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Title: Thermographic analysis and influence of colour on the temperature of building materials in a warm sub-humid climate

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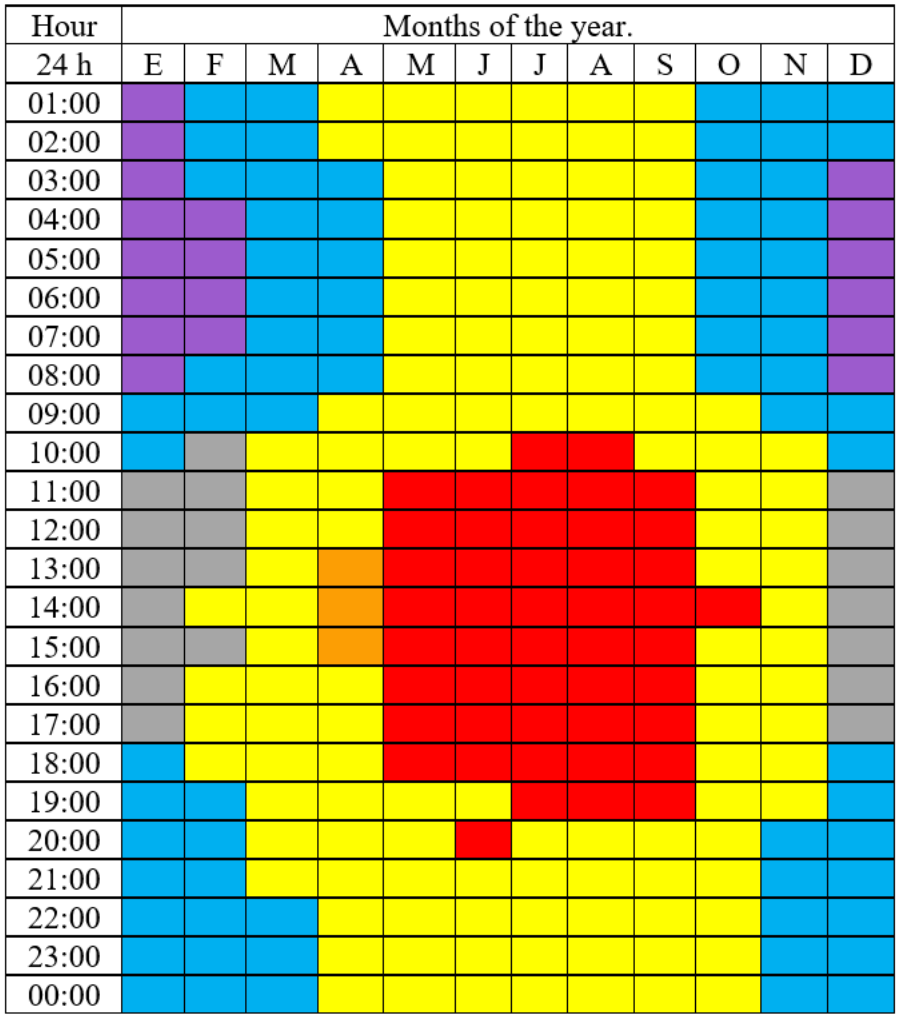
Content

Introduction.

This work presents the results of the research carried out in the Bachelor of Architecture of the FEPZH; research that was also presented in the event of the 29th edition of the summer of science of the UASLP, and deals with the fluctuation in the balance of thermal comfort that can cause the color of the constructive elements; It analyses the oscillation and differences in the temperature of the different walls built with block of different thicknesses; 10cm, 12cm, 15cm, and 20cm; in order to obtain objective information to be able to recommend the range of colors for the sub-humid quality zone, such as Ciudad Valles, and thus support the decision making of urban planners and professionals who are dedicated to architectural design. In June 2023, the nine objects of study were built; walls with a surface area of one square meter, to which paints of different shades were applied, and subsequently the temperatures were recorded with the help of measuring equipment obtained thanks to the support of PRODEP.



Hour	Months of the year.											
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Color Month	Hour	Recommendations
Red **May to September.**	11:00h to 19:00h	Control of solar radiation, relative humidity and radiant temperature. Mechanical ventilation is required.
Orange **April.**	13:00h to 15:00h	Control of solar radiation and radiant temperature. Generate wind.
Yellow **March to November.**	24 hours.	Reduce the relative humidity, the radiant temperature and the solar radiation of the day.
Gray **December to January.**	11:00h to 17:00h	It is not necessary to intervene while there are solar obstructions.
Gray **February.**	10:00h a 13:00h	It is not necessary to intervene while there are solar obstructions.
Blue **November, December, January and February.**	Antes de las 10:00h y despues de las 18:00h	Decrease the wind and increase the radiant temperature.
Purple **January, February and December.**	3:00h a 8:00h	Increase radiant temperature.

Ciudad Valles, San Luis Potosí is located at the geographical coordinate 21°59′12″N 99°01′07″W, located at 85 masl on average, it has a warm sub-humid AW0 climate with a considerable relative humidity of 78% due to the influence of hydrology and the vegetation that abounds due to the proximity to the Sierra Madre Oriental, the average temperature is 24. 7°C; minimum of 6°C and maximum of 47°C according to SMN-CONAGUA information; and according to City newspapers; with maximums of up to 56°C with a thermal sensation of 60°C; wind speed is 6km/hr.

As shown in table 1, Ciudad Valles has an unfavorable climate during most of the year and most of the hours of the day, so it is anticipated that a good thermal performance of the materials is necessary to cushion the climatic effects that affect the indoor environment of the dwellings and the outdoor urban spaces.

Color and temperature have a curious physical relationship and, as such, can be explained by science. This determines, for example, which colors absorb heat and which repel it.

Objective.


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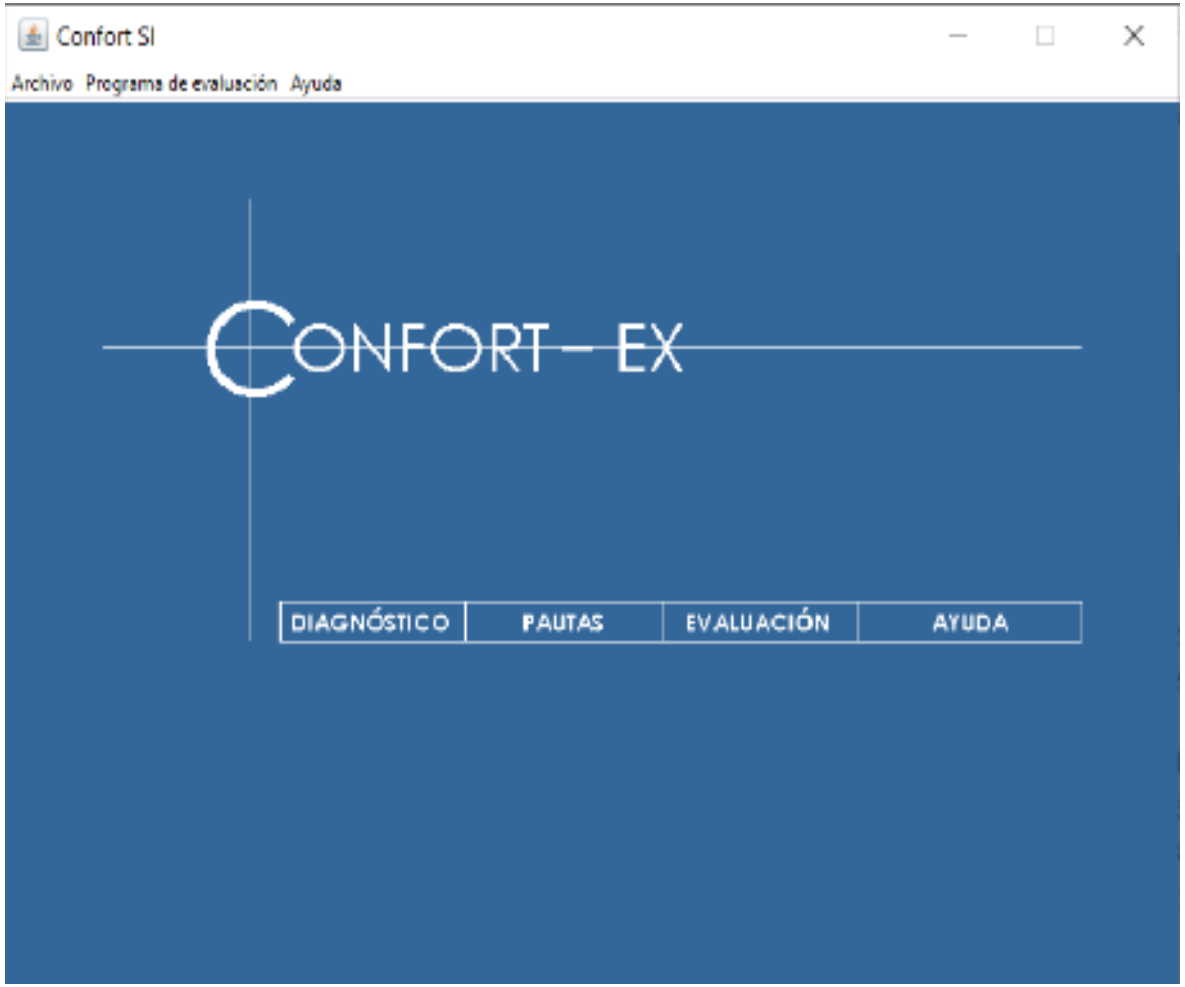
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Specific Objectives.

… documentary analysis of the literature on the subject and integrating a photographic file…

… of construct the nine objects of study…

… record the temperatures of the walls…

… take pictures with the thermographic camera…

… database is created in Excel…

… comparative graphs to analyze the results…

… the comfort ex application is used to calculate the thermal comfort balance by adjusting the temperature of the walls to identify the variation generated by each color.

Hypothesis.

The hypothesis behind this research is that the colors used and the thickness of the block influence the sensation of thermal comfort in urban and architectural spaces, and particularly the temperature of the construction elements themselves. To date, there is no record of similar research for the warm subhumid zone, specifically in Ciudad Valles, San Luis Potosí, so that the temperature variation between different colors such as black and white can be up to 5ºC, and grey vs. white can be 3ºC; This is according to previous activities and assumptions made by the research group formed by the students of the subject Sustainable Living Spaces, of the seventh semester of the Bachelor of Architecture of the FEPZH of the UASLP, also directed by the advisor of the present research.

Justification

It is considered that this research helps to have objective evidence of temperature variations and excessive heating caused by the colors applied in the constructive elements such as walls; with which the specialized personnel in the different disciplines that deal with urban interventions, as well as the authorities in charge of updating construction regulations and generating urban improvement projects, will be convinced to add particular specifications such as the use of appropriate colors according to the climate of the region.

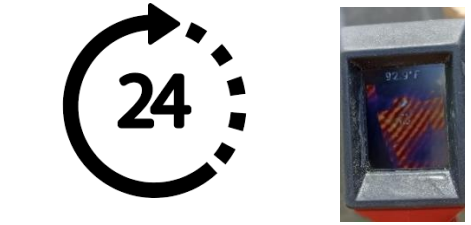
In addition to the above, it is considered that it is possible to improve the urban environment, because by buffering the climatic and environmental conditions of the region; outdoor spaces become more friendly areas for pedestrians and tourists, which can lead to greater social, pedestrian and of course commercial movement in the downtown area; likewise, it would improve the hygrothermal environment inside the family home by reducing the interior heat.

Problematic.

The strong sun exposure in the city, as well as the prolonged time of sun exposure, causes buildings to heat up and therefore creates uncomfortable environments for people in indoor and outdoor spaces, which reduces the quality of life in the city. This also causes people to avoid walking outdoors during the day, thus, businesses are also affected during the day. Ciudad Valles is gradually becoming a tourist city, therefore, it is important to provide comfortable urban spaces for people visiting the city.

The building regulations do not specify a relevant color range of urban spaces, or construction projects, therefore, many buildings use dark colors, which are believed to increase the air temperature in outdoor spaces. The regulation identifies the need to adapt buildings to the context, however, in most cases, it is interpreted only as giving the same architectural language to buildings in the same area; a visually similar design to neighboring buildings to make the urban area look homogeneous.

Materials and methods.

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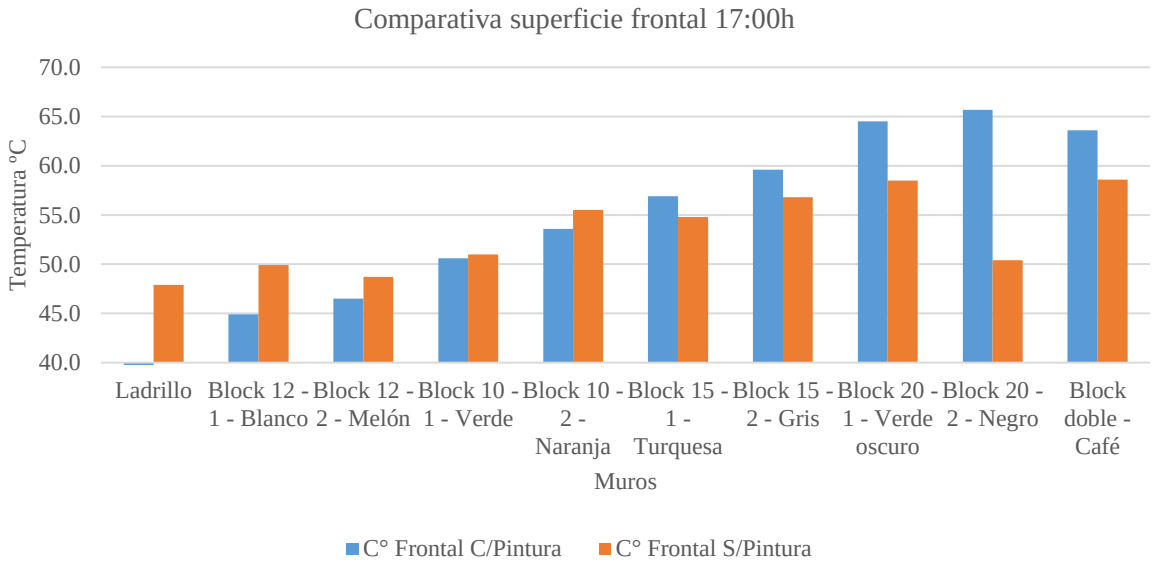
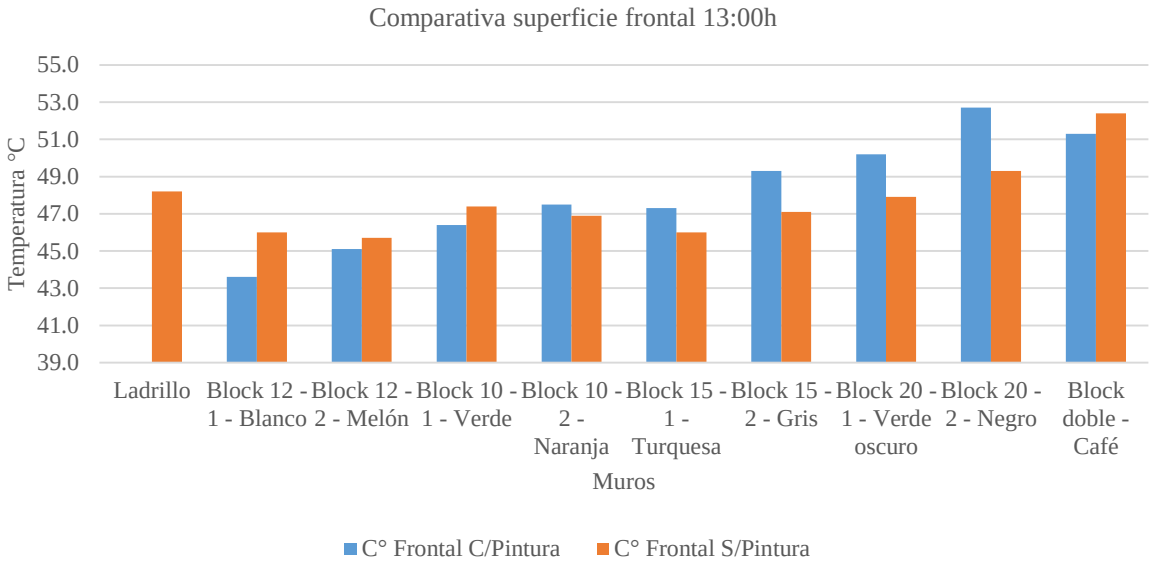
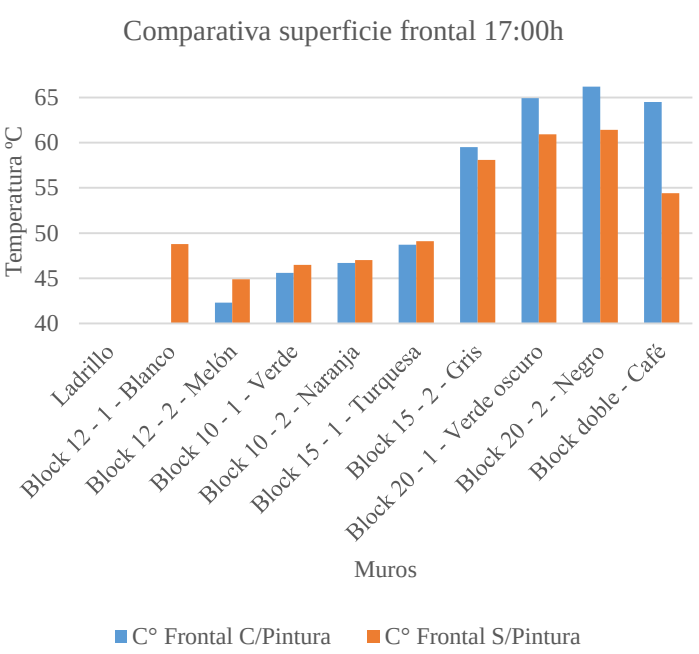
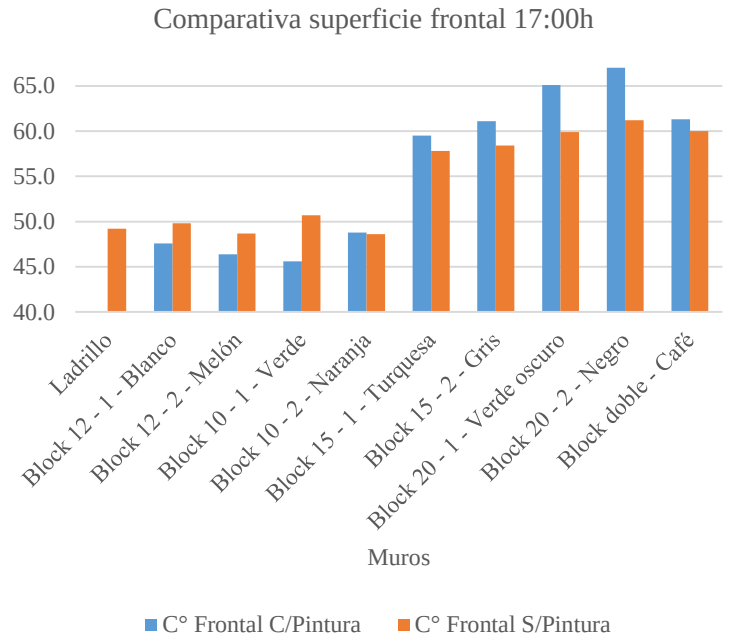
Results.

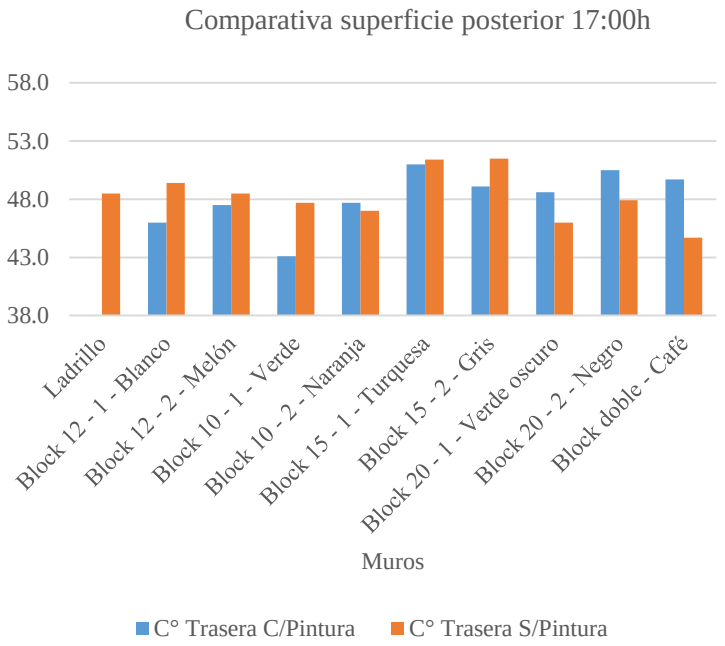




When comparing the temperatures of the blocks without paint, it can be observed that the maximum difference is 6°C at 13:00 h, which is when the energy accumulates in the material, as shown in graph 1. Once the blocks are painted, it can be observed that the light colors in most of the hours lower the temperature of the walls up to 5°C, while the walls with medium and dark paint increase the temperature of the wall from 7°C to 15°C, as is the case of the black color, as shown in graph 2.







Regarding the highest temperatures of the walls, they are identified at 17:00 h as shown in graphs 3 and graphs 4, where it is shown that, due to the color, the walls have differences of up to 25ºC. Another thing that is detected is that the thickness of the block does influence the heating of the walls, to the surprise of the research team, the 20 cm block heats up more in the front part than the wall with a thickness of 10 centimeters; and when the temperature of the back part of the walls with similar temperatures is observed, it can be seen that on average, the insulating capacity is better in the 10cm wall and in the 20cm thick wall, as can be compared in graphs 4 vs. graphs 5.

Radiacion absorbida por la persona (W/m2)	Balance de energia de la persona
□	□
□	□
□	□
□	□
□	□
□	□
□	□
□	□
□	□
288.69	-5.42
□	□
306.77	68.75
□	□
323.58	182.35
□	□
381.65	188.46
□	□
441.02	187.76
□	□

Radiacion absorbida por la persona (W/m2)	Balance de energia de la persona
□	□
□	□
□	□
□	□
□	□
□	□
□	□
□	□
□	□
291.09	-3.02
□	□
308.42	70.41
□	□
329.04	187.82
□	□
388.61	195.42
□	□
421.85	168.60
□	□

Radiacion absorbida por la persona (W/m2)	Balance de energia de la persona
□	□
□	□
□	□
□	□
□	□
□	□
□	□
□	□
□	□
291.09	-3.02
□	□
311.83	73.81
□	□
331.89	190.67
□	□
393.86	200.67
□	□
428.29	175.04
□	□

When calculating the thermal comfort balance in the comfort ex application, it is observed that the color does influence the results, but in a relatively small percentage compared to the influence on the temperature of the objects. We speculate that this is since the radiation generated by a block element does not have a significant distance range, so it is inferred that its contribution to the feeling of comfort in the environment is rather long term. This can be verified by approaching the walls to determine the approximate distance at which the sensation of heat is appreciated, which ranges between 30 cm and 40 cm. Therefore, as soon as we move away from the wall, the radiation is no longer felt.

Conclusions.

After the time invested in the bibliographic studies, it can be affirmed that there is no research on the impact of color on the temperature of the walls in the hot subhumid zone, specifically in Ciudad Valles, San Luis Potosi. In the same way, little evidence of research on thermal comfort in interior and exterior spaces in the city is detected when it is considered that it is necessary because the city has an extremely hot climate.

The difference in block thickness does contribute to the time in which the material cools down or heats up; the color difference has more impact on the surface temperature of the material than on the thermal comfort balance of the person, however, it is important to express the assumption that a black urban area can generate a lot of radiant heat that in the end will be transmitted to the air temperature and could generate hot environments for the pedestrian.

It is particularly important to continue this type of research, since they are interesting and with them it is possible to verify and advise home users about the oscillation and maximum differences that the temperature of their walls can present with a specific color, because to date the work team had no exact idea of the differences. It is well known that light colors vs. dark colors are cooler, but it was not known by how many degrees Celsius.

The experience, the learning and the results were generated in an objective way, thanks to the application of measuring equipment and the application of calculation software; which was another thing that the team did not know: the fact of creating a link between the measured parameters, in relation to the subjective information about the people to calculate the thermal comfort balance.

For your attention thanks!

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