Facades Modules for Eco-Efficient Refurbishment of Buildings: Glazing Thermal Performance Analyses to Coimbra and Faro

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ABSTRACT

New legislation and incentives have been created, showing that there is an attempt to act and to intervene in energy efficiency area. Energy consumption reduction and prevention of energy waste is one of the main objectives of the European Union (EU). Building facades constitute a privileged component to propose solutions, once it has a major influence in the energy consumption in the building and in occupants comfort; because it has elements that contribute significantly with the heat transfer. This paper presents a study on about a new facade concept: "Facade Modules for Eco-Efficient Refurbishment of Buildings", especially on thermal performance of glazing modules. Computational simulation was done with the Design Builder software for ten different double glazing types (composed by green and transparent solar control glass, self-cleaning glass, two low-e glasses types, two extra clear glass) for two climates in Portugal (Coimbra and Faro) and four solar orientations (north, south, east and west). The results were obtained for heating and cooling energy necessities and were compared to all glazing types. These results showed a better performance to glazing compositions that combines solar control and self-cleaning glass with extra clear glass to both cities. Facades with green solar control glass and extra clear glass presented a better performance in comparison with others types studied, decrease cooling energy necessities. The great majority of the glass facade compositions presented heating and cooling energy necessities according to Portuguese standards (RCCTE) recommendations.

1. INTRODUCTION

1.1 Facades

In the last years, the increase of the energy consumption in the buildings sector, as well as the improved public sensitivity for environmental subjects resulted in an attempt to find the causes for such occurrence and to search mitigation solutions to this tendency. Several studies present as conclusion that there is a great potential of energy consumption reduction at the level of housing and services. New legislation and incentives have been created, showing that there is an attempt to act and to intervene in these areas. Energy consumption reduction to prevent energy waste is one of the main objectives of the European Union (EU).

The main function of the facade is to create habitability conditions for the building, protecting the interior environment against the undesirable action of the several agents (heat, cold, sun, rain, wind, humidity, noises, etc.) and controlling them. Now the facades become approached as an important element that it influences in the thermal changes between the interior and the exterior of the building, with a potential impact for the comfort of occupants and for the energy efficiency.

It is possible that the facades contribute in a significant way to the reduction of the energy consumptions in the buildings when working as a selective barrier in relation to the climatic conditions, in way to allow and to maintain conditions of comfort interiors, without resource to HVAC systems, or at least reducing to the minimum the need to appeal to this system type.

In this context, the search for new technologies to energy efficiency in buildings is urgent and pertinent, once conventional technologies currently used in the refurbishment of buildings in the most cases are not efficient. Compared with the technologies that incorporate high performance components, construction industry practically has not been integrating technologies in its operations to pursuit sustainability. New architectural and construction products developed to be applied in building facades are the most effective way to achieve this aim.

Facades are privileged components to propose solutions, since they have a major influence in the energy consumption of building and in occupants comfort; because they have elements that contribute significantly to the heat transfer. To aim project quality it is necessary to search for new facades technologies and to identify parameters and environmental variables that can support the process to obtain adapted solutions in order to reach energy efficiency and ideal conditions of environmental comfort for occupants.

The design facade complexity has had a high level of improvement; it type of facade can be denominated "Intelligent Facade". This term refer to facades that give a dynamic response to exterior and interior environment, with conscious energy consumption. However, there are a large number of elements and configurations that can be chosen, and must be considered the parameters: cost, aesthetics, solar orientation, openings (windows), glass and another (Ochoa; Capeluto, 2008). Compagno (2002), for example, denominate this variety of facade as "intelligent glass facades" it include high performance glass (reflective, low-e, self-cleaning, absorbent, etc.) it had a relevant development in the last years.

Figure 1 presents some of the requirements and aspects that should be considered during the conception of a facade.

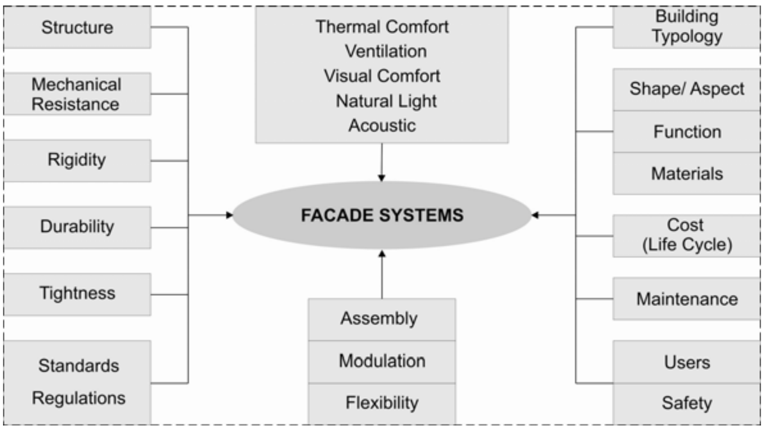

Figure 1. Outline of the parameters and aspects that should be considered during the facade design.
Reference: SACHT, 2010b.

1.1.1 Facade Innovations

Nowadays, the integration of several functions in recent developments in the facades area are important. The facade defines the potential of the building more than any another element, it should be flexible as such. This flexibility could be reached in several ways, for example, in terms of techniques, implementation of solutions with mobile, replaceable and exchanged elements.

Various facade system producers and architects have recently developed service integrated facades. These are composed of parts with fixed glazing, operable windows and decentralized HVAC service installations.

Facade technologies were undergone in the last decades to substantial innovations by integrating specific elements to adapt the mediation of the outside conditions to user requirements, both in the quality of materials and components and in the overall conception and design of the facade system. These improvements include passive technologies, such as multi layered glazing, sun protections, ventilations, etc (Castrillón, 2009).

In the development integrated process, facility managers, climate designers and manufacturers of HVAC components are involved. Due to these short distances, such units provide a high efficiency in air conditioning and heat recovery. As every facade element is equipped with HVAC installations, it is easy to provide individual comfort control for every office space for example. Disadvantages of such systems lie in the lack of compatibility with operable windows and mainly in a large number of maintenance points like filters (Ebbert & Knaack, 2008). As example, one type of modern system of facades can be mentioned, the Capricorn (Fig. 2).

Figure 2. Capricorn Haus Facade, Düsseldorf (a) and section facade detail (b).
Reference: FSL, 2010

The Capricorn Haus Düsseldorf has an exterior facade with integrated active components. The design of the facade includes transparent and opaque components, combining visibility, natural light and reduction of solar gains, when compared to conventional curtain walls. The Capricorn Haus facade incorporates all the technology and equipment to regulate the indoor climate.

The ideal would be the development of a dynamic and flexible facade system in way to adapt to the climatic changes, to the occupants requirements and, however, to adapt to the building. An improvement would be the development of a system that facilitated the assembly of the facade, containing passive elements, glazing and of reception of solar energy to improve the comfort conditions in agreement with the climatic needs and be mounted in agreement with the solar orientations and wanted functions.

The purpose of this paper is to presents initial studies about glazing modules of a new facade system: "Facade Modules for Eco-efficient Refurbishment of Buildings" on the development (SACHT et al. 2010a). The main idea is that this system is a technology in the new and growing need of products that solve the legal, functional and aesthetic demands, executing the function of reducing the energy expenses with HVAC systems and lighting in housing and office buildings, increase the benefits of the solar radiation use. Furthermore, to be a versatile, innovative and attractive product to being applied in the whole buildings type, existing buildings (refurbishment solutions) or new buildings.

2. OBJECTIVES

This work reports the results of an ongoing investigation on a new facade system concept, designed as: "Facade Modules for Eco-Efficient Refurbishment of Buildings" in development initially for Portugal. In this phase was studied glazing modules compound of high performance glasses. This paper presents some results of thermal performance simulation for two Portuguese climates (Coimbra and Faro), considering the use of ten types of glazing modules and analyzing the influence of this in heating and cooling energy necessities for one isolated cell.

3. METHODOLOGY

3.1 Overview

In this initial investigation a model (with an area of 25 m²) was simulated with the software Design Builder (graphical interfaces for EnergyPlus). Initial simulations were made for ten different glazing types, four solar orientations, and two envelope types: a Portuguese traditional system (double masonry) and a light gauge steel framing system (LGSF). After have obtained simulations results, the heating and cooling energy necessities values was compared with values calculated based on "*Regulamento das Características do Comportamento Térmico dos Edifícios*" RCCTE (RCCTE, 2006), the Portuguese thermal comfort standard.

3.2 Climates for Computational Simulations

For the simulation of thermal performance two climates from Portugal were on the analysis, in this case Coimbra and Faro. Simulations were done for four solar orientations (north, south, east and west), considering the annual period. Heating and cooling energy necessities were calculated according to RCCTE (RCCTE, 2006) and the following parameters were used in the results analysis (Tab. 1).

Table 1. Climates for Computational Simulation.

Cities	Climatic Zone		Energy Necessity	
	Winter	Summer	Heating (kWh/m².year)	Cooling (kWh/m².year)
Coimbra	I_1	V_2	68,13	16,00
Faro	I_1	V_2	50,69	32,00

3.3 Design Builder Software

Design Builder software is a friendly graphic interface for the program EnergyPlus simulation engine, to the family of software tools for modeling building facades and fenestration systems. Developed for use at all stages of building design, Design Builder combines state-of-the-art thermal simulation software with an easy-to-use. This software allows calculating building energy use; evaluating facade options for overheating and visual appearance; visualization of site layouts and solar shading; thermal simulation of naturally ventilated buildings; lighting control systems model savings in electric lighting from daylight; calculating heating and cooling equipment sizes, etc.

3.4 Envelope

A Portuguese traditional system (double-wall masonry) usually used and a light gauge steel framing system (LGSF) [1] were considered in the model for the opaque envelope.

The traditional system is composed by lightweight concrete slabs and insulation (stone wool); external walls in double masonry with interior insulation and cement mortar plaster. The light gauge steel framing system is also composed by lightweight concrete slabs and others insulation components (expanded polystyrene - EPS), and EIFS (External Insulation and Finish System), OSB boards, stone wool and gypsum plasterboard was used in the walls.

Table 2 presents a thermal transmission coefficient values (W/m² ºC) for Portuguese traditional system and light gauge steel framing system.

[1] The LGSF envelope composition was based in the work of Santos et al (2009).

Table 2. Thermal Transmission Coefficient (W/m² ºC)

Thermal Transmission Coefficient (W/m² ºC)		
Element-Envelope	Portuguese Traditional System	
	Total Thickness (cm)	U (W/m² ºC)
External Walls	0,365	0,46
Roof Slab	0,280	0,55
Element-Envelope	Light Gauge Steel Framing System	
	Total Thickness (cm)	U (W/m² ºC)
External Walls	0,200	0,14
Roof Slab	0,333	0,22

3.5 Standard Model Definition

The "standard model" was defined considering a one-storey isolated cell, with regular geometry 5,0 x 5,0 (25 m²) (Fig. 3), a ceiling height of 2,80 m, and a total dimension of 2,5 x 2,5 (6,25 m²) for the facade glazing modules composition. These dimensions followed the the recommendations from "*Regulamento Geral das Edificações Urbanas*" (RGEU, 2007) of Portugal.

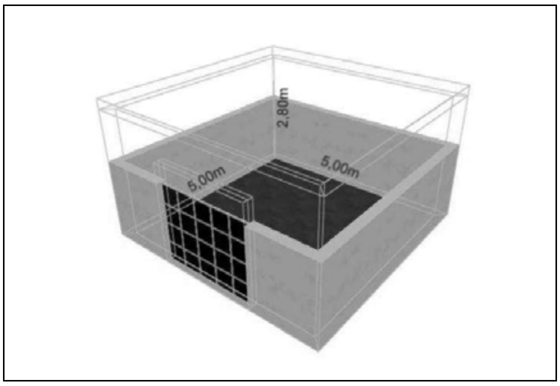

Figure 3. Standard Model.

3.6 Internal Gains and Reference Temperatures

The Portuguese standard RCCTE (2006) presents 4W/m² as an average value for the total internal gains (occupation, lighting and equipments). However, due to possibilities and simulation options offered by the software Design Builder, the internal gains were separated for the occupation, lighting and equipments (Tab. 3).

Table 3. Internal Gains (W/m²)

Internal Gains	Valores (W/m²)	Obs
Occupation	5,6 W/m² (2 people)	70 W per person
Lighting	9,4 W/m²	Illuminance (incidence): 300 lux; Fluorescent lamp (40 W); Efficiency 80 lm/W (40 % delivery efficiency).
Equipments	8 W/m²	Total equipment potency: 200 W.

As RCCTE standard does not contemplate schedules (days of the week, hour and time) of occupation, lighting and equipments use for housing buildings, the values s presented in Table 3 were adopted from Souza (2008).

The value 20°C was considered as reference of heating indoor temperature (winter) and 25°C for cooling indoor temperature (summer), in agreement with RCCTE.

3.7 Glazing Types

Important factors must be observed in the glazing choose as: solar factor (or g-value), solar heat gain coefficient, shading coefficient, and visible transmittance, furthermore U-factor resultant of glazing composition. The glasses selected for the standard facade module simulations are from *Saint-Gobain Glass*. Table 4 presents the mainly properties, where Cool Lite KNT 155 is a temperable solar control glass, manufactured by depositing of metallic oxides coating; Bioclean is a self-cleaning glass and have a low-e coating; Planilux is a multi-purpose clear float glass; Planistar is a clear solar control glass and have a low-e coating; Diamant is a clear float glass; Planitherm Total is a low-emissivity (low-e) glass and Planitherm Futur Ultra N is a glass with emissivity extremely low.

Table 4. Glass types for standard module.

Glass Types								
Properties	Cool Lite KNT 155 Green	Cool Lite KNT 155 Clear	Bioclean	Planilux	Planistar	Diamant	Planitherm Total	Planitherm Futur Ultra N
Thickness (mm)	4 mm	4 mm	4 mm	4 mm	4 mm	4 mm	4 mm	4 mm
Solar Factor g	0.45	0.51	0.84	0.85	0.46	0.90	0.66	0.63
Shading Coefficient	0.52	0.54	0.97	0.98	0.53	1.04	0.78	0.72
Visible Transmittance	0.47	0.54	0.87	0.90	0.79	0.91	0.85	0.88
U (W/m²K)	5.75	5.75	5.87	5.80	5.73	5.80	5.74	5.73

Table 5 presents the glazing compositions made base on in glasses of Table 4. This was used in the computational simulations in Design Builder software to obtain heating and cooling energy necessities to Coimbra and Faro. Furthermore a 12 mm air layer between outermost and inner panes was considered.

Table 5. Glazing Compositions

Glazing Compositions			
Glazings	Outermost Pane	Inner Pane	U (W/m²K)*
Glazing 01	Cool Lite KNT 155 Clear	Planitherm Total	1,79
Glazing 02	Cool Lite KNT 155 Clear	Planitherm Futur Ultra N	1,70
Glazing 03	Cool Lite KNT 155 Green	Planitherm Total	1,79
Glazing 04	Cool Lite KNT 155 Green	Planitherm Futur Ultra N	1,66
Glazing 05	Bioclean	Planitherm Total	1,80
Glazing 06	Bioclean	Planitherm Futur Ultra N	1,72
Glazing 07	Bioclean	Planilux	2,72
Glazing 08	Planistar	Planilux	2,69
Glazing 09	Planilux	Planitherm Total	1,80
Glazing 10	Diamant	Diamant	2,72

* Values obtained from Window 6.2.33.0 software (LBNL, 2010).

4. RESULTS

The results presents heating and cooling energy necessities for four solar orientations (north, south, east and west), considering the annual period. Results analyses are done based on RCCTE value calculated for Coimbra and Faro (heating and cooling energy necessities).

4.1 Coimbra

4.1.1 Heating Energy Necessity

All glazing types analyzed for Coimbra presented heating energy necessity lower than the ones recommended by RCCTE for a model with characteristic and shape factor mentioned previously (Fig. 4 and 5). In thermal simulations were considered as envelope the traditional system (double-wall masonry) and LGSF system, the use of all types of glazing in the model indicated heating energy necessities below that recommended by RCCTE (Fig. 4 and 5). It was observed that the heating energy necessities were lower for LGSF system used in the model. Glazing 10, 9 and 7 presented better results in comparison with the other glazings.

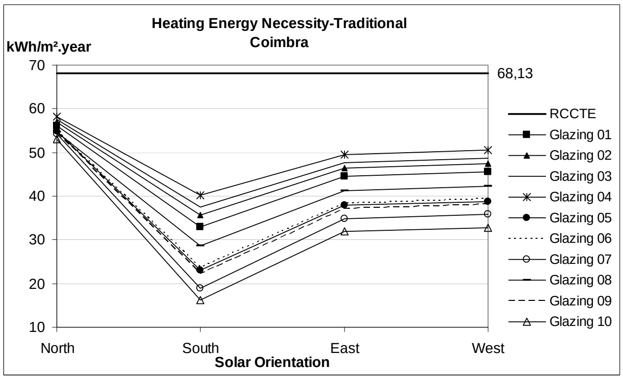

Figure 4. Heating Energy Necessity: Traditional - Coimbra.

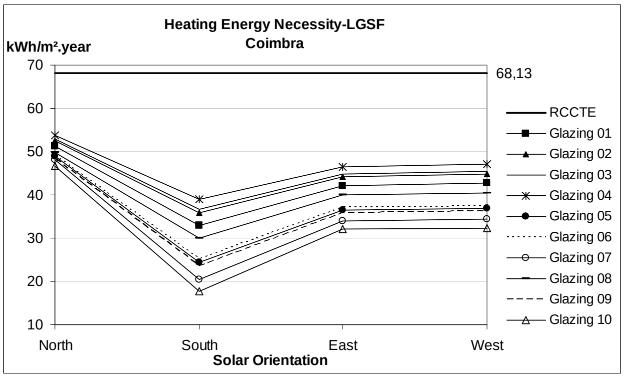

Figure 5. Heating Energy Necessity: LGSF - Coimbra.

4.1.2 Cooling Energy Necessity

Cooling energy necessities for Coimbra, considering LGSF envelope were below the one recommended by RCCTE (16 kWh / m². Years) for great part of glazing types. It taking exception of glazing 07 (Bioclean 4 mm – Planilux 4 mm) and the glazing 10 (Diamant 4 mm - Diamant 4 mm), especially for west orientation (Fig. 7).

It was observed that only the glazing 03 (Cool Lite KNT 155 Green 4 mm - Planitherm Total 4 mm) and glazing 04 (Cool Lite KNT 155 Green 4 mm - Planitherm Futur Ultra N 4 mm) had values below recommended by the RCCTE (16kWh / m². years), the remaining glazings presented higher consumption for the model, mainly for the south and west orientations (Fig. 6).

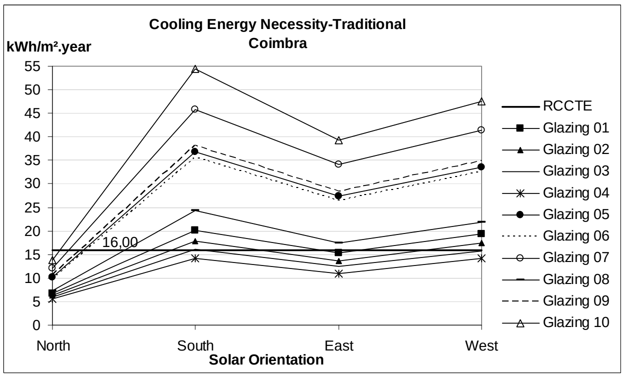

Figure 6. Cooling Energy Necessity: Traditional - Coimbra.

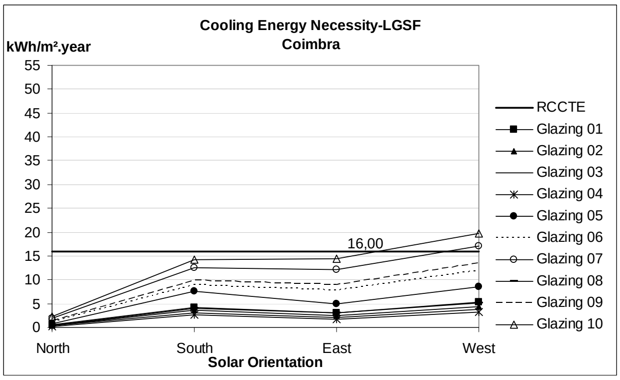

Figure 7. Cooling Energy Necessity: LGSF - Coimbra.

4.2 Faro

4.2.1 Heating Energy Necessity

All glazing types analyzed for Faro presented heating energy necessities lower than the recommended by RCCTE (Fig. 8 and 9). Simulations made in the model considering the traditional system and LGSF system envelope for all glazing types indicated heating energy necessities below the ones recommended for RCCTE. As in Coimbra glazing 10, 9 and 7 presented better results.

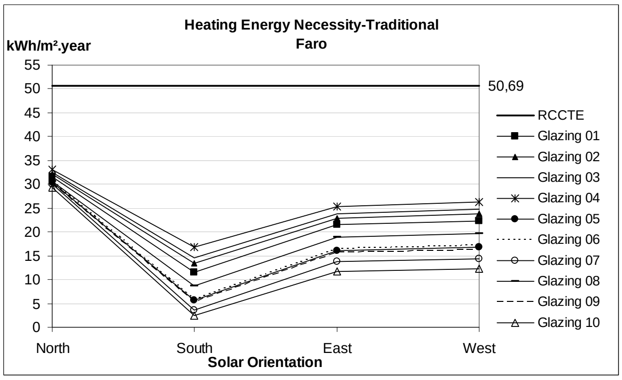

Figure 8. Heating Energy Necessity: Traditional - Faro.

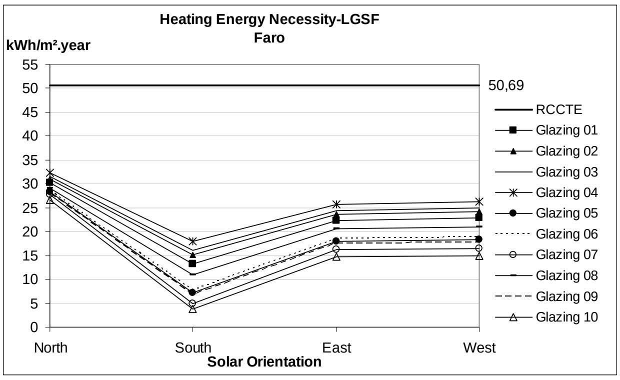

Figure 9. Heating Energy Necessity: LGSF - Faro.

4.2.2 Cooling Energy Necessity

In the cooling energy necessities analysis to Faro was observed that only the glazing 04 (KNT 155 Cool Lite Green 4 mm - Planitherm Futur Ultra N 4 mm) had values below the recommendations of RCCTE (32kWh / m². years). The analysis considered the models as traditional system envelope.

This results indicates that glazing 03 (Cool Lite KNT 155 4mm green - Planitherm Total 4 mm) and glazing 04 (Cool Lite KNT 155 4mm green - Planitherm Futur Ultra N 4 mm) can offer better results for applications in climates that presents high cooling energy necessities, as in Faro.

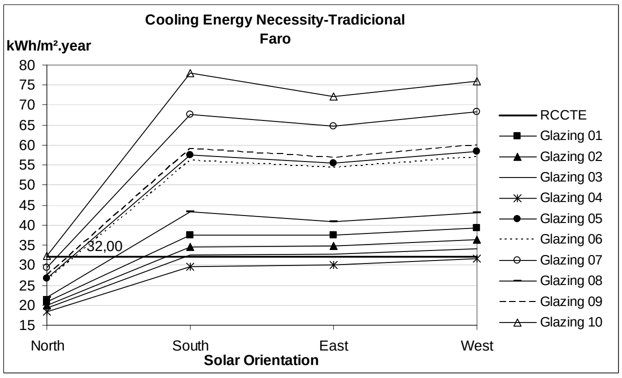

Figure 10. Cooling Energy Necessity: Traditional - Faro.

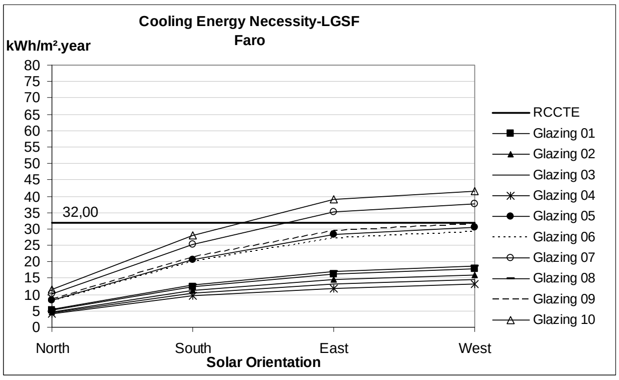

Figure 11. Cooling Energy Necessity: LGSF - Faro.

5. CONCLUSIONS

Thermal simulations with ten glazing types, for two different climates and envelopes were done. Results shows that all glazing types presented heating necessities lower them the maximum limits (for city) recommended by RCCTE. In this case, stood out Glazing 07 (Bioclean 4 mm - Planilux 4 mm) and glazing 09 (Planilux 4 mm - Planitherm Total 4 mm); glazing 10 can be excluded (Diamant 4 mm - Diamant 4 mm), because in spite of presenting the smallest heating energy necessity regarding to the others, it implies in a considerable increase of the cooling energy necessity.

With respect to the cooling energy necessity, glazing 03 (Cool Lite Green KNT 155 4 mm - Planitherm Total 4 mm) and glazing 04 (KNT 155 Cool Lite Green 4 mm - Planitherm Futur Ultra N 4 mm) stood out for presenting values below recommended for RCCTE. Therefore, glazings that can be suitable: glazing 04 (Cool Lite KNT 155 Green 4 mm - Planitherm Futur Ultra N 4 mm); glazing 07 (Bioclean 4 mm - Planilux 4 mm) and glazing 09 (Planilux 4 mm - Planitherm Total 4 mm). However can be indicated the use of glazing 04 in the facade modules, because it answering with a good performance in both cases.

Afterward it is waited that these facade modules application, with add of other types of passive solutions, besides those studied, contribute for the energy consumption reduction with systems HVAC and lighting in the buildings, increasing the benefits of the solar radiation use. Intend to create versatile, innovative and attractive modules, possible of being applied in the whole buildings typology, refurbishment solutions and new buildings, allowing to the architects an application of this facade solution in their projects.

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