Facades Modules for Eco-Efficient Refurbishment of Buildings: An Overview

Helenice Maria Sacht
University of Minho, Guimarães, Portugal

Luis Bragança
University of Minho, Guimarães, Portugal

Manuela G. Almeida
University of Minho, Guimarães, Portugal

ABSTRACT: The search for new technologies for energy efficiency in buildings is urgent once conventional technologies currently used in the refurbishment of buildings, in the most cases are not efficient. The work presents the initial studies about a new facade system: "Facade Modules for Eco-Efficient Refurbishment of Buildings". It is expected to be a new technology among the new and growing set of products that will solve the need for functional and aesthetic demands. These new elements should result in a modular system, capable of being used combined or separately with simple, flexible and versatile application procedures. Initial studies and simulations in Design Builder software were done having as object a cell (25 m²) with different arrangement of facade modules with passive and current solutions to Guimarães city. Preliminary results show a decrease of energy consumption in the analyzed cases, representing an advantage from passive solar systems and the reduction of energy consumption.

1 INTRODUCTION

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).

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.

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).

The "intelligent glass facades" 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. It is likely to the impact and further development of improved materials and construction systems become widespread. Facade 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).

1.1 *Recent developments*

Today, the integration of several functions in recent developments in the facades area had proceeded. As 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.

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, two types of modern systems of facades can be mentioned, the Capricorn (Fig. 1) and the Temotion (Fig. 2).

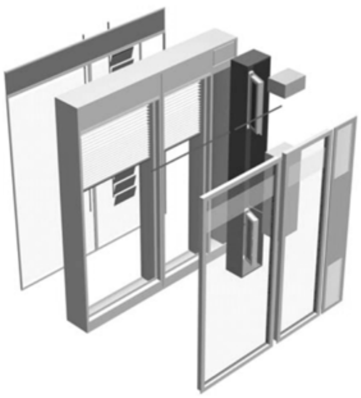

Figure 1. Temotion Facade.
Reference: Wicona Productos y Referencias. Temotion, 2009.

Figure 2. Capricorn Facade.
Reference: Schineider Electric. Capricorn Haus, 2009.

The Capricorn Haus Düsseldorf (Fig. 2) have an exterior facade with integrated active components, was recently developed by the firm Trox and Schueco. 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 company Wicona-Hydro, the Fachhochschule Biberach, and the Universität Dortmund have developed a facade that includes a number of functions, including optimized energy management, automatic adjustment of heating and cooling needs and natural and mechanical ventilation. Also integrated in the facade are sun and glare shields, and it is also possible to regulate the daylight admission and lighting, as well as the colour of the light (Castrillón, 2009).

The main feature is the integration of a vertical operable element in the facade that allows natural ventilation and at the same time includes within the volume of the vertical louvered space to receive equipment that provides mechanical heating cooling and ventilation when needed. The box-cased double facade in the window element is separated from the ventilation system, allowing direct fresh air admission. Additional features are the deflection of natural light and the integration of artificial light in the module.

In the new facades technologies, the future foresees the use of materials that can provide several functions. The objective is the development in membranes, molecules and nanotechnology area (nano coatings, adhesive materials technology, smart materials - glass coatings, phase change materials, etc.). The "future envelope" includes insulation, transparency, air quality, waterproofing and flexible permeability (Knaack & Klein, 2008).

The future facade includes various functionalities. A better integration with the building services concept, such as adaptability in response to changing climatic conditions and user requirements, as well as the integration with the structure of the building are all tasks of "tomorrow façade". Energy considerations constitute the main driving force behind new developments in the facade industry: the necessity of energy savings, insulation against heat and cold, energy storage measures as well as alternatives for energy generation have to be explored (Knaack et al, 2007).

However it is observed that some facade modules or panels have larger dimensions to integrate facade systems with various functions. This standardizes the building respecting aesthetic, and, furthermore, decreases the architect's freedom of creation.

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 idea 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.

Before in this article presents the initial studies on the development of a new facade system: "Facade Modules for Eco-efficient Refurbishment of Buildings". Waited 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; to be a versatile, innovative and attractive product to being applied in the whole buildings type, existing buildings (refurbishment solutions) or new buildings, allowing to architects an active drawing and application of this facade solution.

2 OBJECTIVES

The main objective is presents the initial results of thermal performance simulations to prove advantages of passive elements incorporation in a proposal to modulate facade system, with the purpose of decreasing heating energy consumption.

3 METHODOLOGY

In this initial research studies were accomplished by means of computational simulation with the software Design Builder for a model that will be detailed later on. Initial simulations with different glazing types were made. Later on were proposed in those model different arrangements of facade modules with passive and traditional solutions for two envelope types: a Portuguese traditional system in double masonry and a light gauge steel framing system.

3.1 *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 yet powerful 3D modeller. 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.

3.2 *Standard Model Definition*

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

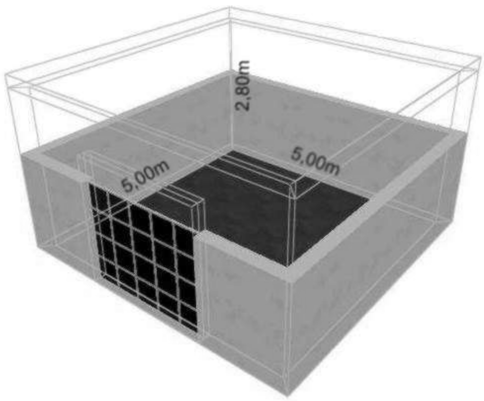

Figura 3. Standard Model

3.3 *Envelope*

Simulations were executed for the south solar orientation, considering the annual period for Guimarães city. A portuguese traditional system in double masonry and walls usually used in a light gauge steel framing system was 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 other 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 1 presents thermal transmission coefficient values (W/m² ºC) for portuguese traditional system components. It was initial simulations; this way was considered for the traditional system slabs the composition of the lightweight concrete and insulation layers only.

Table 1. Synthesis - Thermal transmission coefficient values (W/m² ºC)

Thermal transmission coefficient - Traditional System		
Element	**Thickness (cm)**	**U (W/m²) ºC)**
External Walls	0,365	0,464
Roof	0,25	0,584
Ground Floor	0,30	0,578
Thermal transmission coefficient – LGSF System		
Element	**Thickness (cm)**	**U (W/m² ºC)**
External Walls	0,199	0,14
Roof	0,223	0,216
Ground Floor	0,27	1,248

3.4 *Internal Gains*

RCCTE Portuguese standard (RCCTE, 2006) presents 4W/m² as value for referring to total internal gains (occupation, lighting and equipments), however due to possibilities and simulation options offered by the software Design Builder, the internal gains was separated for the occupation, lighting and equipments (Table 2).

Table 2. Internal Gains (W/m²)

Internos Gains	Valores (W/m²)
Occupation *	5,6 W/m² (2 people)
Lighting *	9,4 W/m²
Equipaments	8 W/m²

* Values from Swiss standard.

As RCCTE standard does not contemplate schedules (days of the week, hour and time) of occupation, lighting and equipments use for housing buildings, those values were adopted from research "Obtenção dos perfis de utilização, iluminação e de equipamentos das habitações residenciais " (SOUZA, 2008).

3.5 *Temperatures*

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.

3.6 *Glazing*

After the execution of 3 glazing types simulations (Table 3) for a project typical day in winter (December 21) and summer (June 21), was chose the solar control glazing to do the facades composition of the initial simulations.

Table 3. Glazing Types

Glazing	Outermost Pane	Inner Pane
Double Solar Control	Solar Control Glass 6mm	Low-e Glass 6mm
Double Self-Cleanning	Self-Cleanning Glass 6mm	Low-e Glass 6mm
Simple Glass	Simple extra-claro float glass 6mm	

3.7 *Module variety*

The facade modules considered in the simulations were:

- Standard module (SM): basically composed for double glass with thickness of 6mm (solar control glass and low-e glass) and air layer of 12mm;

- Trombe wall module (TW): an extra-clear float glass (6mm) for the composition of trombe wall (0,5 x 2,50m²) was used to this module. This glass has a high shading coefficient (SC) allowing the maximum solar radiation penetration. The trombe wall was considered with and without superior and inferior ventilation opening (0,10 x 0,20m²) in the storage wall.

In winter these openings stayed open from 9:00h to 18:00h and in summer closed during the day and opened during at night. Furthermore was considered in the trombe wall a box-of-air, to 5cm offset of glazing. Trombe wall storage element was composed in traditional concrete (0,15m of thickness). Figures 4a, b, c presents the facade compositions simulate for Guimarães city in Portugal.

Figure 4. Facade Module. a. Standard module facade (low-e double glass); b. 1 Trombe wall and standard module; c. 2 Trombe wall and standard module.

4 RESULTS

The first results presents the internal temperatures for a typical project day in the Winter (December 21) and in the Summer (June 21), with use of different glazing and sunshades (horizontal blinds and overhang) in the facade.

4.1 *Glazing*

Figure 5 and 6 present the mean air temperature variation for winter and summer with the use of three glazing compositions: solar control glass, self-cleaning glass and extra-clear float glass. Considering that: SCG = double solar control glass CG = double self-cleaning glass and ECG = Simple extra-clear float glass.

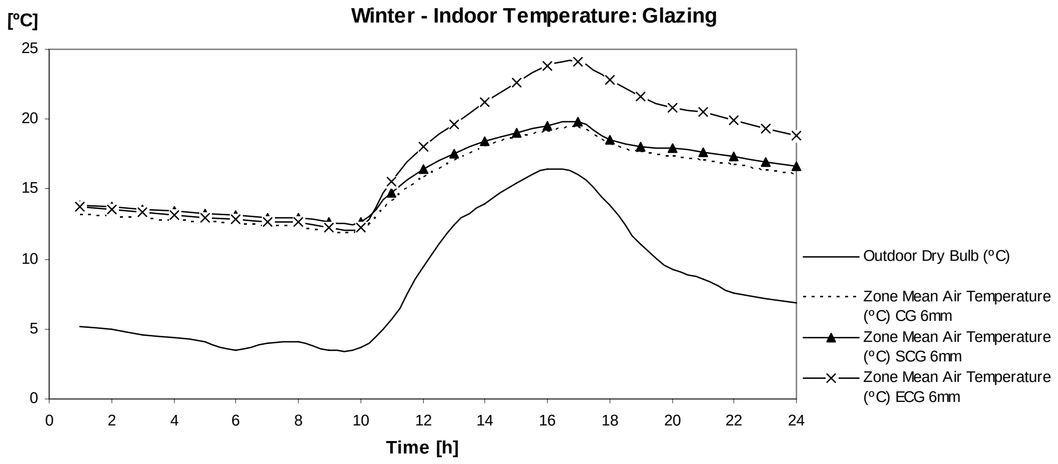

Figure 5. Indoor Temperature - Winter

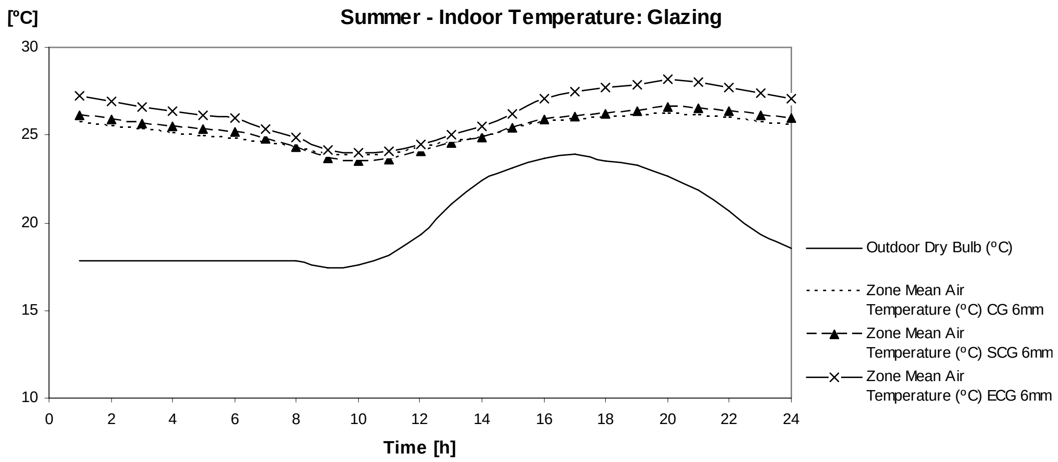

Figure 6. Indoor Temperature - Summer

Graphs indicate that for winter, that extra-clear float glass use provided an increase of the indoor temperature towards other glazing types; this indicates that glass type presents a good performance to use in passive systems as trombe wall.

Double solar control and double self-cleaning glazing had practically identical performance. Double solar control and double self-cleaning glazing had temperatures below the maximum recommended by RCCTE (25ºC) for the summer. Simple glazing had higher temperatures. Choosing randomly the double solar control glazing, for example, and considering the use of horizontal blinds and overhang was obtained results of indoor temperatures for winter and summer in agreement with the Figure 7 and 8.

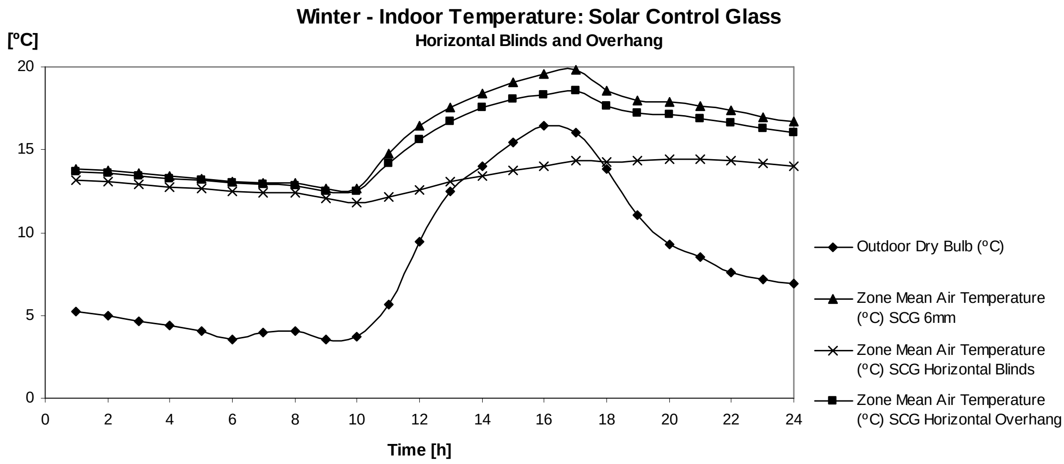

Figure 7. Indoor Temperature - Winter.

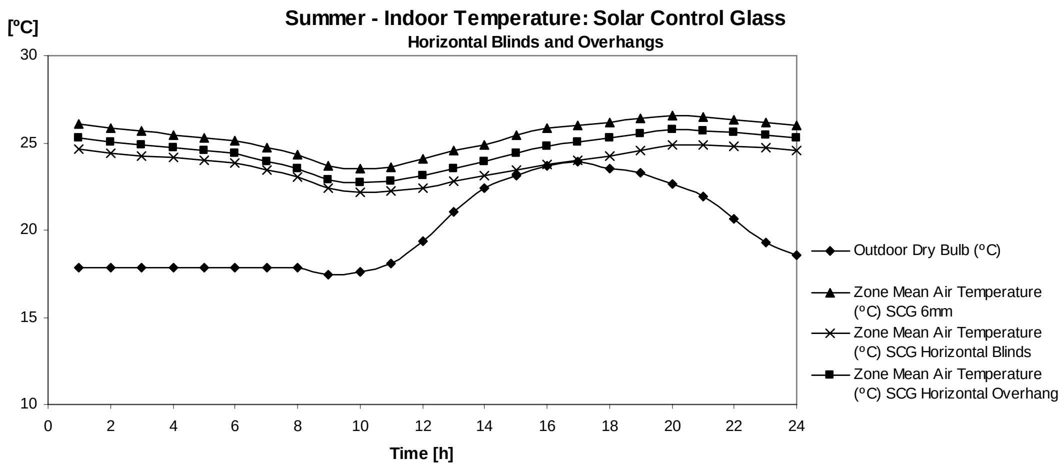

Figure 8. Indoor Temperatures - Summer.

That indicates the temperature differences between horizontal blinds use towards horizontal overhang use. Horizontal blinds caused a mean air temperature decrease in winter, this means that it for use in the facade should be mobile, in way to facilitate the solar radiation entrance in the winter and to cause an indoor temperatures increase. For summer, horizontal blinds use implied in the indoor temperatures decrease more than horizontal overhang use.

Figure 9 presents the heating energy values needs for 5 types of facades composition, simulated for Guimarães climate and positioned in the south solar orientation.

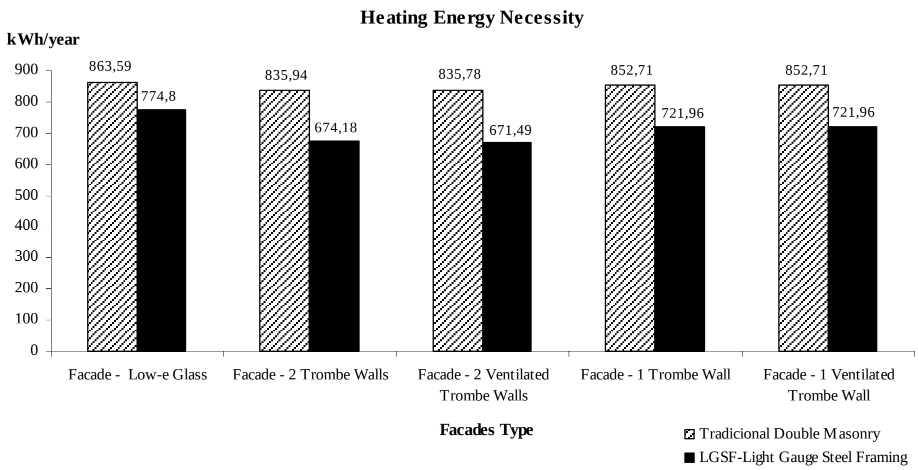

Figure 9. Heating Energy Necessity

Figure 9 show that walls and slabs of the light gauge steel framing system use in the simulation model had smaller energy consumption for heating, mainly due to facade with 2 trombe walls.

Decrease of the energy consumption happens in agreement with the addition of heating passive solutions, in this case trombe wall. Table 4 presents the energy expenses decrease based in a double solar control glass facade (Solar control glass 6mm - Air 12mm - low-e glass 6mm).

Table 4. Consumption decrease according to the façade type.

Cover	Facades Type	Annual Heating Necessity (kWh)	%
Traditional	Facade - *Low-e Glass*	863,59	-
	Facade - 2 Trombe Walls	835,94	-3,20
	Facade - 2 Ventilated Trombe Walls	835,78	-3,22
	Facade -1 Trombe Wall	852,71	-1,26
	Facade - 1 Ventilated Trombe Wall	852,71	-1,26
LGSF	Facade - *Low-e Glass*	774,8	-
	Facade - 2 Trombe Walls	674,18	-12,99
	Facade - 2 Ventilated Trombe Walls	671,49	-13,33
	Facade -1 Trombe Wall	721,96	-6,82
	Facade - 1 Ventilated Trombe Wall	721,96	-6,82

5 CONCLUSIONS

Passive technologies both for heating and cooling, have a decisive importance to carry out, and are necessary that new studies are developed to demonstrate effectiveness and importance its to the energy consumption decrease. Preliminary results showed an energy consumption decrease to heating (13%) with the incorporation of passive technologies (trombe wall). This indicates the advantages of the passive solutions incorporation in the facade.

Thereafter it is waited that these facade modules application, with 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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