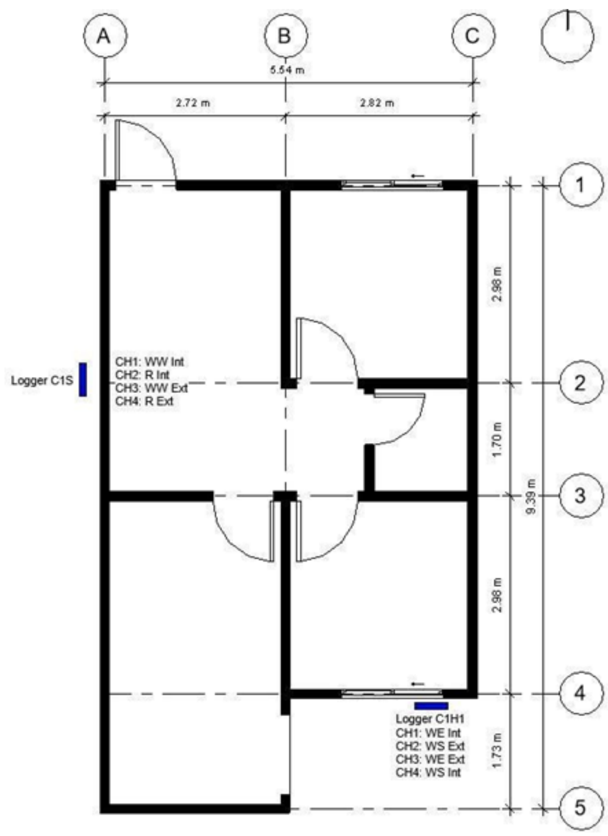

Figure 3 Location of channels in case 1
Source: Own elaboration

Likewise, the location of each code in case 2 it's represented in the next plan (Figure 4) and the meaning can be consulted in the list:

- C2-R Ext: External side Roof.
- C2-R Int: Internal side Roof.
- C2-WW Ext: External side West Wall.
- C2-WW Int: Internal side West Wall.
- C2-WS Ext: External side South Wall.
- C2-WS Int: Internal side South Wall.

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- C2-WE Ext: External side West Wall.

- C2-WE Int: Internal side West Wall.

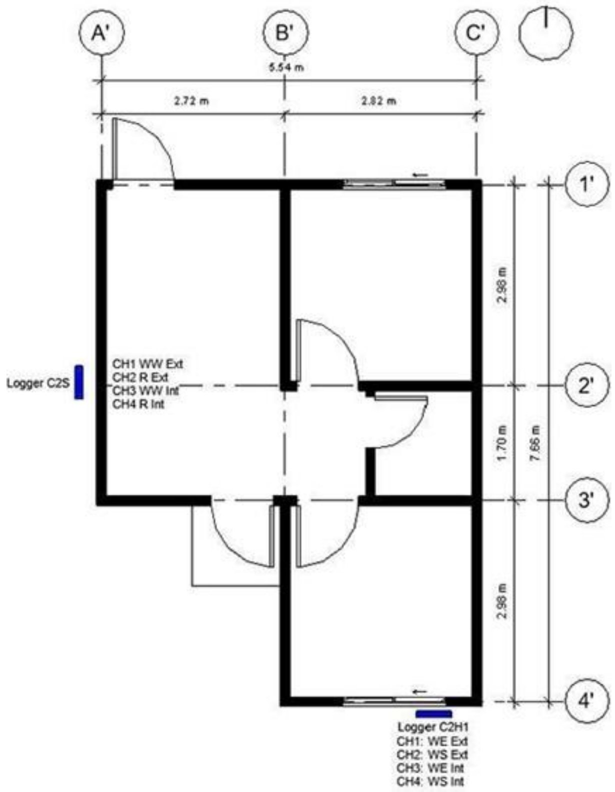


Figure 4 Location of channels in case 2
Source: Own elaboration

To keep a log of ambient temperature, a RC-51H thermic stress sensor was placed in the front yard of Case 1, this data is shared by both houses.

Results and discussions

To separate the period type it was performed a global inspection of the dry bulb temperature (DBT), based on the majority of the log we can establish a classification; once done, we identify a critical day through the maximum temperature in DBT in warm periods and the lowest in cold periods.

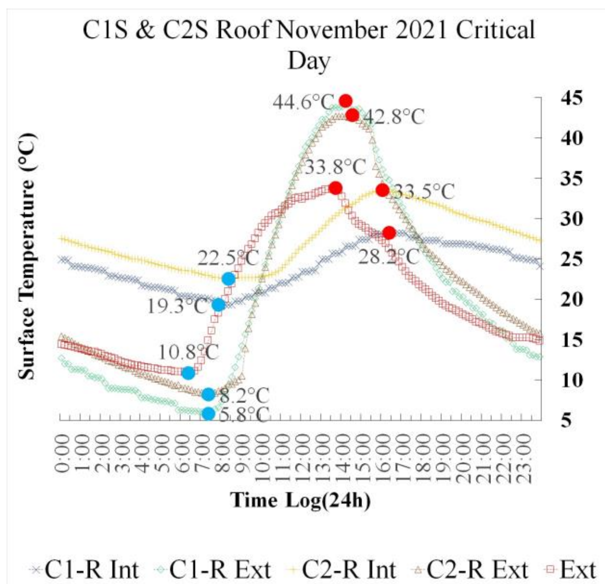
Two months were selected in this paper, representative under their classification: November as the transition period and January as the cold period.

Transition period monitor

The following analysis corresponds to the comparison of thermal retardation (outside to inside) between the same orientation of both houses. In this period it was analyzed November 15th, because it was the day with the maximum environmental temperature logged, which was 33.8°C, and its lowest temperature reached 10.8° C. Therefore, the oscillation of this day is 28°C.

As the next graphic shows (Graphic 1) the outside surface of the house 1 (C1-R Ext) increases its temperature up to 10.8°C and its oscillation is 38.8°C, thermal heat gain is reflected in the inside (C1-R Int) with a thermal lag of two hours, thus its minimized to 28.2°C and its oscillation is 19.1°C less than environment's oscillation.

The same phenomenon of thermal heat gain takes place in the roof of house 2, the maximum surface temperature of the outside (C2-R Ext) is 42.8°C and its lowest is 8.2°C, that results in an oscillation of 34.6°C, similar to Case 1, the heat gain reflects in two hours on the inside (C2-R Int), where its maximum temperature is 33.5°C and its oscillation is 11°C, which is steadier than environment's per 17°C.



		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	33.8°C	10.8°C
C1-R Int	C1- Internal side Roof	28.2°C	19.3°C
C1-R Ext	C1- External side Roof	44.6°C	5.8°C
C2-R Int	C2- Internal side Roof	33.5°C	22.5°C
C2-R Ext	C2- External side Roof	42.8°C	8.2°C

Graphic 1 Critical day (11/15/21) and comparison on roofs during transition period
Source: Own elaboration

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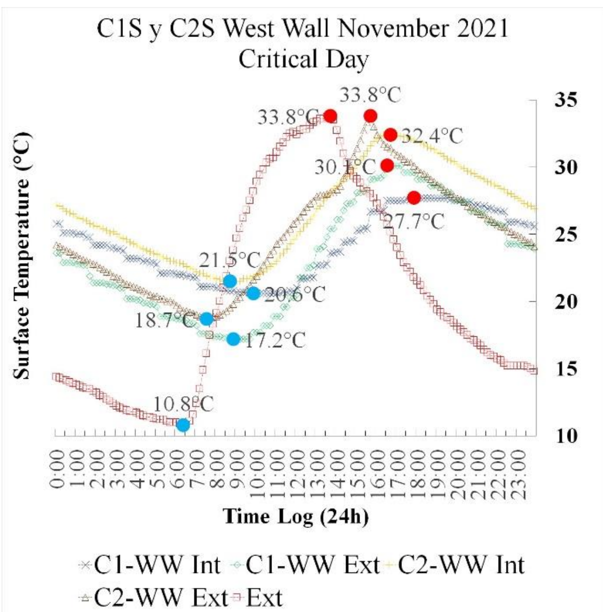
Next it's analyzed the thermal behavior of the west walls (Graph 2). It can be appreciated that the maximum temperature on the external surface is the same or minor to the environment. In Case 1 the maximum temperature on the outside (C1-WW Ext) was the same as the environment, and its oscillation is 12.9°C, meanwhile inside (C1-WW Int) the thermal transfer occurs two hours later, which decreased to 27.7°C, that means it reduces 6.1°C and its thermal oscillation is 7.1°C, thus represents a steadier oscillation than the exterior side per 5.8°C.

Meanwhile in Case 2 the maximum temperature of the exterior side (C2-WW Ext) is 32.4°C, inferior to the environment's and its oscillation results in 15.1°C, as well in case 1 the thermal lag reflects in two hours in the interior (C2-WW Int), which decreases to 32.4°C and its oscillation results in 10.9°C, compared with the thermal oscillation of the environment, this one is steadier with a difference of 17.1°C.



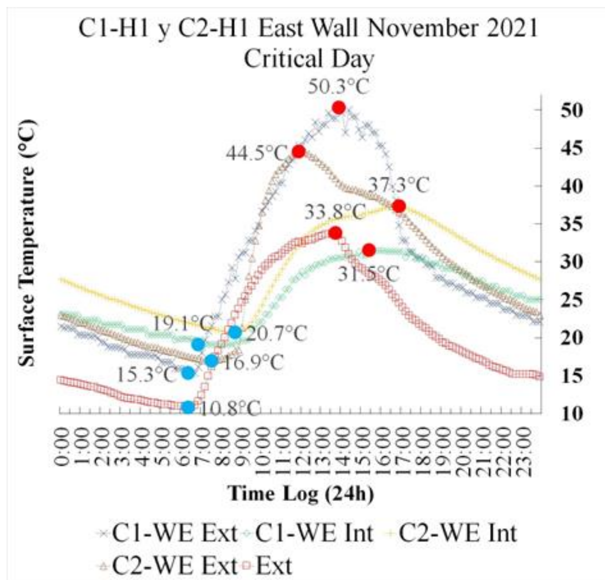
		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	33.8°C	10.8°C
C1-WW Int	C1- Internal side West Wall	27.7°C	20.6°C
C1-WW Ext	C1- External side West Wall	30.1°C	17.2°C
C2-WW Int	C2- Internal side West Wall	32.4°C	21.5°C
C2-WW Ext	C2- External side West Wall	33.8°C	18.7°C

Graphic 2 Critical day (11/15/2021) and comparison on west wall during transition period
Source: Own elaboration

Next it is analyzed the wall oriented to the east (Graph 3), a global inspection allows us to observe the existence of thermal heat gain in both exterior sides, meanwhile the interior side has temperatures close to the environment.

On this day, the external side of case 1 (C1-WE Ext) reached its maximum temperature at the same hour as the environment, which increases to 50.3°C, its minimum temperature, in the same way, happened at the same hour as the environment which is 15.3°C, it's oscillation is 35°C, this means is less steady than the environment's oscillation. On the other hand, in the interior side (C1-WE Int), in this orientation, the maximum temperature occurs three hours later, it decreases to 31.5°C and its oscillation gets steadier, it results in 12.4°C.

These results maintain a similitude for case 2, the exterior side (C2-WE Ext) gets a heat gain and reaches to 44.5°C, with an oscillation of 27.6°C, in this wall the thermic lag is of five hours, and its maximum temperature in the inside (C2-WE Int) logs at 37.3°C, its oscillation results in 16.6°C.



		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	33.8°C	10.8°C
C1-WE Int	C1- Inernal side East Wall	31.5°C	19.1°C
C1-WE Ext	C1- External side East Wall	50.3°C	15.3°C
C2-WE Int	C2- Inernal side East Wall	37.3°C	20.7°C
C2-WE Ext	C2- External side East Wall	44.5°C	16.9°C

Graphic 3 Critic Day (11/15/21) and comparison on east wall during transition period
Source: Own elaboration

Last, we analyzed south orientation (Graph 4). We can observe that the maximum temperature in the exterior side (C1-WS Ext) goes to 50.1°C and its oscillation is 36.8°C, meanwhile in the interior side (C1-WS Int) has a maximum temperature of 46.4°C which occurs with a thermal lag of two hours and its oscillation is 26.6°C, that is more stable than environment's.

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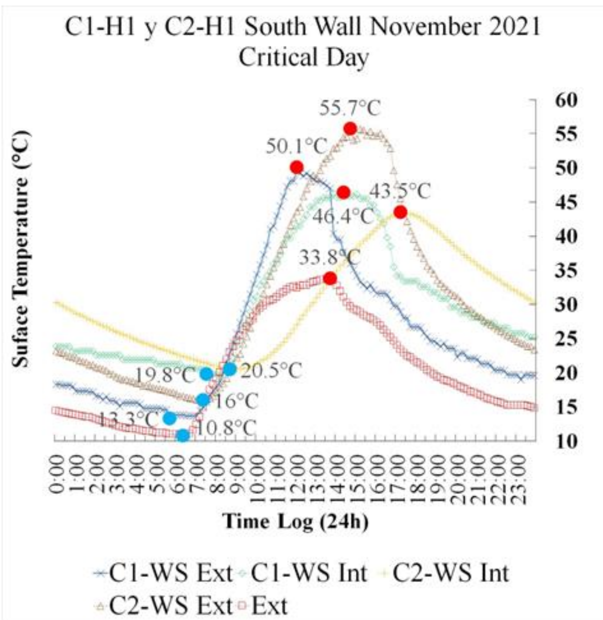
Case 2 logged its maximum temperature at the same hour as environment's (C2-WS Ext) which is 55.7°C, this represents a thermal heat gain of 21.9°C, and its minimum is 16°C, this indicates that it's oscillation is 39.7°C, similarly to east orientation, is higher than environment's; on the other hand, in the interior side (C2-WS Int) the maximum temperature is 43.5°C, which is higher than environment's for 9.7°C, and it's oscillation is 23°C, this imply that is more steady than its exterior side and environment's.



		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	33.8°C	10.8°C
C1-WS Int	C1- Internal side South Wall	46.4°C	19.8°C
C1-WS Ext	C1- External side South Wall	50.1°C	13.3°C
C2-WS Int	C2- Internal side South Wall	43.5°C	20.5°C
C2-WS Ext	C2- External side South Wall	55.7°C	16°C

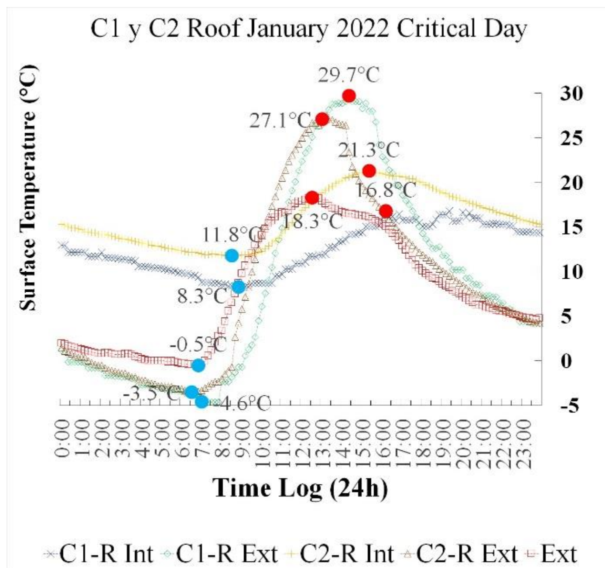
Graphic 4 Critic Day (11/15/21) and comparison on south wall during transition period
Source: Own elaboration

Cold period monitor

This section corresponds to January, classified as a cold period due to its low temperature. Its critical day is January 4th, with a maximum temperature of 18.3°C and a minimum of -0.5°C, whereby its thermal oscillation is 18.8°C. The following graph shows the same orientations as the previous chapter.

In the next graph (Graphic 5) it's analyzed the thermal behavior of the external side of Case 1's roof (C1-R Ext), which presents a maximum temperature of 29.7°C and a minimum temperature of -4.6°C, this results in a thermal oscillation of 34.3°C, this difference in temperatures reflects seven hours later; evenly, this oscillation is found in the interior side of the roof (C1-R Int), where the highest temperature was 16.8°C and the lowest reached 8.3°C, that results in a difference of 8.5°C, in the same window of seven hours.

This same situation shows in Case 2's roof in the exterior side (C2-R Ext) where its highest temperature was 27.1°C and minimum -3.5°C, that results in a difference of 30.6°C which occurs in a six hours window; meanwhile in the interior side (C2-R Int) the highest temperature was 21.3°C and the lowest temperature was 11.8°C whereby results in a thermal oscillation of 9.5°C, in the interval of eight hours.



		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	18.3°C	-0.5°C
C1-R Int	C1- Internal side Roof	16.8°C	8.3°C
C1-R Ext	C1- External side Roof	29.7°C	-4.6°C
C2-R Int	C2- Internal side Roof	21.3°C	11.8°C
C2-R Ext	C2- External side Roof	27.1°C	-3.5°C

Graphic 5 Critic Day (04/01/22) and comparison in roofs during cold period
Source: Own elaboration

The next graph (Graph 6) focuses on the west wall and its thermal behavior through this critical day. In Case 1, the exterior side of the wall (C1-WW Ext) got its maximum temperature at 18.1°C, meanwhile its minimum was 12°C, which represents a difference of 6.1°C in a five hour gap.

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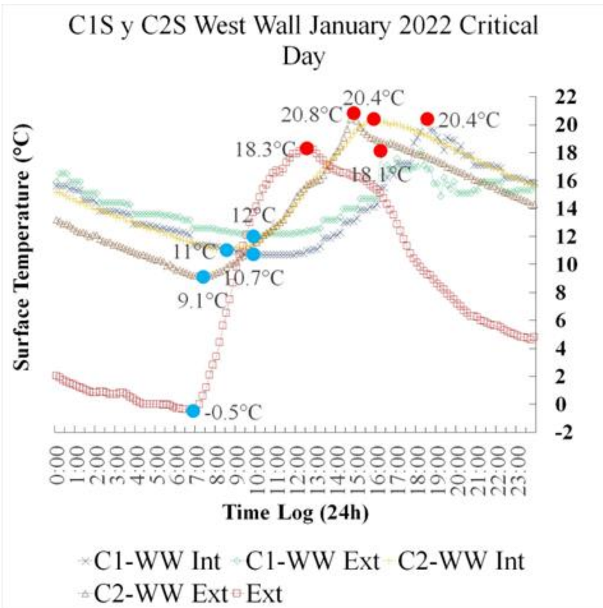
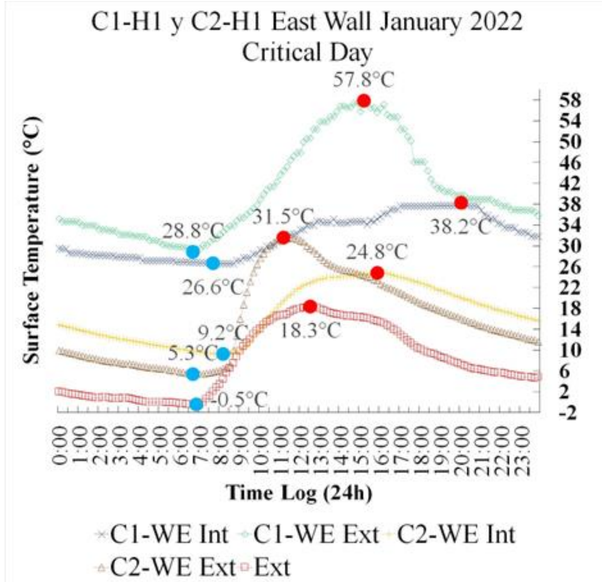
Similarly, in the interior side (C1-WW Int) the maximum temperature shown was 20.4°C and its lowest was 10.7°C, with a thermal lag of six hours. Moreover, in Case 2 west wall exterior side (C2-WW Ext) maximum temperature reached 20.8°C and the minimum temperature decreased to 9.1°C, this represents an oscillation of 11.1°C in an eight hour lapse. On the other hand, the interior side of the wall (C2-WW Int) got a maximum temperature of 20.4°C and its minimum reduced to 11°C, whose oscillation is 9.4°C and has a thermal lag of eleven hours.



		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	18.3°C	-0.5°C
C1-WW Int	C1- Internal side West Wall	20.4°C	10.7°C
C1-WW Ext	C1- External side West Wall	18.1°C	12°C
C2-WW Int	C2- Internal side West Wall	20.4°C	11°C
C2-WW Ext	C2- External side West Wall	20.8°C	9.1°C

Graphic 6 Critic Day (01/04/22) and comparison on west small during cold period
Source: Own elaboration

The next graph (Graphic 7) shows the behavior of the east wall, where Case 1 exterior side (C1-WE Ext) maximum temperature was 57.8°C and its minimum 28.8°C, this means its oscillation is 29°C with an eight hour window lag; on the inside (C1-WE Int) its highest temperature was 38.2°C while the lowest was 26.6°C, the oscillation in the interior is 11.6°C which occurs in twelve hours. In Case 2, the wall's exterior side (C2-WE Ext) maximum temperature reached 31.5°C and its minimum temperature got to 5.3°C, with a thermal lag of four hours; same way in the interior side (C2-WE Int) it logged its maximum temperature at 24.8°C, and its minimum temperature was 9.2°C with an oscillation that happens in an eight hours window.



		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	18.3°C	-0.5°C
C1-WE Int	C1- Inernal side East Wall	38.2°C	26.6°C
C1-WE Ext	C1- External side East Wall	57.8°C	28.8°C
C2-WE Int	C2- Inernal side East Wall	24.8°C	9.2°C
C2-WE Ext	C2- External side East Wall	31.5°C	5.3°C

Graphic 7 Critic Day (01/04/2022) and comparison on east wall during cold period
Source: Own elaboration

Finally, the following graph shows the thermal behavior in the south oriented wall (Graph 8), a superficial observation indicates that all the variables are maintained with higher temperatures than the environment's.

In Case 1, the exterior side (C1-WS Ext) logged a maximum temperature of 46.9°C which happened at the same hour as the environment's, meanwhile its minimum temperature was 27.7°C, which also takes place at the same hour as environment's lowest temperature; therefore the external side oscillation is 19.2°C; as for the interior side (C1-WS Int) the maximum temperature was 41.1°C which occurred with a thermal lag of four hours, meanwhile the minimum temperature was 25.6°C, whereby happened with an eight hours gap, it's thermal oscillation is 15.5°C.

As for Case 2, the outside surface (C2-WS Ext) logged the highest temperature as 42.9°C and a oscillation of 38.3°C, meanwhile in the inside (C2-WS Int) the maximum temperature was 31.1°C with a thermal lag of four hours and it's lowest temperature was 8.9°C, this represents an oscillation of 22.2°C, which means the internal oscillation is less steady than environment's by 3.4°C.

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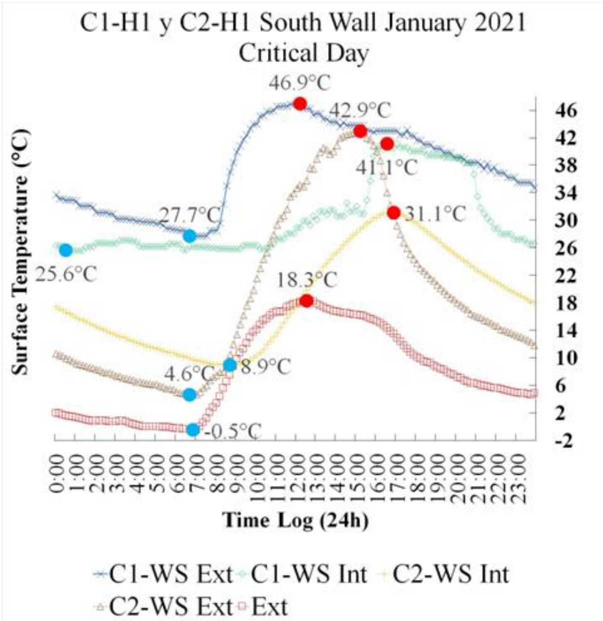

		Surface Temperature °C	
		Maximum	Minimum
Ext	Environment	18.3°C	-0.5°C
C1-WS Int	C1- Internal side South Wall	41.1°C	25.6°C
C1-WS Ext	C1- External side South Wall	46.9°C	27.7°C
C2-WS Int	C2- Internal side South Wall	31.1°C	8.9°C
C2-WS Ext	C2- External side South Wall	42.9°C	4.6°C

Graphic 8 Critic Day (01/04/2022) and comparison on south wall during cold period
Source: Own elaboration

The following pictures (Figure 5) (Figure 6) display a summary of the graphs analyzed on their respective periods.

		Surface Temperature °C		Oscillation
		Maximum	Minimum	
Ext	Environment	33.8°C	10.8°C	23°C
C1-R Int	C1- Internal side Roof	28.2°C	19.3°C	8.9°C
C1-R Ext	C1- External side Roof	44.6°C	5.8°C	38.8°C
C1-WS Int	C1- Internal side South Wall	46.4°C	19.8°C	26.6°C
C1-WS Ext	C1- External side South Wall	50.1°C	13.3°C	36.8°C
C1-WW Int	C1- Internal side West Wall	27.7°C	20.6°C	7.1°C
C1-WW Ext	C1- External side West Wall	30.1°C	17.2°C	12.9°C
C1-WE Int	C1- Inernal side East Wall	31.5°C	19.1°C	12.4°C
C1-WE Ext	C1- External side East Wall	50.3°C	15.3°C	35°C
C2-R Int	C2- Internal side Roof	33.5°C	22.5°C	11°C
C2-R Ext	C2- External side Roof	42.8°C	8.2°C	34.6°C
C2-WS Int	C2- Internal side South Wall	43.5°C	20.5°C	23°C
C2-WS Ext	C2- External side South Wall	55.7°C	16°C	39.7°C
C2-WW Int	C2- Internal side West Wall	32.4°C	21.5°C	10.9°C
C2-WW Ext	C2- External side West Wall	33.8°C	18.7°C	15.1°C
C2-WE Int	C2- Inernal side East Wall	37.3°C	20.7°C	16.6°C
C2-WE Ext	C2- External side East Wall	44.5°C	16.9°C	27.6°C

Figure 5 Summary during warm period on critical day (11/15/2021)
Source: Own elaboration

		Surface Temperature °C		Oscillation
		Maximum	Minimum	
Ext	Environment	18.3°C	-0.5°C	18.8°C
C1-R Int	C1- Internal side Roof	16.8°C	8.3°C	8.5°C
C1-R Ext	C1- External side Roof	29.7°C	-4.6°C	34.3°C
C1-WS Int	C1- Internal side South Wall	41.1°C	25.6°C	15.5°C
C1-WS Ext	C1- External side South Wall	46.9°C	27.7°C	19.2°C
C1-WW Int	C1- Internal side West Wall	20.4°C	10.7°C	9.7°C
C1-WW Ext	C1- External side West Wall	18.1°C	12°C	6.1°C
C1-WE Int	C1- Inernal side East Wall	38.2°C	26.6°C	11.6°C
C1-WE Ext	C1- External side East Wall	57.8°C	28.8°C	29°C
C2-R Int	C2- Internal side Roof	21.3°C	11.8°C	9.5°C
C2-R Ext	C2- External side Roof	27.1°C	-3.5°C	30.6°C
C2-WS Int	C2- Internal side South Wall	31.1°C	8.9°C	22.2°C
C2-WS Ext	C2- External side South Wall	42.9°C	4.6°C	38.3°C
C2-WW Int	C2- Internal side West Wall	20.4°C	11°C	9.4°C
C2-WW Ext	C2- External side West Wall	20.8°C	9.1°C	11.7°C
C2-WE Int	C2- Inernal side East Wall	24.8°C	9.2°C	15.6°C
C2-WE Ext	C2- External side East Wall	31.5°C	5.3°C	26.2°C

Figure 6 Summary during cold period on critical day (01/04/22)
Source: Own elaboration

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Conclusions

During this period it was observed a decrease in the thermal oscillation between the surfaces of both cases of study, thus a clear tendency to a major stability in the housing, where it was applied an extra covering, which was our research objective.

During the transition period, three out of the four orientations showed to be more stable in their internal side of the dwelling that has an additional layer, where the oscillation of the internal side is 2.1°C inferior in comparative with the other house (Case 2); in the west orientation the difference is 3.1°C, the east is steadier for 4.2°C. The south side increases its oscillation at a rate of 3.6°C in respect to Case 2.

Regarding the cold period, three orientations indicated positive results in comparison with Case 2, the internal side oscillation in the roof achieves to be more stable for 1 °C, the east wall with 4 °C and the wall oriented to the south, 6.7 °C. Instead, the west side during the cold period is slightly more unstable for 0.2 °C in comparative with Case 2.

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It can be concluded that the use of the finish material studied in this paper in construction systems helps the thermal lag and the reduction of superficial temperature, this is reflected in the disminution of thermal amplitude. This allows the possibility to reduce earnings and heat loss inside the habitable space and facility in the control of environmental temperature.

Mention is made that the material analyzed does not have a certificate of the regarding norms to be qualified as thermal insulation, therefore it is invited to submit to GHPA tests and emit a public result of its physical characteristics.

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