Portugal SB07. Sustainable Construction, Materials and Practices
L. Bragança et al. (Eds.)
IOS Press, 2007

Jee - Janela Eco-Eficiente (Eco Efficient Window); Development of a high performance standard window

Miguel Veríssimo
Armadilha Solar - arquitectura, Porto, Portugal – a.solar@oniduo.pt

Manuela Guedes de Almeida, Luís Bragança
Departamento de Engenharia Civil; University of Minho, Guimarães, Portugal

ABSTRACT:
Eco Efficient Window (JEE) it's a design and R&D project, consisting in the production of a high performance window to be applied, both in refurbishing and new construction. JEE aims to reduce the energy demands and the CO2 emissions, during the Life Cycle, tacking advantage of sun radiation and recyclable materials on its construction.
Patented as a standard indivisible object, the Eco-Efficient Window functions 24h a day, in buildings south facing and good envelope conditions. JEE is composed by two systems that respond to different phenomena:
1) Span (glazed window or door) - daylight, ventilation and acoustics;
2) Thermodynamic (vertical part of the span): sunspace ventilated Trombe Wall, facultative electrical heating backup system to increase autonomy to the object, and reactivity to the natural processes, avoiding the use of another acclimatization system, saving money and resources.
To respond to the conceptual and technological objectives, the methodologies had to be solid and clear, finding in the final drawing, the correct compromise between: visual aspects, technological performance, eco-efficiency, and cost/benefit values in a large scale production.

1 INTRODUCTION

The building industry, being one of the most important economic sectors, resists to innovation, and still relies on traditional technologies, methodologies, legislation and production lines, that are somewhat "old fashioned". However, new products and innovative technical solutions are gradually coming out, pushing positively the construction sector productivity indexes, leading to a better quality of the building systems and increasing the global living standards (doing "more, with less", reducing the construction environmental impacts). Several studies have shown that energy consumptions in buildings can be reduced more than 30%, if energy-efficient solutions are adopted. But, even with a growing sensitiveness, persists a lack; of energy efficient products or eco-efficient standard technologies on the market.

"SOLAR TRAP-architecture", found in this void, the motivation to develop an idea, and to create "synergies" with the Civil Engineering Department of Minho University, to join their experience working on the field of bioclimatic architecture and in physical performance of building materials and technologies. This experience gave us the ability to clearly identify some common problems, to create methodologies and the correct tools to solve such a complex problem. So, the Eco Efficient Window (JEE) was the right opportunity to develop a design and R&D multidisciplinary project, consisting in the industrial production of a window, which integrates high standard technological solutions, for thermal, acoustic, ventilation and visual performances. As an innovative project, JEE aimed in the first place, to put questions and to give creative answers to the citizens, projectors, entrepreneurs and constructors, following recent political strategies to rationalize the use of energy and minimise the dramatic environmental impact of the buildings. In that sense, eco-design is not only a tool, but also a mean to change, from a linear destructive paradigm, to a new ecological and circular civilization. Another objective of JEE project, was to go beyond the established "common-sense" of projecting the exterior spans of buildings, only as aesthetic architectural symbols, forgetting that, they are a fundamental element of the façades, acting as important filters of physical phenomena linked to heat, light and sound, that occur between the interior and exterior of dwelling spaces. JEE also wanted, since the very first moment, to be a large spectrum conceptual object, to be applied both, in new and in refurbished buildings, trying to refresh, with a new window system, the exterior image of an immense amount of unqualified buildings – constructed since de 60´s, were JEE can be easily applied, in good performance conditions, contributing to give them a second life, without them being demolished. Finally, JEE, wanted to, give a low-tech response to complex issues, without compromising their simplicity, versatility, ergonomics and operational aspects.

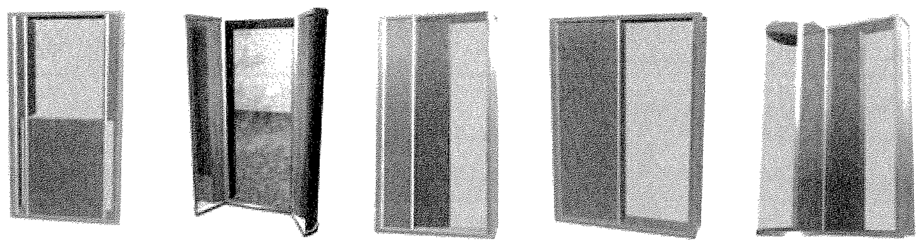
To achieve such an ambitious objective, the project methodologies had to be solid and clear, finding in the final drawing the right compromise between: design concepts and aesthetic aspects, technological performance, eco-efficiency, and cost/benefit values on a large scale production. The A.Solar and U.Minho teams, followed latter by the SAPA-building systems team, never had hermetic postures. The ideas flowed between teams, in brain storming encounters. But finally, although the strict directions of the Visual DOE 3.1 and Ecotect software simulations models were respected, intuition played very important role, in what concerns the energy issues, and architectural or design thinking. That's why, it is so important to architects, to have a comprehensive knowledge of basic physics. Architects and designers have a trained capacity to visualize and resolve abstract 3d problems, and understand that energy flows in 3dimentional complex space geometries. So, with proper training, they can integrate those issues, from the very beginning of the project. But the scale of the phenomena is both interactive and infinite in space time and scale; from the atom to the universe, passing by the materials, the biosphere and human behavior. The task is immense. As creators, we know, that every drawing action, plays a role, under our great energy source, the Sun.

First Steps:

1) Form / Function (methodology)

a) Design Team – The tasks started before the software validation models, trying to find as much as possible combinations and drawing possibilities, to shape the very first idea (to attach to a window, two basic passive solutions, a sun-space, and a ventilated Trombe wall), and to find the right combination between: winter, mid season, and summer solar heat gains, energy dynamic flows, daylight and visual aspects. Our intuitions were later confirmed by software outputs. It was a very creative stage, and a lot of interesting ideas were explored. The "Eureka moment" came. The option: "sun space and Trombe wall vertically disposed to the side of the span", was chosen. An "insulation door and sun radiance concentrator" was added, to improve the heating power of the sun, into the Trombe wall accumulator (different stages Fig.1).

Fig 1 design research stages



b) Dimension / Standard measures – We started to take notes, of the measures of different windows. 300 files were opened with the following inputs: photos; address; dimensions; and building system. Soon, that task showed results, but it was too difficult to conclude. So, we started inquiring directly, windows building system industries and appliers, by mail or phone. The results offered more possibilities, as how to define the correct dimension of a standard window. The most common Height (related to the concrete portico system) was under or 2,4m; Width = 1,5m; Depth = 0,31m.

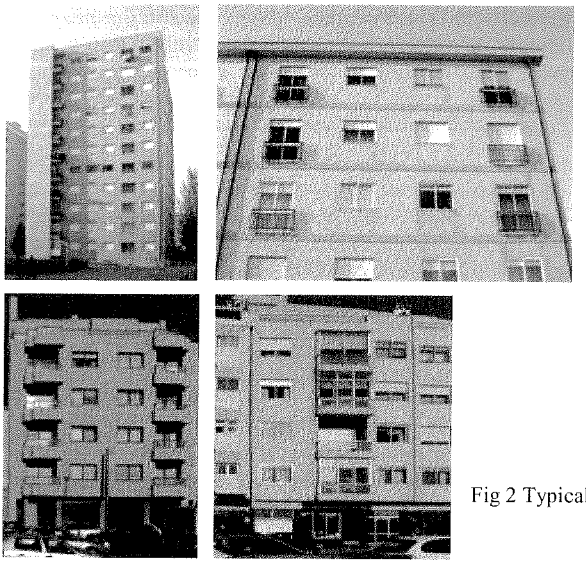
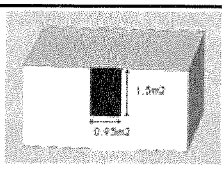
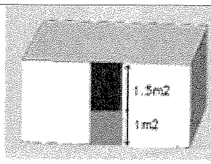


Fig 2 Typical refurbishing "JEE buildings"

c) Case Study characterization: - Building site – Guimarães; Meteorological data - monitorized on site; recent construction; south facing orientation; domestic occupation; LCA 20years, error margin 5%.

Envelope conditions:
- Ext. wall/40 cm - U = 0.48 W/m2K
- Int. wall/15 cm - U = 2.11 W/m2K
- Pav - U = 2.11 W/m2K
- Roof – U = 2.84 W/m2K Last line of first page

	Model	Descr.	Option	Necessities	
Case 1		A_p=25m^2 A_{env}=1.425m2 A_t= 0 m2 V_c=62.5m^3	Lateral shaded. Trombe wall - No.	HNec.t=	913 KWh
				HNec.n=	681 KWh
Case 3		A_p=25m^2 A_{env}=1.425m2 A_t= 0 m2 V_c=62.5m^3	Lateral shaded Ventilated Trombe wall	HNec.t=	898 KWh
				HNec.n=	630 KWh

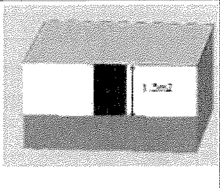
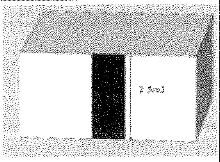
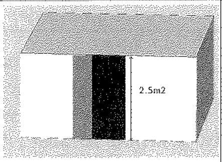
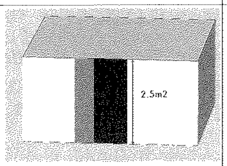
Case 4		A_p=25m^2 A_{env}=1.425m2 A_t= 5 m2 V_c=62.5m^3	Lateral shaded Ventilated Trombe wall	HNec.t= HNec.n=	841 KWh 456 KWh
Case 7		A_p=25m^2 A_{env}=2.375m2 A_t= 0 m2 V_c=62.5m^3	Lateral shaded - No Trombe wall - No	HNec.t= HNec.n=	743 KWh 560 KWh
Case 8		A_p=25m^2 A_{env}=2.375 m^2 A_t= 1.25 m2 V_c=62.5m^3	**Lateral shaded - No** **Ventilated Trombe wall**	**HNec.t=** **HNec.n=**	**726 KWh** **499 KWh**
Case 9		A_p=25m^2 A_{env}=2.375 m^2 A_t= 1.25 m^2 V_c=62.5m^3	Lateral shaded - No Trombe wall	HNec.t= HNec.n=	719 KWh 539 KWh

Table 1 - Confronting solutions with heat necessities

2) Materials - Thermal properties:

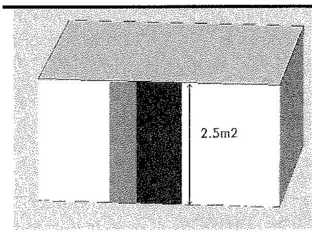
CASE STUDY	MATERIAL TROMBE WALL	Thickness (cm)
	1. Granite	15
	2. Earth - Adobe	15
	3. Ceramic - Red clay	15
	4. Stone - Schist	15
	5. Concrete	20
	6. Stone – Granite	20
	7. Earth - Adobe	20
	8. Ceramic - Red clay	20
	9. Stone - Schist	20

Table 2 – Case Study representation, material thermal performance

CASE STUDY	GLASED				Trombe Wall				Heat Nec (kWh)	Night (kWh)
	Lat. Shaded	High (m)	Large (m)	Area (m^2)	Ventilated	High (m)	Large (m)	Area (m^2)		
CB	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	726	499
1	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	725	496
2	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	729	516

3	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	727	503
4	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	726	498
5	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	727	500
6	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	726	496
7	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	730	518
8	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	727	504
9	No	2.5	0.95	2.375	Yes	2.5	0.5	1.25	726	498

Table 3 – materials and heat necessities

Analysing (1) (2) steps:

The vertical arrangement increases on all respects the energy performance of a window with an associated thermal system as we want to create.

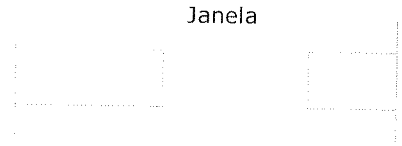
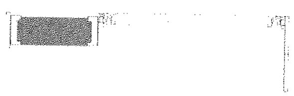
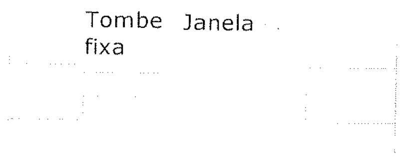
Allowing sun radiation to penetrate more profoundly into the interior space, by the glazed span, the direct sun gains and natural daylight reflection possibilities are increased. The thermal performance of the attached ventilated Trombe wall system, being vertically disposed, will work better than others - horizontally disposed (see. Table1). This can be justified because, if the energy flows vertically, there is an increment of heat exchange properties - by contact, radiation or convection. Natural thermal circulation will be also be increased. (case 4) (case 8).

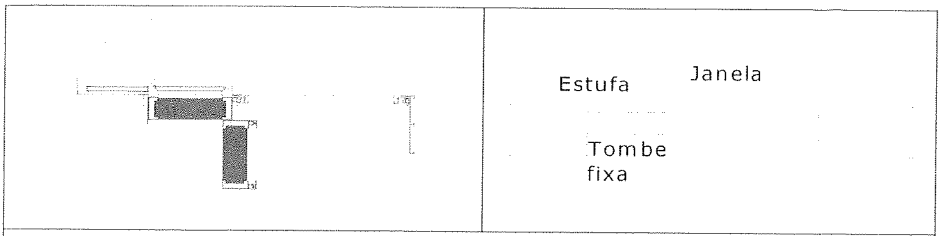
Analysing the thermal properties of the materials, we can conclude that granite, followed by concrete; achieve better results in thermal accumulation. By increasing the thickness of the Trombe wall, there is an increment of heat necessities to achieve space thermal comfort.

3) Technology / Functioning:

a) Simulating association - Trombe Wall + Sun Space:

Table 4 – Thermal influence of associated systems.

Schemes	Visual DOE3.1
	
1- Window	
	
2- Trombe Wall	



3- Trombe Wall+ Sun Space

Case Study	Glazed			Trombe				S. Space		Heat needs (kWh)	Night consum (kWh)
	H (m)	W (m)	area (m^2)	Vent	H (m)	W (m)	area (m^2)	Ventil.	area (m^2)		
1	2.35	0.95	1.43	-	-	-	-	-	-	686	357
2	2.35	0.95	1.43	Yes	2.35	0.45	1.06	-	-	635	310
3	2.35	0.95	1.43	Yes	2.35	0.45	1.06	Yes	0.8	615	289

Analysing 3a) Step: Associate a Sun Space to a Ventilated Trombe Wall increase, 18% to 19% the energy efficiency of the single glazed system. The study showed that the need to include an electrical backup system.

b) Fixing the Technology:

Patented as a standard indivisible object, the Eco-Efficient Window is composed by two systems that respond to different phenomena:
1) Span system (Glazed window or door) - daylight, ventilation and acoustic control;
2) Thermodynamic system (attached to the side part of the span) including: a sunspace, a sun heat accumulator following the technological principles of a "Ventilated Trombe Wall". An electrical heating backup system can also be added to the thermo-accumulator, to increase reactivity to the natural processes, and also, autonomy and flexibility to the object, avoiding the use of another acclimatization system, saving money and resources. The JEE functions 24h a day in optimal conditions, in buildings south facing, and good envelope system:

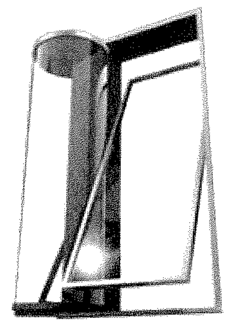
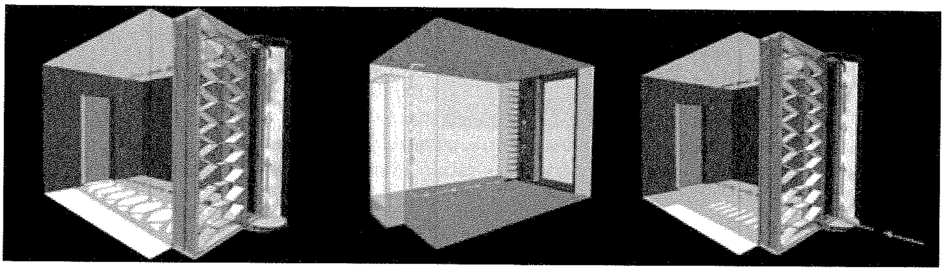


Fig.2 "Eureka moment"

Winter and mid season, sunny and light cloudy day:
Insulation door opens, facing a mirror to sunlight. That helps to concentrate the sun radiation into the thermal accumulator. This system keeps the energy to be released at dawn to interior spaces. Meanwhile the direct sun radiation heats the sunspace. This green house effect increases a thermo circulation (by natural convection), passing thru ventilation grids, heating the interior rooms.

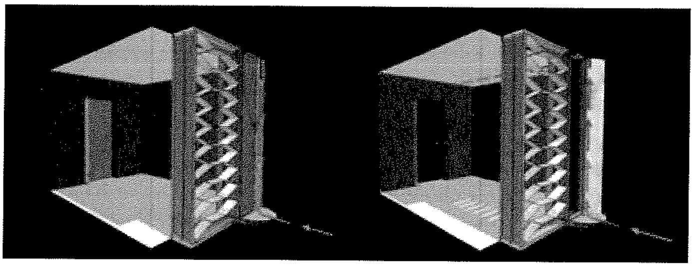
Fig.3 – winter / mid station – sun space during the day, heat radiation and convection at night



Summer and mid season sunny day:

Insulation door is closed, but an upper ventilation canal is open, functioning as a "thermo siphon", "sucking" to the exterior all the heat gains concentrated in the ceiling. That occurs, because the sunspace ventilation system is open, allowing the air flow to go up, causing a depression and suction phenomenon.

Fig.4 – Summer / mid station – thermo siphon, night cross ventilation mode.



A blind system, made in polished aluminum, disposed in the glazed part of the span, improves daylight reflection into the interior white ceiling, diffusing the sunlight, avoiding electrical lighting, to be used to achieve visual comfort in dark cloudy days. The glazed, also allows important direct sun heat gains in winter and mid season. In summer and in some mid station sunny days, the direct gains have to be retained outside, by shadowing the glaze.

Building the Prototype:

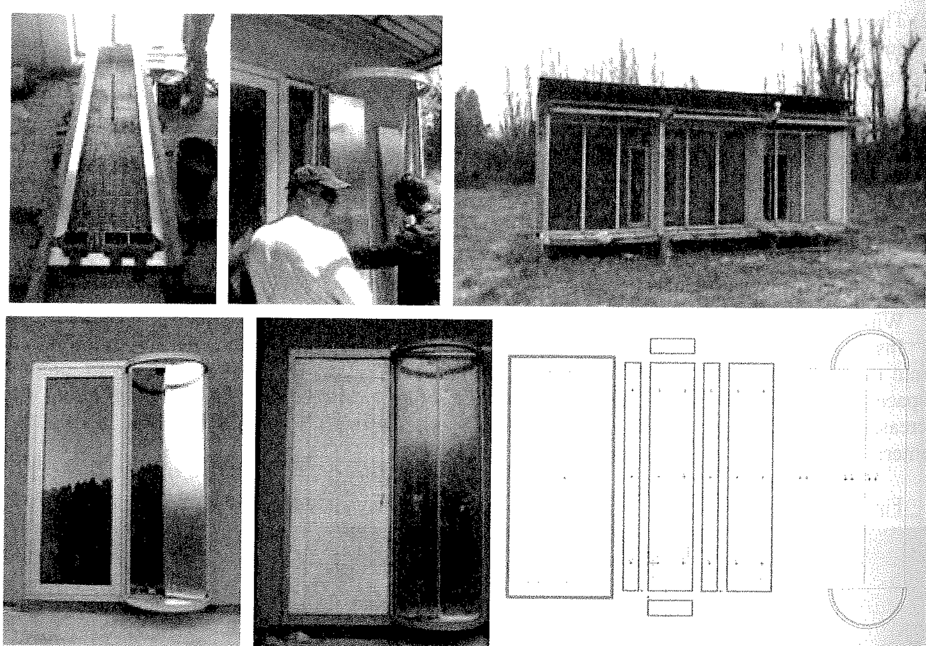


Fig.5 Instrumentation

Final Conclusions at this point (Jun 2007):

The Eco-Efficient Window is yet, a "work-in-progress".

Already patented, we want to conclude the prototype instrumentation and after, to proceed with some improvements, and start to build the pre-industrial prototype.

Until now, we faced problems that can be solvable. The first prototype had problems with the night insulation door, and the test cell, was made with feeble envelope insulation. So, there are losses in the system efficiency.

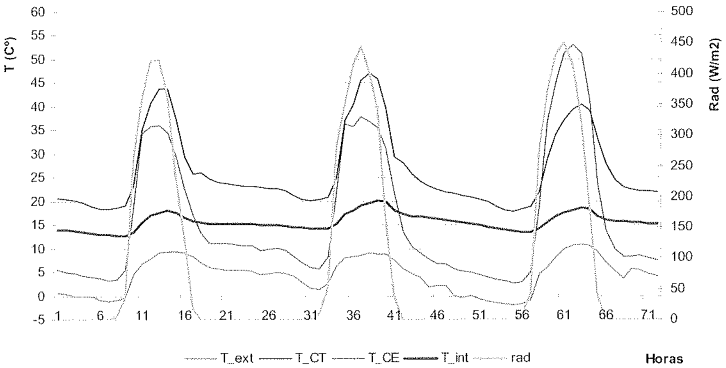


Table 5 – 3 Winter sunny days 06, before improvements, we see that the sun space (CE), and the Trombe accumulator (CT), functions. But the comfort level, due to the test cell insulation, is not at comfort levels.

Only recently we could do the necessary improvements. But until now, we can already achieve 20% of efficiency, comparing JEE tech, with a normal double glass and thermal cut window; Our aim is to pass over 30%, to push payback time, to less than 9 years (thermal system+window).

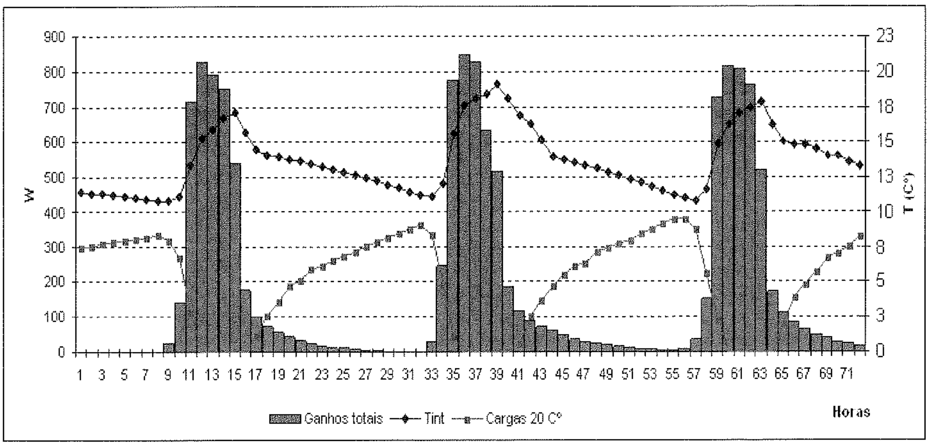


Table 6 – Dec. sunny days; energy balance. Improving insulation, JEE, as to provide above 300wh (night)

This graphic was made after tuning the test cells environment in VisualDOE improving the insulation. As we can see, JEE can provide the necessary heat charges to maintain the comfort levels during the day. As previewed, we can achieve 400Wh gains in a December sunny day between Trombe and Sun Space. At night, the backup system must provide 300Wh to maintain the room comfort levels. Numbers that can be easily achieved, making few adjustments.