THERMAL PERFORMANCE IN LIGHT MULTI-LAYERED FAÇADES

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ABSTRACT

Traditional façade systems are at the point where the minimum comfort guarantees have peaked, showing hygrothermic performance deficiencies which result in higher heating consumption, which is why it´s necessary to make improvements in design and building construction, especially in envelopes, for which efficient building enclosures should be used, generating notable benefits. For these reasons, the study of new façade construction systems is essential, particularly light multi-layers, which offer favorable characteristics for energy consumption savings. With this background, the main aim of this study is to generate knowledge to find out to what extent light multi-layered façades are better, determining which façades are the most efficient and guarantee the comfort conditions of a building, contributing in this way to energy consumption savings. To carry out this study, a methodology of analysis shall be used, signifying that in the first phase a theoretical study has been made, analyzing different configurations of the sample façades, to obtain their thermal performance, using two different methods, thermographic and thermal, obtaining in the thermographic study: surface temperatures of the façades, while in the thermal simulation, generating isotherms, heat flows, data on thermal coupling coefficients to calculate the value of the thermal transmittance and surface conditions, among others. Therefore, using this data, the conclusion has been reached that comparing a traditional enclosure to a light multi-layered one of equal thickness, an improvement of 65% can be achieved in the thermal transmittance, which signifies a saving in energy consumption, exceeding the Technical Building Code.

1. - Introduction.

Currently, traditional façade systems are at the point where the minimum comfort guarantees have peaked, showing hygrothermic performance deficiencies which result in higher heating consumption and increased CO2 emissions, which are in detriment to the environmental impulses proposed by the European Directive on Energy Efficiency and the Technical Building Code as well as the Kyoto Protocol.

Energy awareness is increasing, and it is necessary to adapt to this new situation and with this, the use of an envelope as an active membrane has arisen, which can contribute great benefits to the construction sector.

For these reasons, the study of new façade construction systems is essential, particularly light multi-layers, which offer favorable characteristics for energy consumption savings and can in turn, be industrialized systems, obtaining benefits for the construction sector and the people themselves, such as improvements in quality, reduced build time, better security, improved benefits and greater lightness, among others.

The general objectives of this study, is to explore a methodology to analyze highly energy efficient light multi-layered enclosures and be able to characterize their thermal performance in a theoretical manner for later experimental contrasts. While at the same time, generating knowledge to find out to what extent light multi-layered façades are better, determining which façades are the most efficient and guarantee the comfort conditions of a building, contributing in this way to energy consumption savings.

2. - Methodology

The methodology followed for this study is based on the following phases:

2.1. - Phase I: Study of Variables

The performance of light multi-layered façades is influenced by a series of variables which to a greater or lesser extent make up part of its composition. The most important variables taken into account have been: materials, insulation positioning, different compositions of façades and location, which in this case is Madrid.

It´s important to mention, that during this research, the following aspects have been taken into account: different façade orientations, acoustics, the possibility of industrialization and economic studies, among others.

2.2. - Phase II: Sample Selection.

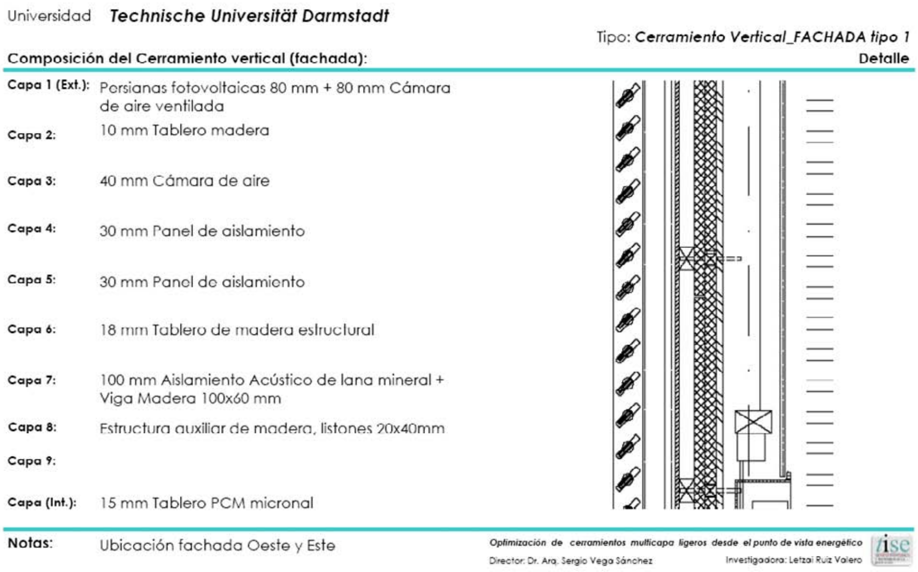
The study, part of the Solar Decathlon Contest 2007, organized by the US Department of Energy in Washington, in which 20 universities from all over the world participated. In this edition, two European universities participated: Technische Universität Darmstadt and Universidad Politécnica de Madrid as well as 18 universities from the US, Canada and Puerto Rico.

The contest consists of designing and building an energetic self-sufficient prototype house fitted out with all the technology to enable maximum energy efficiency. The final phase consisted of building it at the National Mall in Washington D.C., where the so-called “Solar City” is located and where the 20 selected prototypes competed and were exhibited, undergoing the 10 tests that make up the contest (Decathlon).

Apart from these 20 prototypes, a traditional façade used in Spanish construction has also been selected, particularly in Madrid, to be able to draw comparisons between light multi-layered façades and this traditional one. It has been taken from the Ceramic Solutions Catalogue to comply with the Technical Building Code 2008, proposed by Hispalyt and the Eduardo Torroja Science Institute of Construction.

2.3. - Phase III: Study of the composition of the façades

Once the samples were selected, the different compositions of light multi-layered façades used for the solar houses were analyzed. As in most of the prototypes there is more than one type of façade composition, but for this study, the main composition has been used as a base, which makes up the greater part of the vertical enclosures. In turn, the layers that constitute the traditional façade have been studied. To compile this data, a chart has been drawn up (fig.1), showing the university, enclosure type, description of the materials in each layer, enclosure details and notes.



Universidad **Technische Universität Darmstadt**

Tipo: *Cerramiento Vertical_FACHADA tipo 1*

Composición del Cerramiento vertical (fachada): **Detalle**

Capa 1 (Ext.):	Persianas fotovoltaicas 80 mm + 80 mm Cámara de aire ventilada
Capa 2:	10 mm Tablero madera
Capa 3:	40 mm Cámara de aire
Capa 4:	30 mm Panel de aislamiento
Capa 5:	30 mm Panel de aislamiento
Capa 6:	18 mm Tablero de madera estructural
Capa 7:	100 mm Aislamiento Acústico de lana mineral + Viga Madera 100x60 mm
Capa 8:	Estructura auxiliar de madera, listones 20x40mm
Capa 9:	
Capa (Int.):	15 mm Tablero PCM micronal
Notas:	Ubicación fachada Oeste y Este

Optimización de cerramientos multicapa ligeros desde el punto de vista energético

Director: Dr. Arq. Sergio Vega Sánchez Investigadora: Letzai Ruiz Valero

Fig. 1 “Composition of the light multi-layered façades”

2.4. - Phase IV: Methods of Analysis

In this phase of the study, two types of analysis have been considered to study the performance of the light multi-layered façades: a thermographic analysis using ThermaCAM™ Researcher Professional software and a thermal analysis using AnTherm.

For the thermographic analysis, a Flir Systems ThermaCAM™ P25 infrared thermal camera has been used, which is compact and robust, and capable of producing totally radiometric images, so the temperature of objects can be measured with no contact. It offers a range of temperatures from -40°C to +500°C and up to +1000°C and a thermal sensitivity of 0.08°C to 30°C. The ThermaCAM™ P25 captures images at a speed of 50 Hz and can explore moving objects.

Thermographic images were taken of all 20 solar houses in all four orientations and at different times of day, to evaluate possible variations in performance of façade surface temperature produced throughout the day, and to study these thermographs, ThermaCAM™ Researcher Professional 2.8 SR-2 software was used, which analyses in real time. This study consists of placing two lines of reference, one on opaque enclosures and another on translucent or transparent ones.

With the AnTherm, the distributions of temperature and heat flows in the building are calculated, placing special emphasis on thermal bridges. It´s designed to provide reliable information and background on thermal performance according to current European regulations (EN). In addition, the software generates information that enables the calculation of the thermal transmittance of each of the façades and the theoretical evaluation of all the layers in each enclosure.

3. - Results

Presented taking into account each of the simulation programs carried out for the thermal performance analysis of the light multi-layered façades.

3.1. - Thermographic Analysis

This method generated the following information:

3.1.1. - Thermographic Images, the thermographic camera captures the image, generating a thermograph as in fig.2. In the same image, information is shown on the conditions present where it was taken, e.g.: reflected temperature, atmospheric temperature, relative humidity, date, time, etc. Fig.3 was taken with ThermaCAM software, using fig.2 as a base which was previously worked on.

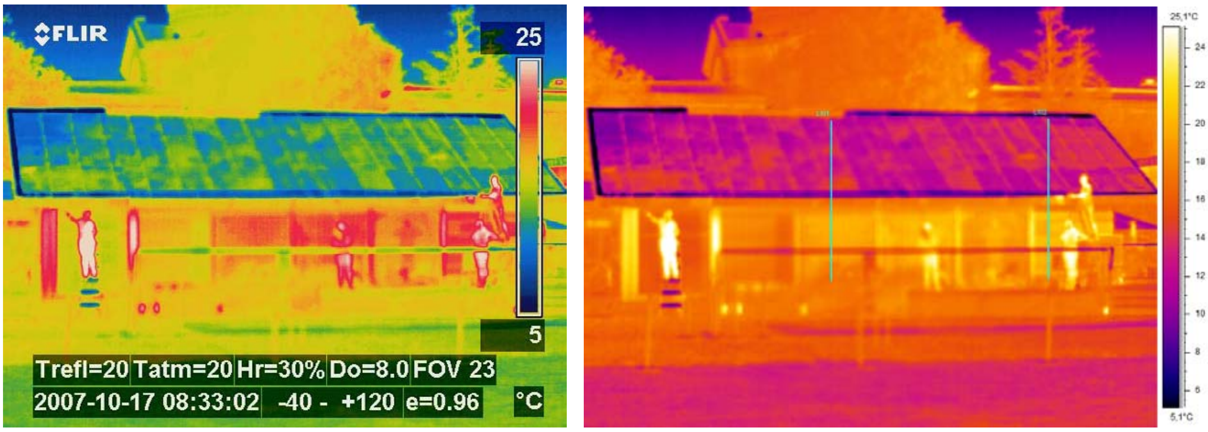
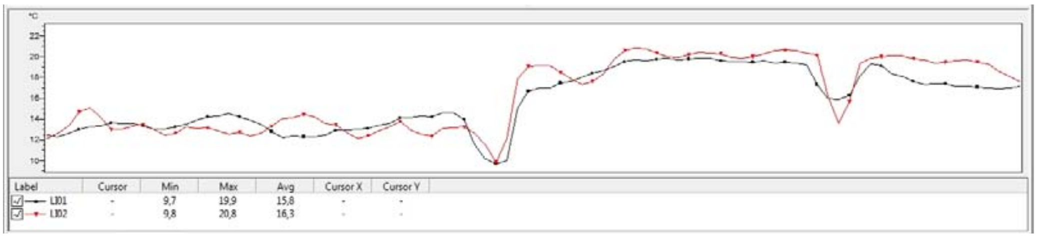


Fig. 2 y Fig. 3 “Thermographic Images of the south façade at UPM”

3.1.2.- Photographic images, it´s essential to take these images at the same time as the thermographic ones, as they help to identify any details, thermal bridge, etc., which appear in the thermographic images.

Fig.4 “Photograph of the south façade at UPM”

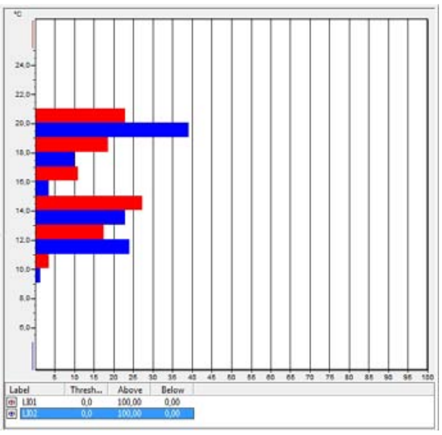
3.1.3. - Temperature profiles, this graph (fig.5) shows the performance of the surface temperature of the lines placed as reference on the opaque enclosures and translucent or transparent enclosures. (Red line = translucent or transparent enclosures, black line = opaque enclosures).



Label	Cursor	Min	Max	Avg	Cursor X	Cursor Y
☑ LI01	-	9,7	19,9	15,8	-	-
☑ LI02	-	9,8	20,8	16,3	-	-

Fig.5 “Temperature Profiles for the south façade at UPM”

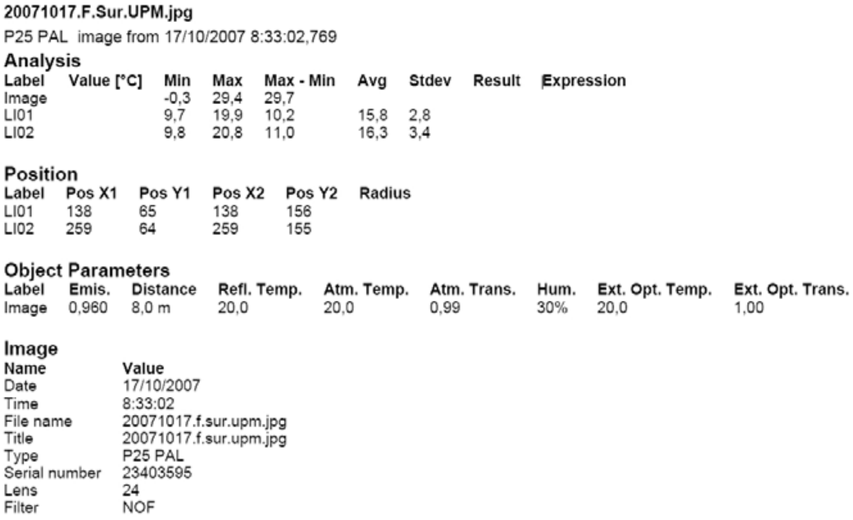
3.1.4. - Histogram, this graph (fig.6) shows façade surface temperatures in opaque enclosures as well as translucent or transparent ones. (Red bar = translucent or transparent enclosures, blue bar = opaque enclosures).



Label	Thresh...	Above	Below
LI01	0,0	100,00	0,00
LI02	0,0	100,00	0,00

Fig.6 “Histogram for the south façade at UPM”

3.1.5. - Data Analysis, this chart (fig.7) is a data report showing minimum and maximum temperatures and measurements of the two lines placed as reference. In turn, it indicates the object parameters, the values of the image as a name, date taken, time, serial number, lens type, etc.



20071017.F.Sur.UPM.jpg

P25 PAL image from 17/10/2007 8:33:02,769

Analysis

Label	Value [°C]	Min	Max	Max - Min	Avg	Stdev	Result	Expression
Image		-0,3	29,4	29,7				
LI01		9,7	19,9	10,2	15,8	2,8		
LI02		9,8	20,8	11,0	16,3	3,4		

Position

Label	Pos X1	Pos Y1	Pos X2	Pos Y2	Radius
LI01	138	65	138	156	
LI02	259	64	259	155	

Object Parameters

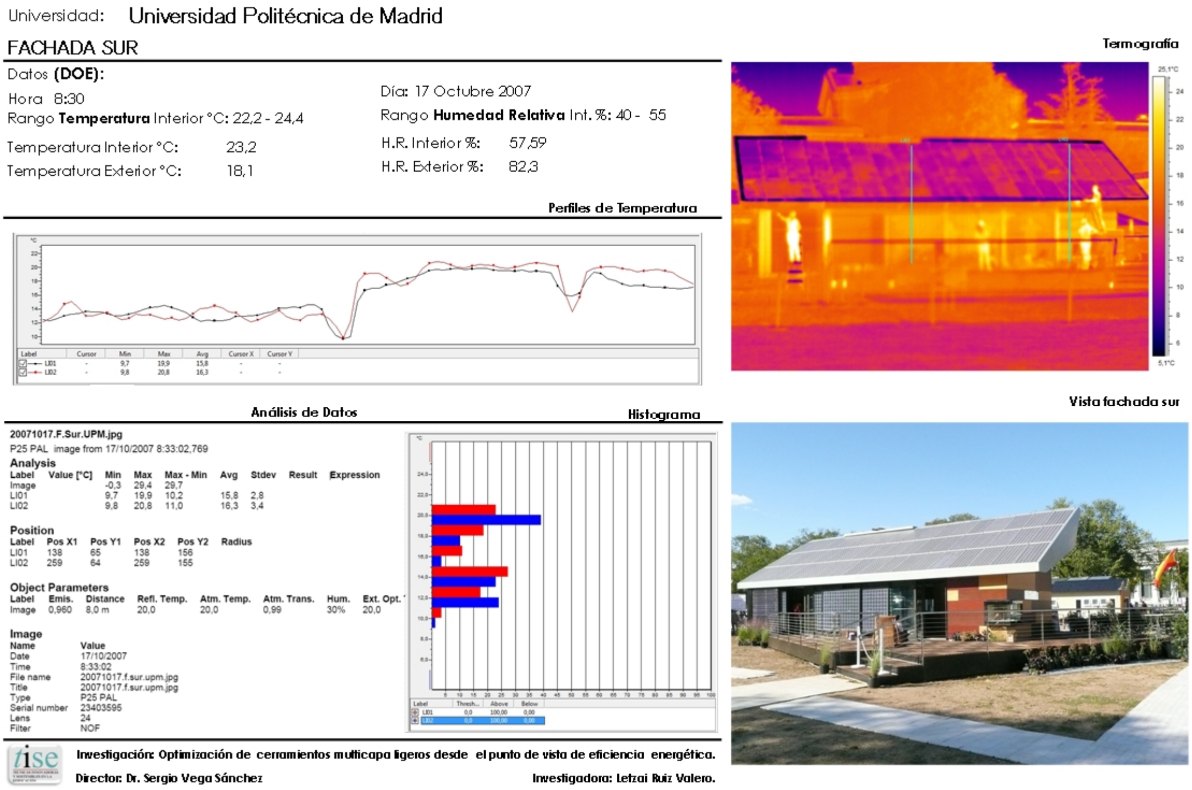
Label	Emis.	Distance	Refl. Temp.	Atm. Temp.	Atm. Trans.	Hum.	Ext. Opt. Temp.	Ext. Opt. Trans.
Image	0,960	8,0 m	20,0	20,0	0,99	30%	20,0	1,00

Image

Name	Value
Date	17/10/2007
Time	8:33:02
File name	20071017.f.sur.upm.jpg
Title	20071017.f.sur.upm.jpg
Type	P25 PAL
Serial number	23403595
Lens	24
Filter	NOF

Fig.7 “Data Report Chart for the south façade at UPM”

To organize this data the following charts have been drawn up (fig.8):



Universidad: Universidad Politécnica de Madrid

FACHADA SUR

Datos **(DOE):**

Hora 8:30

Rango **Temperatura** Interior °C: 22,2 - 24,4

Temperatura Interior °C: 23,2

Temperatura Exterior °C: 18,1

Día: 17 Octubre 2007

Rango **Humedad Relativa** Int. %: 40 - 55

H.R. Interior %: 57,59

H.R. Exterior %: 82,3

Termografía

Perfiles de Temperatura

Label	Cursor	Min	Max	Avg	Cursor X	Cursor Y
☑ LI01	-	9,7	19,9	15,8	-	-
☑ LI02	-	9,8	20,8	16,3	-	-

Análisis de Datos

20071017.F.Sur.UPM.jpg

P25 PAL image from 17/10/2007 8:33:02,769

Analysis

Label	Value [°C]	Min	Max	Max - Min	Avg	Stdev	Result	Expression
Image		-0,3	29,4	29,7				
LI01		9,7	19,9	10,2	15,8	2,8		
LI02		9,8	20,8	11,0	16,3	3,4		

Position

Label	Pos X1	Pos Y1	Pos X2	Pos Y2	Radius
LI01	138	65	138	156	
LI02	259	64	259	155	

Object Parameters

Label	Emis.	Distance	Refl. Temp.	Atm. Temp.	Atm. Trans.	Hum.	Ext. Opt.
Image	0,960	8,0 m	20,0	20,0	0,99	30%	20,0

Image

Name	Value
Date	17/10/2007
Time	8:33:02
File name	20071017.f.sur.upm.jpg
Title	20071017.f.sur.upm.jpg
Type	P25 PAL
Serial number	23403595
Lens	24
Filter	NOF

Histograma

Label	Thresh...	Above	Below
LI01	0,0	100,00	0,00
LI02	0,0	100,00	0,00

Vista fachada sur

Investigación: Optimización de cerramientos multicapa ligeros desde el punto de vista de eficiencia energética.

Director: Dr. Sergio Vega Sánchez

Investigadora: Letzai Ruiz Valero.

Fig.8 “Thermographic Results Chart for the south façade at UPM”

3.2. - Thermal analysis

This software is capable of generating results of great interest to this study, as highlighted by the following:

3.2.1. - Isotherms, represent the lines of constant temperature that exist in the enclosure of a specific unit, the graph below (fig.9) shows the thermal performance of the enclosure.

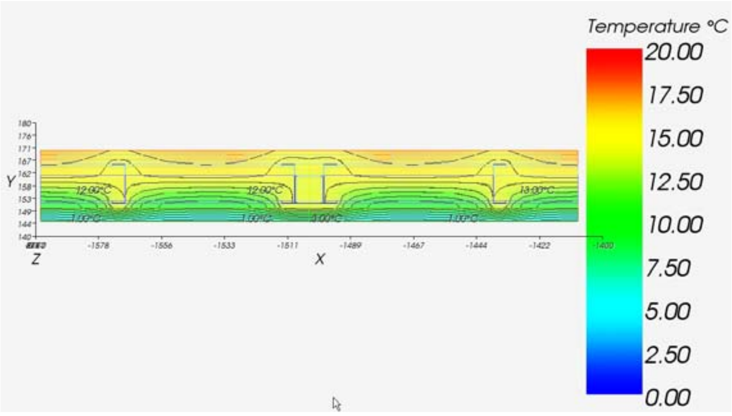


Fig.9 “Isotherms in the south façade at UPM”

3.2.2. - Heat flow, this graph (fig.10) shows the heat transmission in the enclosure, the thermal bridges can also be seen in the areas where heat is more easily transmitted, due to different materials or thickness.

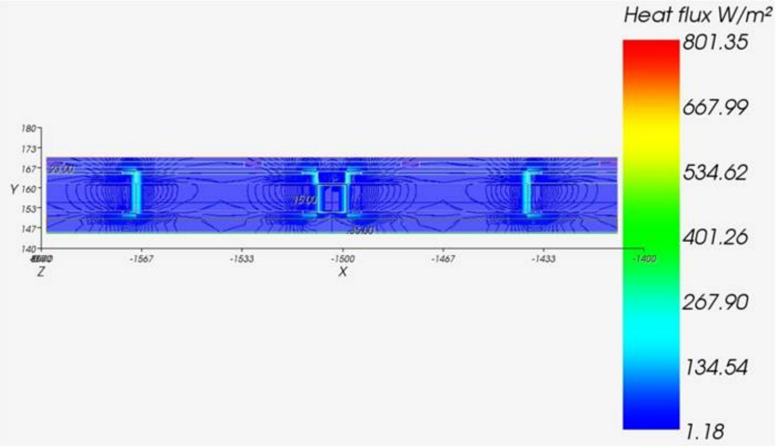
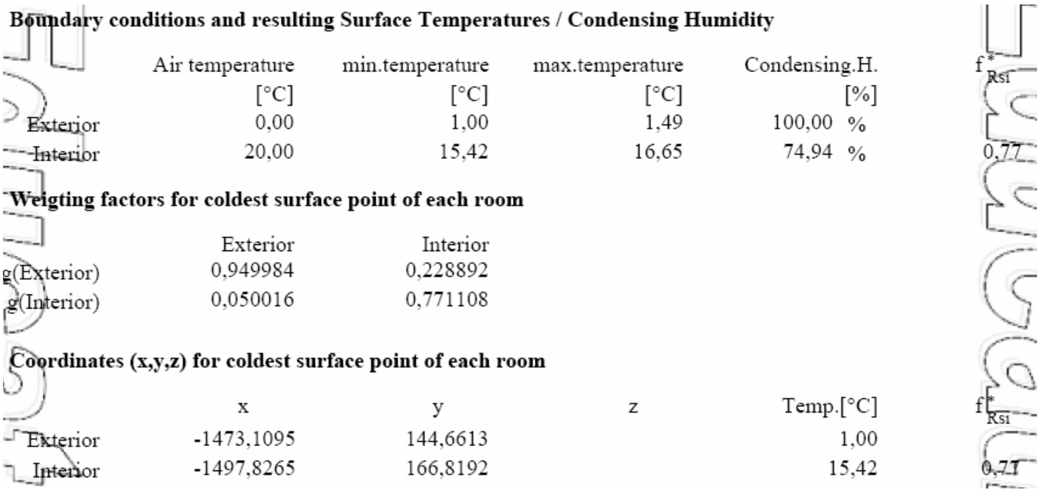


Fig.10 “Heat flow in the south façade at UPM”

3.2.3. - Data, numerical report chart (fig.11), shows air temperature conditions (minimum and maximum), as well as surface temperature values (minimum and maximum), exterior as well as interior, and the condensation humidity percentage, among others.



Boundary conditions and resulting Surface Temperatures / Condensing Humidity

	Air temperature [°C]	min.temperature [°C]	max.temperature [°C]	Condensing.H. [%]		f^*_{Rsi}
Exterior	0,00	1,00	1,49	100,00	%	
Interior	20,00	15,42	16,65	74,94	%	0,77

Weigting factors for coldest surface point of each room

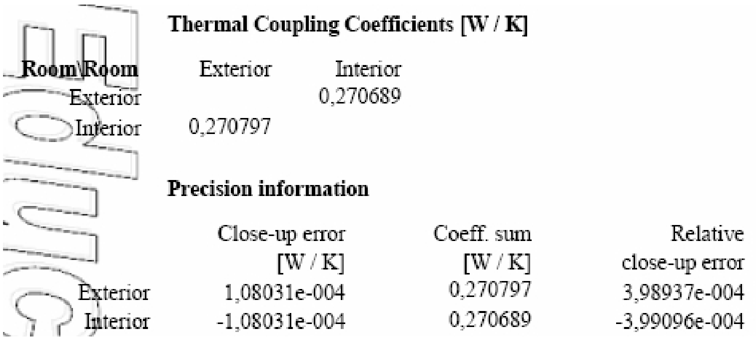
	Exterior	Interior
g(Exterior)	0,949984	0,228892
g(Interior)	0,050016	0,771108

Coordinates (x,y,z) for coldest surface point of each room

	x	y	z	Temp.[°C]	f^*_{Rsi}
Exterior	-1473,1095	144,6613		1,00	
Interior	-1497,8265	166,8192		15,42	0,77

Fig.11 “Data Report Chart for the south façade at UPM”

3.2.4. - U value (W/m^{2}K), the software generated the thermal coupling coefficient L2D (fig.12) used to obtain the U value. The European standard EN 13830 on light façades has been taken into account



Thermal Coupling Coefficients [W / K]

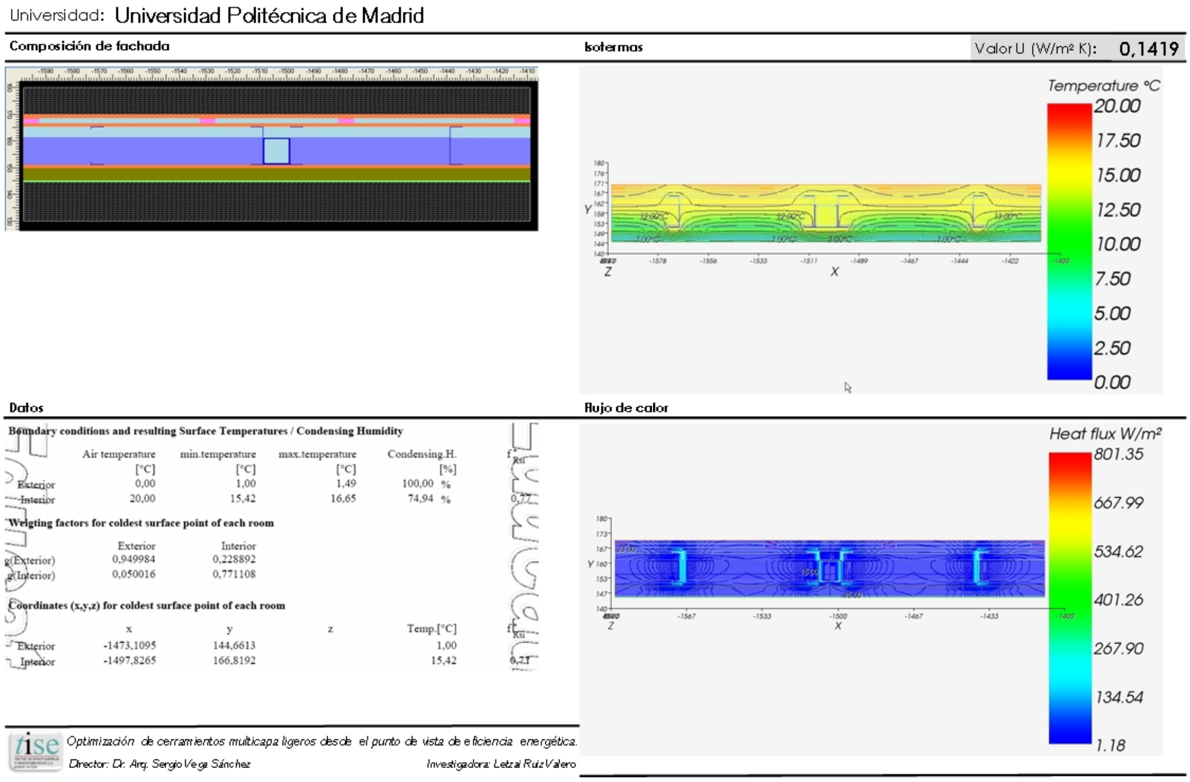
Room\Room	Exterior	Interior
Exterior		0,270689
Interior	0,270797	

Precision information

	Close-up error [W / K]	Coeff. sum [W / K]	Relative close-up error
Exterior	1,08031e-004	0,270797	3,98937e-004
Interior	-1,08031e-004	0,270689	-3,99096e-004

Fig.12 “Thermal coupling coefficient for the south façade at UPM”

To organize this data the following charts have been drawn up (fig.13), which evaluate thermal performance in the façades.



Universidad: Universidad Politécnica de Madrid

Datos

Boundary conditions and resulting Surface Temperatures / Condensing Humidity

	Air temperature [°C]	min.temperature [°C]	max.temperature [°C]	Condensing.H. [%]	f_{Rsi}
Exterior	0,00	1,00	1,49	100,00 %	
Interior	20,00	15,42	16,65	74,94 %	0,77

Weigting factors for coldest surface point of each room

	Exterior	Interior
g(Exterior)	0,949984	0,228892
g(Interior)	0,050016	0,771108

Coordinates (x,y,z) for coldest surface point of each room

	x	y	z	Temp.[°C]	f_{Rsi}
Exterior	-1473,1095	144,6613		1,00	
Interior	-1497,8265	166,8192		15,42	0,71

Optimización de cerramientos multicapa ligeros desde el punto de vista de eficiencia energética.

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Fig.13 “UPM thermal analysis results chart”

4. - Conclusion

Of all the enclosures analyzed, the four with the highest thermal performance are Cornell, Lawrence, Darmstadt y UPM. Cornell and Lawrence use a sandwich panel with a thickness of 26.5 cm. While, Darmstadt and UPM use a variety of multi layers made of different materials to guarantee excellent thermal performance.

Therefore, the conclusion has been reached that comparing a traditional enclosure to a light multi-layered one of equal thickness, an improvement of 65% can be achieved in the thermal transmittance (U value), which signifies a saving in energy consumption, exceeding the Technical Building Code.

It can also be said that the methods of analysis using thermal images aren´t ideal to carry out this type of research, as different variables exist that influence the real appreciation of thermal performance in enclosures, which is the case when photovoltaic/thermal panels and evacuation tubes are present and form part of the façade, making the thermographic reading not the performance of the façade but in reality the surface temperature of these capture systems. Nevertheless, for this study of thermal bridges in buildings, this method is essential due to the data generated and the ease with which the images can be interpreted.

Thermal analysis is an extremely important method for evaluating thermal performance in any enclosure, and for analyzing values, graphs and compositions of different façades, and it can be concluded that light multi-layered enclosures offer increased thermal performance compared to traditional ones. Taking into account that light multi-layered façades produce greater heat transmission, 0.28 W/m2K compared to 0.40 W/m2K in a traditional façade, signifying that these façades sufficiently comply with the demands of current regulations.

In turn, heat loss produced in a traditional enclosure is 8 W/m2, which corresponds to 100% in this study. While the highest level of heat loss in a multi-layered façade is 71.77 % with a lowest loss of 27.27 %, signifying that all this is directly related to different layers that make up a façade and the type of construction system used, which is key to present areas that ease the flow of heat, thus becoming thermal bridges.

5. - References

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