Façade Modules for Eco-Efficient Refurbishment of Buildings: Glazing Thermal Performance to Guimarães Climate

Helenice M. Sacht
University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
hmsacht@civil.uminho.pt

Luís Bragança
University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
braganca@civil.uminho.pt

Manuela Almeida
University of Minho, School of Engineering, Department of Civil Engineering, Guimarães, Portugal
malmeida@civil.uminho.pt

ABSTRACT: During the last decades façade technologies have undergone to substantial innovations by integrating specific elements to adapt the mediation of the outside conditions to user requirements. This work reports the results of an ongoing investigation on a new façade system concept called "Façade Modules for Eco-Efficient Refurbishment of Buildings" and initially developed for Portugal. In this phase glazing modules made of high performance glasses were studied. Some results of thermal performance simulation for the Portuguese Guimarães city climate will be presented considering the use of three types of glazing modules and analyzing the influence of some parameters in heating and cooling energy needs for one room (size 25m²). Computational simulation was done with the Design Builder software considering the following parameters: three different double glazing types; two envelope types and four solar orientations. The results were obtained for heating and cooling energy needs and were compared to all glazing types. It can be noted a better performance to glazing compositions that combines solar control and self-cleaning glass with extra clear glass. The results indicated a decrease of heating energy needs by the use of self-cleaning glass and clear float glass. Additionally cooling energy needs decrease was observed by the use of a green solar control glass with low-e glass.

1 INTRODUCTION

1.1 *New Façades Systems*

Recent studies have discussed the possibilities of improving energy performance of old existent buildings by their sustainable restoration and/or retrofitting, using new envelopes. Energy performances and building energy quality can be achieved by high performance envelopes.

Façades 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 achieve a good project quality it is necessary to search for new façade technologies, to identify parameters and environmental variables that can support the process to obtain adapted solutions to reach energy efficiency and adequate conditions of environmental comfort for occupants.

One workable solution in such situation is, e.g., the use of “dynamic” façade systems whose properties can be actively controlled to achieve the desired operating behavior in response to the indoor and outdoor changing conditions. In the considered “best new solutions” the façades play multiple and complementary roles in providing natural ventilation, daylight and thermal tempering. But this requires a high degree of integration that must be thought already in the early stage of the design process. It also suggests levels of technology integration that are not routinely practiced in buildings, although they are consistently achieved in other manufacturing sectors such as the automotive and aircraft industries (Selkowitz et al. 2003b).

Nowadays, the integration of several functions in recent developments in the façade technology area is important. The façade defines the potential of the building more than any another element and 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.

1.1.1 *Façade Innovations*

In recent decades façade technologies have undergone to substantial innovations both in quality of materials/components and the overall design concept of the façade system by integrating specific elements to adapt the mediation of the outside conditions to user requirements. These improvements include passive technologies, such as multi layered glazing, sun protections, ventilation, Trombe walls, etc. (Castrillón, 2009).

The "intelligent glass façades" including the glass performance, such as the late development of reflective, low-e, self-cleaning, absorbent, etc. had a relevant development in the last years. Façade types have been suffering an important development and they are being diffused more and more, including new technologies, besides passive and active solutions of climatic adaptation (Compagno, 2002).

The ultimate development is the "interactive façade". It should respond intelligently and reliably to the changing outdoor conditions and internal performance needs. It should exploit available natural energies for lighting, heating and ventilation should be able to provide large energy savings compared to conventional technologies, and at the same time maintain optimal indoor visual and thermal comfort conditions. As photovoltaic costs are expected to decrease in the near future, these onsite power systems will be integrated within the glass skin and these façades will become local, non-polluting energy suppliers to the building. The potential for facilitating sustainable building operations in the future by exploiting these concepts is therefore great (Selkowitz et al. 2003a).

The current philosophy is to design the envelope with responsive, interactive systems, also often called "intelligent envelopes". The envelope systems should react sensibly to the changes in the exterior climate and adjust solar gain, daylighting, heat loss and ventilation to the changing needs of the occupants and the building (Wigginton et al. 2002). As an example, one type of modern system of façades can be mentioned, the Capricorn (Fig. 1a, b).


a

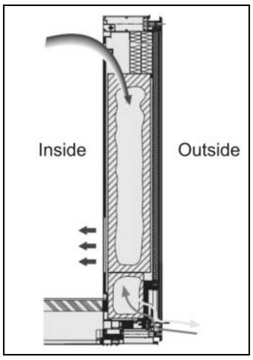

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Figure 1. Capricorn Haus Façade, Düsseldorf (a) and section façade detail (b).
Reference: FSL, 2010.

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

Another example is the Kansai Electric Power in Osaka, Japan. In this building, the energy consumption is estimated to be reduced by 30% less than conventional office building. "Eco-Frame" columns and beams jutted out by 1.8m outside from the window surface, shows effects of eaves to block the direct solar radiation during 10AM to 2PM, the peak period of the cooling load in the summer time. Low-e glass, which has a high performance in a direct solar radiation blocking and insulation, is adopted in a window to reduce an inflow of heat from exterior. By adopting these technologies, a cooling load in perimeter zone is greatly reduced (2/3 of a perimeter annual load to standard used in Japan), so that an air conditioning system for perimeter zone such as a fan-coil unit becomes unnecessarily (Fig. 2a, b) (Aschehoug & Andersen, 2008).


a

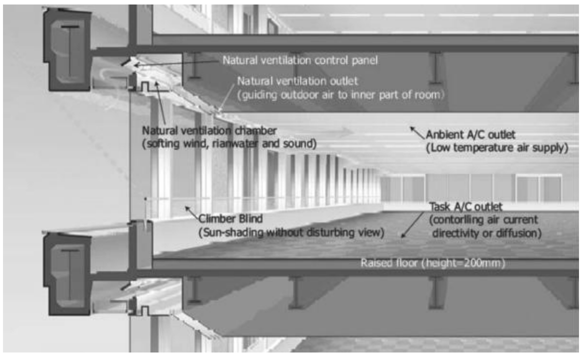

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Figure 2. Kansai Electric Power, Osaka – Japão, 2005 (a) and Façade Detail (b).
Reference: Aschehoug & Andersen, 2008.

The Nikken Sekkei in Tokyo building presented a total energy use about 50% reduction compared to reference with a "Window system responding outside environment". The development of this system started from the redesign of old Japan "Bamboo blind" as sun shade from strong west sun of summer under such a condition (Fig.3a, b) The architects and the engineers achieved coexisting of securing the flexibility of the design and the energy saving by the collaboration, and aimed at the construction of "Integrated system of “construction” and “equipment”. This system combines the electromotion exterior blind and a double-layer electric heater glass, and has controlled these automatically by the open network system.


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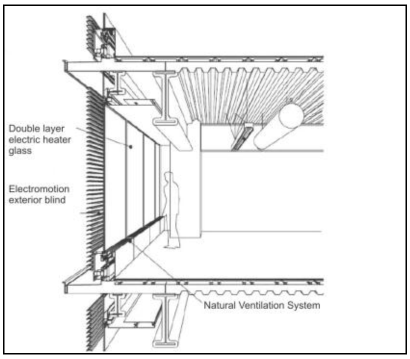

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Figure 3. Nikken Sekkei Tokyo Building (2003) (a) and Façade Detail (b).
Reference: Aschehoug & Andersen, 2008.

The ideal goal would be the development of a dynamic and flexible façade 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 façade, containing passive elements, glazing and 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.

This work presents partial results of an ongoing investigation about glazing modules of a new façade system: "Façade Modules for Eco-efficient Refurbishment of Buildings" on the development (Sacht et al. 2010a).

2 OBJECTIVES

This work reports the results of an ongoing investigation on a new façade system concept called "Façade Modules for Eco-Efficient Refurbishment of Buildings" and initially developed for Portugal. In this phase glazing modules composed by high performance glasses were studied. This paper presents some results of thermal performance simulation for the Portuguese climate of Guimarães city, considering the use of three types of glazing modules and analyzing the influence of glazing in heating and cooling energy needs for one isolated cell.

3 METODHOLOGY

3.1 *Overview*

In this initial investigation a model (25 m²) was computationally simulated with the software Design Builder (graphical interface for EnergyPlus). Initial simulations were made considering the following parameters: (i) three different glazing types, (ii) four solar orientations and (iii) two envelopes: a Portuguese traditional system (double masonry) and a light gauge steel framing system (LGSF). For validation purposes, the heating and cooling energy needs values obtained by thermal simulations were compared with the ones calculated in accordance with the Portuguese energy building performance regulation, "*Regulamento das Características do Comportamento Térmico dos Edifícios - RCCTE*" (RCCTE, 2006).

For the simulation of thermal performance the Portuguese climate was analyzed, in this case, Guimarães city climate. Simulations were done for four solar orientations (north, south, east and west), considering the annual period, and the following parameters were used in the analysis (Table 1).

Table 1. Climates for Computational Simulation.

Climate	Climatic Zone		Energy Needs	
	Winter	Summer	Heating (kWh/m².year)	Cooling (kWh/m².year)
Guimarães	I_2	V_2	81,64	18,00

3.2 *Standard Model Definition and Envelopes*

The "standard model" was defined considering a one-storey isolated cell, with regular geometry 5,0 x 5,0 (25 m²), a ceiling height of 2,80 m, and a total dimension of 2,5 x 2,5 (6,25 m²) for the façade glazing modules composition (Fig. 4). These dimensions followed the recommendations of the Portuguese Urban Building Regulation "*Regulamento Geral das Edificações Urbanas*" (RGEU, 2007).

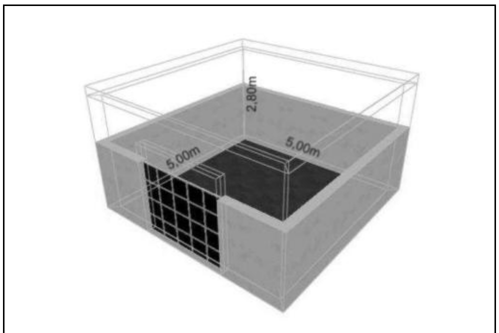


Figure 4. Standard Model.

A Portuguese conventional construction system (double-wall masonry) and a light gauge steel framing system (LGSF) were considered in the model for the opaque envelope. The LGSF envelope composition was based in the work of Santos et al (2009). 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 the overall heat transfer coefficient values - U-factor (W/m² ºC) for Portuguese conventional construction system and light gauge steel framing system.

Table 2. Overall Heat Transfer Coefficient (W/m² ºC)

Heat Transfer Coefficient (W/m² ºC)		
Element-Envelope	Portuguese Conventional System	
	Total Thickness	U (W/m²ºC)
External Walls	0.365	0.46
Roof Slab	0.280	0.55
Element-Envelope	Light Gauge Steel Framing System	
	Total Thickness	U (W/m²ºC)
External Walls	0.200	0.14
Roof Slab	0.333	0.22

3.3 *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 façade module simulations are from Saint-Gobain Glass. Table 4 presents the mainly properties, where Cool Lite KNT 155 green is a solar control tempered glass, manufactured by depositing of metallic oxides coating; Bioclean is a self-cleaning glass; Planilux is a multi-purpose 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	Bioclean	Planilux	Planitherm Total	Planitherm Futur Ultra N
Thickness	4 mm	4 mm	4 mm	4 mm	4 mm
Solar Factor g	0.45	0.84	0.85	0.66	0.63
Shading Coefficient	0.52	0.97	0.98	0.78	0.72
Visible Transmittance	0.47	0.87	0.90	0.85	0.88
U (W/m²K)	5.75	5.87	5.80	5.74	5.73

Table 5 presents the glazing compositions based on the glasses types presented in Table 4. These glasses were used in the computational simulations in Design Builder software to obtain heating and cooling energy needs to Guimarães city. Furthermore, a 12 mm air layer between outermost and inner panes was considered. It should be noted that these values were obtained from Window 6.2.33.0 software (LBNL, 2010).

Table 5. Glazing Compositions

Glazing Compositions			
Glazings	Outermost Pane	Inner Pane	U (W/m²K)*
Glazing 04	Cool Lite KNT 155 Green	Planitherm Futur Ultra N	1.66
Glazing 07	Bioclean	Planilux	2.72
Glazing 09	Planilux	Planitherm Total	1.80

4 RESULTS

The heating and cooling energy needs for four solar orientations (north, south, east and west), considering the annual period, are presented. The analysis of the results is done based on the heating and cooling energy needs estimation for Guimarães city performed according the RCCTE energy calculation method.

4.1 *Heating Energy Needs*

All glazing types analyzed for Guimarães climate presented heating energy necessity lower than the ones calculated according to RCCTE (81.64 kWh/ m².year) for a model with characteristic and shape factor previously mentioned (Fig.5a, b). In thermal simulations were considered as envelope the Portuguese conventional system (double-wall masonry) and LGSF system. Glazing 07 presented better results in comparison with the other glazing types. It was observed that the heating energy needs presented approximate values for the both analyzed envelopes.

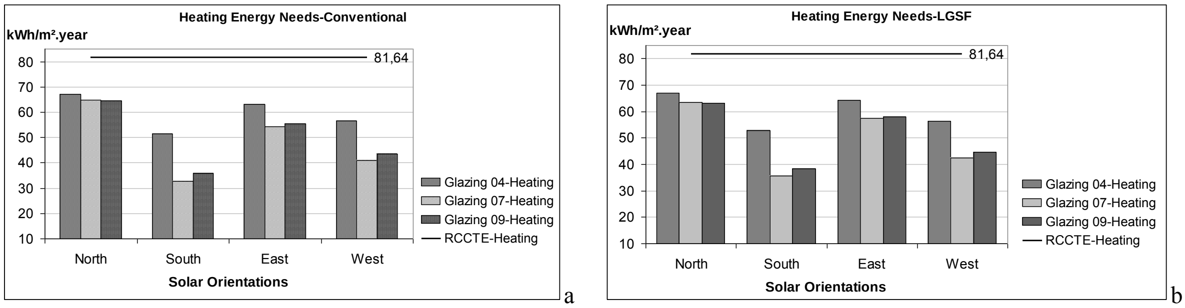


Figure 5. Heating Energy Needs. Conventional System (a) and LGSF System (b).

4.2 *Cooling Energy Needs*

Cooling energy needs for Guimarães were according to RCCTE (18 kWh/ m².year) only for glazing 04. This analysis considered just the conventional envelope and did not take into account the west solar orientation. The results obtained for LGSF envelope were below the ones estimated according to RCCTE for the most analyzed glazing types. The performed analysis did not take into account the glazing 07 and 09 for west solar orientation (Fig. 6a, b). It was observed that only the glazing 04 (Cool Lite KNT 155 Green 4 mm - Planitherm Futur Ultra N 4 mm) presented lower than RCCTE predicted value. It was observed that the cooling energy needs presented lower values to LGSF envelope.

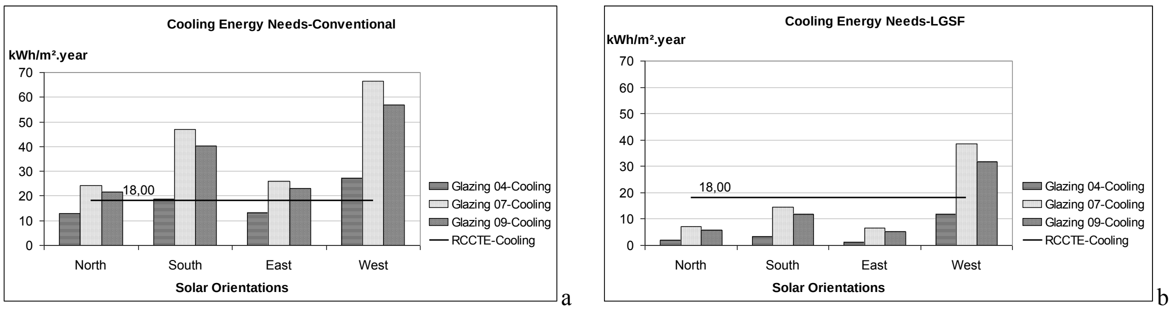
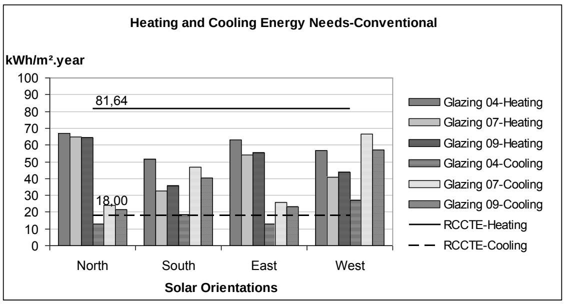


Figure 6. Cooling Energy Needs. Conventional System (a) and LGSF System (b).

Figure 7 presents heating and cooling energy needs for the conventional system and LGSF envelopes. In this case, it is possible to observe both glazings performances for the results presented previously: better results for glazing 07 and 04 concerning to heating energy and cooling energy needs, respectively.



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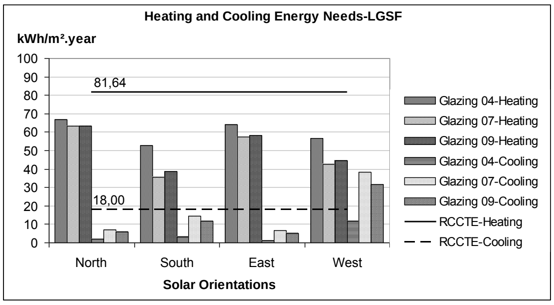

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Figure 7. Heating and Cooling Energy Needs. Conventional System (a) and LGSF System (b).

5 CONCLUSIONS

The energy simulations for the three glazing types and for the Guimarães climate were done in this research. The results showed that all glazing types presented heating energy needs lower than the maximum limits according to the Portuguese energy building performance regulation RCCTE. In this case, Glazing 07 (Bioclean 4 mm - Planilux 4 mm) stood out due to the smallest heating energy need when compared with the others, but presented a considerable increase of the cooling energy needs. It was observed that the heating energy needs were similar to both of the envelopes analyzed in this work, but the cooling energy needs were lower for the LGSF envelope.

Concerning the cooling energy needs, Glazing 04 (KNT 155 Cool Lite Green 4 mm - Planitherm Futur Ultra N 4 mm) stood out for presenting values below the ones allowed by the Portuguese energy regulation according - RCCTE.

According to RCCTE, seven months is the period of heating season for Guimarães climate. It means that during seven months per year heating is necessary to maintain comfortable conditions. Based on this period, the use of Glazing 07 in the façade modules can be indicated, due to the good performance to decrease the heating energy needs. However, Glazing 04 presented cooling and heating energy needs according to the RCCTE in spite of not presenting the better thermal performance to heating energy need.

As expected for these façade modules application, the addition of other types of passive solutions (besides those presented in this paper), contribute for the energy consumption reduction with systems HVAC and lighting in the buildings. The presented system will enable the conception of versatile, innovative and attractive modules for refurbishment solutions and new buildings, allowing to the architects an application of this façade solution in their projects.

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