RELATION BETWEEN DAYLIGHT FACTOR AND THERMAL CONTROL IN A WINDOWS SUB-SYSTEM STUDY CASE

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ABSTRACT

Building envelopes innovation concerns several elements, materials and sub-component technologies. Windows are important sub-components; they have to satisfy and control different parameters. It regulates the interaction between windows dimension, daylight and the dimensions energy parameters control, in relation with room dimension. The design of dimensions and characteristics of materials include the regulation of three parameters: sun light factor, daylight comfort; insulation and energy consumption; natural ventilation in summer regime and protection from sun irradiation. Acoustic comfort won't be analysed. An appropriate windows project is a good opportunity to design an energy flow through buildings.

In this paper we describe a simple windows design solution (using ordinary components and materials), which was proposed for a bio climatic building competition.

During the windows design, the relations between room dimension and windows and brick-wall dimension were calculated, in order to achieve satisfactory daylight factor, insulation, energy gain and natural ventilation. The aim of this research is to use a simple system to calculate, implying ordinary building materials. This kind of solution could be a way to introduce a building envelope in updated architectonic projects

INTRODUCTION

Windows are important components in traditional architecture in Mediterranean area where they are used mainly to control indoor comfort parameter.

In this architecture window are composed by three part: window-pane and frame used to regulate light and sun radiation penetration; wood shutter, with directional wood lamina, that gives sun protection and allows to control wind; window-pane joint with solid shutter allows to reduce a thermal dispersion.

We must say that window could be an opportunity to regulate indoor comfort parameter: thermoigrometric and day light factor. Design of windows have several solution, dimension and components, in relation with a locate climate and architecture typology.

They are one flexible element to control a different climate condition in each season. Window components must be reducing energy dispersion in winter and in the same time they must guarantee a light factor. In summer windows sub-system must protect from insulation, in springtime this system must protect from wind.

In this paper we present a concept design of a window sub-component system, which has been inspired from vernacular architecture window joint with bio climate and physic approach. This sub-component has been studied and proposed at concourse, the aim would be to study a flexible system for each season.

Figure 1: inspiration: windows in a vernacular architecture.

DESCRIPTION

The design of windows sub-system is make up by:

- Windows frame with two kind of openings;
- Brick wall (with gap between curtain and brick wall: 40 cm) in front of vasistas opening;
- Shutter wood in the right and left side of brick wall;
- Cleristorio window (strip window) at the top of curtain wall;
- Ceiling and horizontal structure project used to repair sun radiation in summer time.

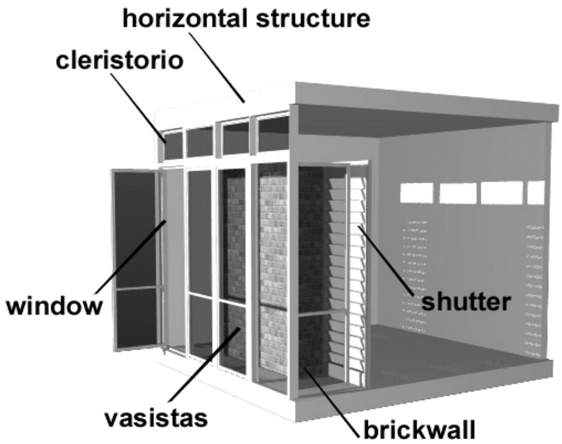

Figure 2: geometry of sub-component system

This design has been studied to control separately daylight factor, energy dispersion, solar gain and insulation. Next step is to describe sub-component "*energy control*" characteristic.

Windowpane and frame is used to control light and sun penetration, the energy dispersion with high thermal performance glass, and insulate penetration in horizontal (floor) and vertical (wall) structures. In the other hand windows pane and frame should control wind penetration: if window frame is all open they introduce a transverse ventilation inside the room; if window vasistas frame it's open it will allow wind to refresh a brick wall element ad reduce a phase-disclaimer thermal accumulation in hot season. If windows lateral frame are open the wind will change indoor air quality and reduce pollution.

Brick wall is used to do thermal insulation and accumulator, with 11 hours of phase-displacement. The sun radiation incident on wall during day (in winter and in middle season) is re-introduced in room during nighttime. In summer thanks to vasistas ventilation we reduce a phase displacement and thermal accumulation.

Shutters are used to control the sun radiation in summer and an isolation component in winter. In summer time shutter could be closed to repair from sun radiation. In this case day light factor are assured by cleristorio window at top of curtain wall. Closed shutters reduce insulation penetration during summer and hot season trough a curtain wall.

FLEXIBILITY OF SUB COMPONENT

In the middle season this system is flexible, in effect it's possible to use this three sub-component to regulate an energy balance in relation with outdoor climate condition.

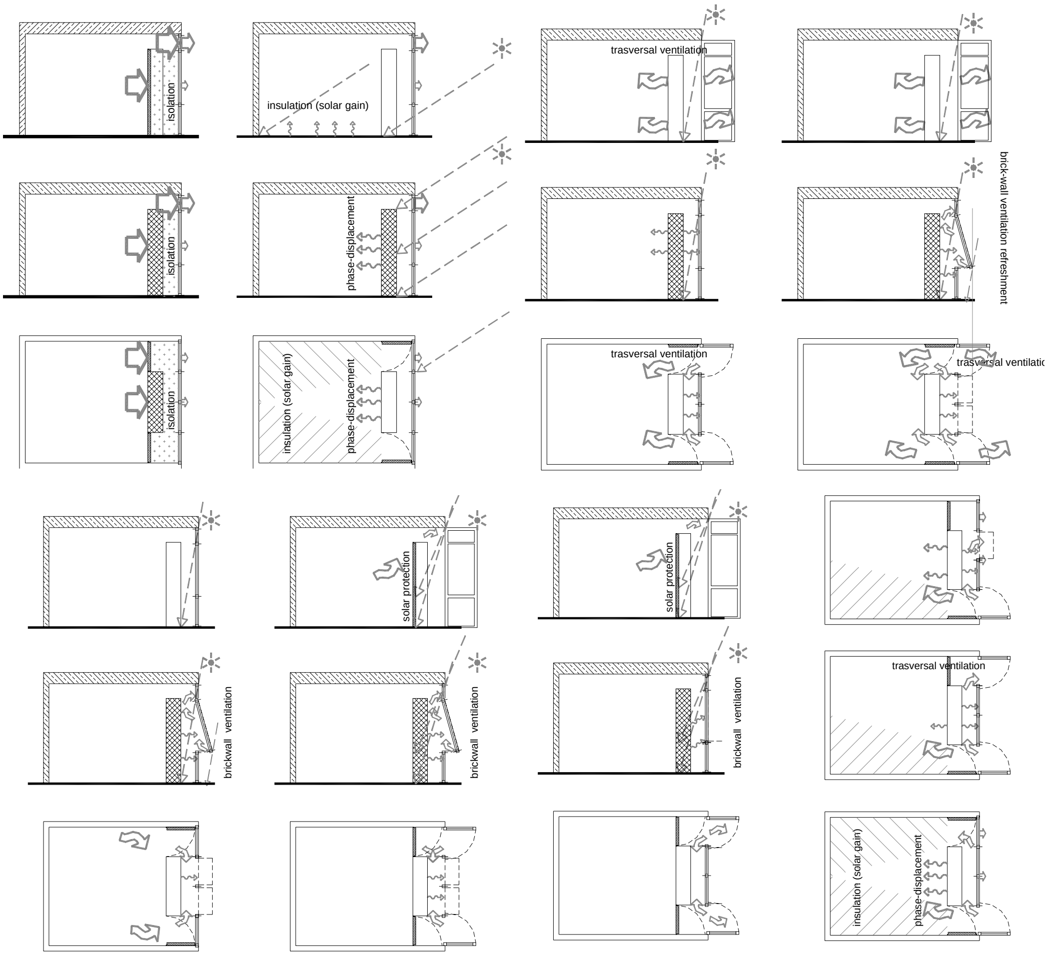

Figure 3: Scheme of flexibility energy action of the sub-component system

Each component has several "*energy action*":

- Shutter control insulation and isolation and repairs from outdoor agent,

- Vasistas frame on central window reduce phase disclaimer of the brick wall,

- Lateral frame window control wind penetration in the room, isolation and repairs against outdoor agents,

- Air space, gap between wall and curtain wall, contribute to isolate against thermal dispersion and wind,

-Brick wall contribute to isolate, reduce insulation, thermal accumulation and phase displacement,

-Cleristorio window control day light factor, when shutters are closer in summer.

In fig.3 are represented possible configurations of these components from max isolation to max aperture.

ENERGY BALANCE

Energy balance valuation and day light factor parameters are calculated in winter and summer regime, during day and during night period.

	Transmittance	Thermal resistance	Geometry
U wall	0.62 W/m^2K		1.80x2.30x0.40
U curtain wall	1.86 W/m^2K		3.20x2.30
U wall+air gap+window frame		2.8474 m^2K/W	3.2x0.40
U shutter+air gap+window frame		1.7556 m^2K/W	80 size wide
Temperature gap	Inside 20°C	Outside –5°C	

Table 1: Thermo physic characteristics.

Winter season. Sub system in winter day could be used to reduce energy dispersion, to take advantage of sun penetration and to guarantee a day light factor.

<u>Day Light Factor</u>

$$FLDm = \frac{Aw \cdot \tau \cdot \varepsilon}{Stot(1-\sigma m)} = \frac{7.0848 \cdot 0.47 \cdot 1}{57.74 \cdot (1-0.49)} = 11.30\% > 2\%(law - parameters) \qquad (1)$$

Aw= Area Window τ=glass transparency coefficient ε=projection factor S=total inside surface σ=inside surface reflection coefficient

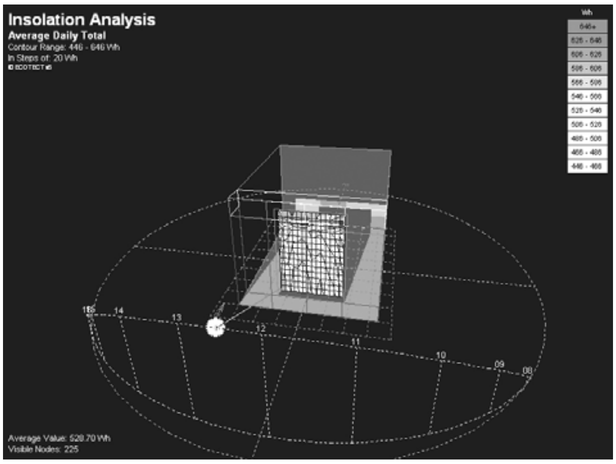

Figure 4: Winter shade and solar gain wall insulation

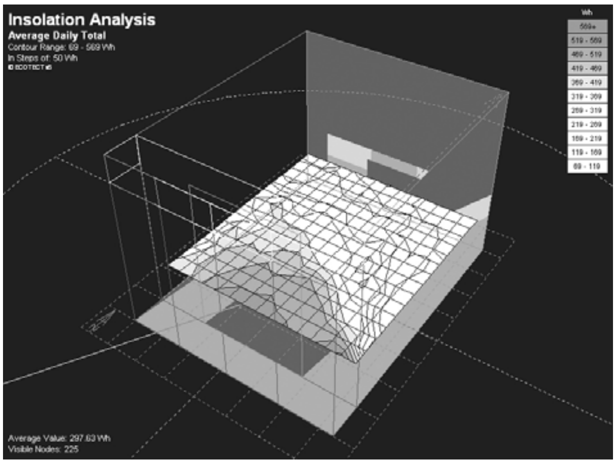

Figure 5: Winter shade and solar Gain pavement insulation

Calculation thermal dispersion (Qd) during daytime

Thermal dispersion is calculated during sun route in daytime: from 8.00 am to 4.00pm (8 hours)

$$Qd_{(waal)} = A_{wall} \cdot U \cdot \Delta T \cdot \Delta\tau = 3.68 \cdot 0.62 \cdot (20-(-5)) \cdot 8_{(hours/day)} = 456.32Wh \quad (2)$$

$$Qd_{(window)} = A_{window} \cdot U_{curtainwall} \cdot \Delta T \cdot \Delta\tau = 8.84 \cdot 1.86 \cdot (20-(-5)) \cdot 8 = 3214.06Wh \quad (3)$$

Am=Area (m^2); U= transmittance coefficient (W/m^2K); ΔT= temperature gap (°t); Δτ=day period

Solar gain: brick wall average value: 258.70 Wh/m^2, pavement average value =297.63 Wh/m^2. (Solar gain are calculate by software Ecotect simulation)

$$\Phi_{wall} = A \cdot (F_{irr} \cdot U \cdot r_{ext} \cdot c) = 3.68 \cdot (528.78 \cdot 0.62 \cdot 0.33 \cdot 0.86) = 342.38(Wh) \quad (4)$$

$$\Phi_{ventilation} = F_{irr} \cdot n \cdot \frac{r_{ext}}{A} \cdot c = 528.78 \cdot 0.50 \cdot 0.089 \cdot 0.86 = 74.44(Wh) \quad (5)$$

Φ=phase displacement accumulation; Firr=solar gain average value; r= thermal external area resistance.

Solar gain through windows pavement insulation:

$$Firr_{pavement} xArea_{pavement} = 297.63x(4.10x3.20) = 3904.90Wh \quad (6)$$

Solar gain volume (by Ecotect simulation) $Firr_{(volume)} = 2002.96Wh$

Energy Balance:

$$-Qd_{(wall)} - Qd_{(window)} + \Phi_{waal} + \Phi_{ventilation} + Firr_{pavement} = +651.34Wh \quad (7)$$

$$-Qd_{(wall)} - Qd_{(window)} + \Phi_{waal} + \Phi_{ventilation} + Firr_{(volume)} = -1230.90Wh \quad (8)$$

The energy requirement with this sub-system component are low (7) or (8). It's possible to change a sub-component configuration in relation with outside temperature.

Calculation thermal dispersion (Qd) during night time (from 4.00 pm to 8.00am, 16 hours)

$$Qd_{(wall)} = \frac{Am \cdot \Delta T \cdot \Delta\tau}{R_T} = \frac{3.68(m^2) \cdot (25) \cdot 16_{(hours/night-nosunperiod)}}{2.8474} = 516.96(Wh) \quad (9)$$

$$Qd_{(cleristorio)} = Am \cdot \Delta T \cdot \Delta\tau \cdot U = (0.40x3.20) \cdot (25) \cdot 16 \cdot (1.86) = 952.32(Wh) \quad (10)$$

$$Qd_{(shutter+aru.gap+window)} = \frac{A \cdot \Delta T \cdot \Delta\tau}{R_T} = \frac{3.68_{(shutter.area)} \cdot (25) \cdot 16}{1.7556} = 838.46(Wh) \quad (11)$$

Energy balance

$$-Qd_{wall} - Q_{(cleristorio)} - Qd_{(shutter+air.gap+window)} = -2307.74(Wh) \quad (12)$$

with phase-displacement

$$-Qd_{wall} - Q_{(cleristorio)} - Qd_{(shutter+air.gap+window)} + \Phi_{(wall)} + \Phi_{(ventialtion)} = -2307.74(Wh) \quad (13)$$

Summer season. Window frame during summer time could be open to favour wind refreshment. Shutter could be closed (both or only one) to reduce sun insulation inside the room. The projection of the horizontal structure reduces sun penetration during hot hours and it also protects the brick wall. Brick wall guarantee 11 hours of phase disclaimer to reduce inside surface temperature.

When both shutter are closed the daylight factor in room is guaranteed by cleristorio window at the top of sub system.

$$FLDm = \frac{A_{cleristorio} \cdot \tau \cdot \varepsilon}{Stot(1-\sigma_m)} = \frac{(0.40x3.20)\cdot 0.47 \cdot 1}{57.74 \cdot (1-0.49)} = 2.04\% \approx 2\%(law - parameters) \quad (14)$$

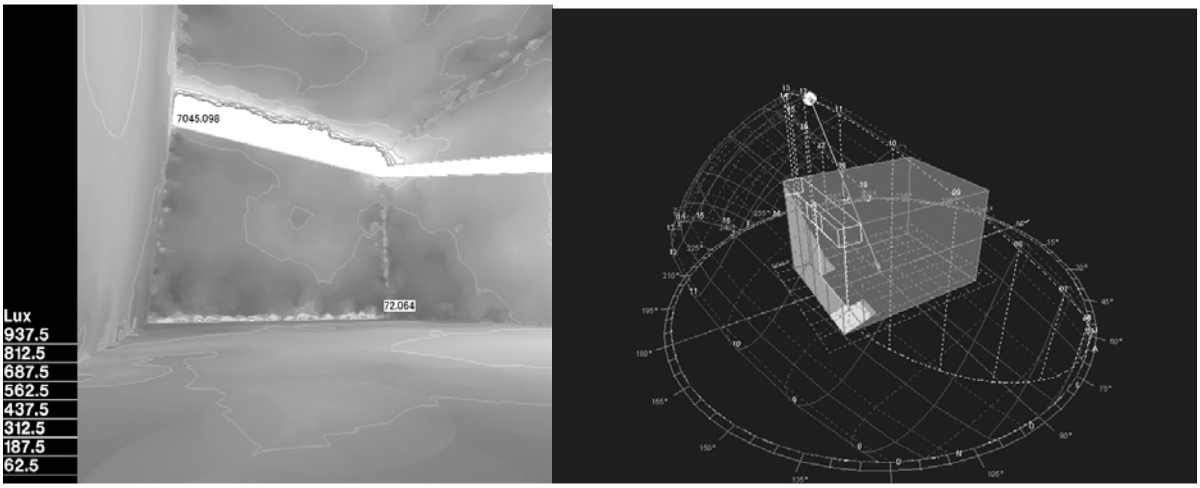

Figure 6: Summer season: (sx) daylight factor when shutter are closed, (dx) model of summer shade projection

CONCLUSION

This sub-system component has been proposed to study one simple and flexible architectonic solution, which could be built with ordinary building store. It's possible to change a sub-system configuration in relation to external climate condition simply using manual controls. These kinds of simple solution are a way to introduce and implement building envelope in up to date architectonic projects.

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