Building Renovation, Bio Architectural Techniques and Save Energy: an applied study-case in Kore University of Enna City (Italy)

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Abstract

The process of building renovation presents a good opportunity to increase the use of solar energy in existing buildings and to reduce energy demand and CO_2 emissions The introduction of innovatory technologies to optimize energy balance of buildings is frequently necessary to reduce thermal losses of inhabited wrapper below that ones allowed by Italian regulations. But the equipments linked up to new technologies could look as architectural themes conflicting with traditional canons of classic architecture. Such contrast increases in the particular case of restoration of existing buildings, showing well definite architectural characterizations, owing the difficulty to find "the right point of contact" between the beauty of the building and the equipments of the innovatory technologies reducing thermal losses.

The presence and spatial distribution of glass surfaces in building facades are one of the tools frequently adopted by designers to give architectonic characterization of building volumes but such techniques, conversely, are sources both of increase of thermal energy consumption, because of low thermal resistance offered by glazed surfaces, and source of thermal discomfort for inhabitants. Likewise, one of the most significant tool of bioclimatic architecture is that one which uses particular devices making the most solar energy to supply energetic needs of buildings. To the aim to find previous "right point of contact", the designers of renovating of an important building of Kore University replaced part of wrapper built with traditional building materials with glazed volumes appropriately arranged in the main façade of building. The aim to design a kind of solar greenhouse that, by means of its energetic supply, can improve both the energy balance of building and, at one and the same time, the architectural beauty of building not appreciable indeed in the state of things.

The paper wants to show:

1 Theoretical evaluation of the greenhouse energy performance by means the Energy plus code
2 The results of temperature measurements post "operam aedificatam";
3 The comparison between data forecasted by Energy-Plus code and data measured in situ;
4 Some helpful indications, coming from analysis of results save energy and indoor temperatures concerning architectural design in renovation by appliance of such bioclimatic technique.

Keywords: solar energy, building renovation, bioclimatic technique

1. Introduction

Building and facade renewal is the common denominator of the most improved solar renovation concepts. The other needs for facade renovation, like the cure of structural problems, comfort, etc. come as a secondary benefits.

The greenhouses are a typology of façade renewal that includes the cure of structural problems, thermal improvements and upgrading of the appearance. A greenhouse is a passive solar element, constituted from a closed volume with transparent walls, used to control the thermoigrometric flows and the energetic consumptions of the indoor spaces (Fig.1). Utilization of passive solar is achieved from a south facing glazed façade added to the building.

In the planning of the solar greenhouses it is necessary to estimate, beyond to the gain solar, both the performance during summer period, in order to avoid situations of discomfort due to the excessive heating, and the insertion of a new building element in the architectonic context.

The contribution to the heating of indoor spaces, obtained from solar energy that go through the greenhouse, has been determined both in reference to the seasonal climatic variations and to daily climatic variations

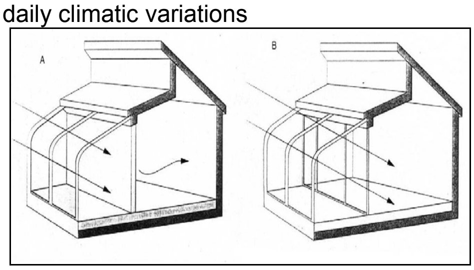

Fig. 1: Example of greenhouse

Energy savings are defined as reduction of transmission losses due to the lower U-value of the renovated building or building part because of the application of the solar system. The solar energy gains are evaluated as the energy demand reduction by the effects of the solar radiation[1]. The solar gains achievable is make up by (Fig. 2):

a. Solar gain transmitted by the window (Φ_{sdg})
b. Wall partition energy collection (Φ_{smv})
c. Reduction of thermal loss (Φ_{sg})
d. Pre-heated of ventilation air (Φ_{sa})

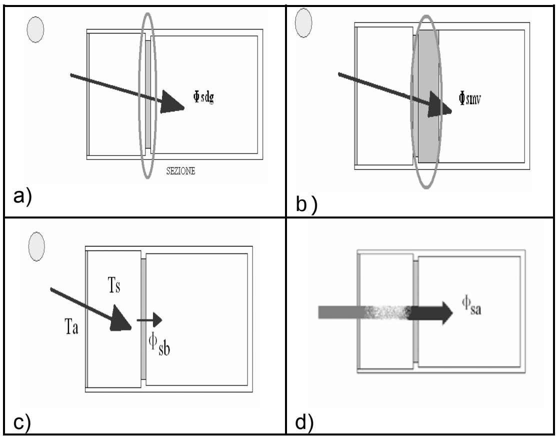

Fig. 2 - Typologies of greenhouse solar gains

The solar gains achievable by the greenhouse will be calculated from the summation of the contributions previously listed.

$$Esol = \phi_{sdg} + \phi_{smv} + \phi_{sb} + \phi_{sa} \qquad (1.1)$$

The several modalities of solar gain have to be calculated in function of the temperatures of each component of solar greenhouse (wall absorber, glass enclosure of greenhouse, etc.)
These temperatures could be obtained from the energy equilibrium equations for the whole different components of the passive solar heating system in according to the following assumptions:

- the air temperature is uniform in the heating room and in the greenhouse.
- all surfaces of partition wall, glass enclosure and roof of greenhouse are considered as the grey bodies.
- the enclosure, including the partition wall of the heating room and the wall and roof of heating room, is considered as thermally insulated.

Therefore, observing the availability of solar energy during the day, the adoption of a passive solar systems will turn out particularly effective in the case of the energy requirements for the heating if it is contemporary to its availability, i.e. for schools, public and private office. In that cases a wall absorber could not be necessary, in fact its own function is to release the energy after the sunset and its construction involves a not indifferent complication for the inclusion of the greenhouse related to the architectonic modifications requested in renovation of existing buildings.Therefore, it is not necessary to build an absorbent wall in the solar greenhouse for buildings operated only during the daytime.
Under previous assumptions the govening energy equation for the air inside can be written as:

$$\rho_a C_a V_a \frac{dT_a}{d\tau} = \sum_i A_G G_{Gsun} - A_{Gw} G_{Gwgsun} - $$
$$-Q_{ai} - Q_{ae} - \dot{m} C_p dT \qquad (1.2)$$

G_{Gsun}= rate of solar flux transmitted by the external glass enclosures of the greenhouse,
G_{Gwsun} = rate of solar flux transmitted by the glass partition wall of the greenhouse
Q_{ai} = heat exchange between the air inside greenhouse and the air in the heating room,
Q_{ae} = heat exchange between the air inside of the greenhouse and the outdoor air,
m = mass flow rate
dT = temperature difference between the air inside of the greenhouse and the outdoor air

$$G_{Gsun} = \sum_i \left(H_\beta K_{Gsh} A_G SGHC\right)_i \qquad (1.2)$$

$SGHC_i$ = Solar Heat Gain Coefficients of glass enclosure of the greenhouse
A_{Gi} = the surfaces of glass enclosure of the greenhouse
H_β = total solar radiation received by a tilted surface
K_{Gsh}= geometrical shading coefficient of greenhouse surfaces
In this equation are neglected the thermal radiation exchange of the glass enclosure with the layer surface, partition wall and the sky. The rate of solar flux absorbed by the partition wall and layer surface of the greenhouse are neglected too. Equation (1.2) can be integrated, during the diurnal period of insulations, for hourly interval or daily interval, related to a reference day, in function of the data available for solar radiation. To the aim to study such typology of passive solar element the Energy plus code has been utilised. Energy Plus is an energy analysis and thermal load simulation program. The total solar gain on any exterior surface is a combination of the absorption of direct and diffuse solar radiation given by

$$Q_{so} = \alpha\left(I_b \cos J \frac{S_s}{S} + I_s F_{ss} + I_g F_{sg}\right) \qquad (1.3)$$

α = solar absorptance of the surface
θ = angle of incidence of the sun's rays
S = area of the surface
S_s = sunlit area of the surface
I_b = intensity of the beam (direct) radiation
I_s = intensity of the sky diffuse radiation
I_g = intensity of the beam (direct) radiation
$F_s s$ = angle factor between the surface and the sky
F_{sg} = angle factor between the surface and the ground
For the surface of a building located on a featureless plain

$$F_{ss} = \frac{1+\cos\varphi}{2}; F_{sg} = \frac{1-\cos\varphi}{2} \qquad (1.3)$$

If the surface is shaded the program modifies F_{ss} by a correction factor that considers the radiance distribution of the sky. The internal heat balance involves the inside faces of the zone surfaces. This heat balance is modelled with four coupled heat transfer components:
1) conduction through the building element,
2) convection to the air,
3) short wave radiation absorption and reflectance

4) long wave radiant interchange.
The incident short wave radiation come both from the solar radiation entering the zone through windows and emittance of internal sources such as lights.

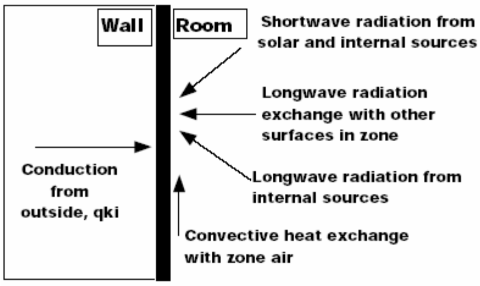

Fig. 3 – Thermal fluxes of internal heat balance

$$q''_{LWX} + q''_{SW} + q''_{LWS} + q''_{ki} + q''_{sol} + q''_{conv} = 0 \qquad (1.4)$$

where:

q''_{LWX} = Net long wave radiant exchange flux between zone surfaces.,

q''_{SW} = Net short wave radiation flux to surface from lights

q''_{LWS} = Long wave radiation flux from equipment in zone.

q''_{ki} = Conduction flux through the wall.

q''_{sol} = Transmitted solar radiation flux absorbed at surface.

q''_{conv} = Convective heat flux to zone air

2.The case study

An interesting application of solar greenhouse has been applied at the Montessori Room , which is a lecture hall used for the teaching activities of the Kore University of Enna (Fig. 3).
This room is located inside a building that has been renovated setting up a solar greenhouse in front of the façade.
The floor surface of Auditorium is about 545.00 m², with a capacity of 600 seat.

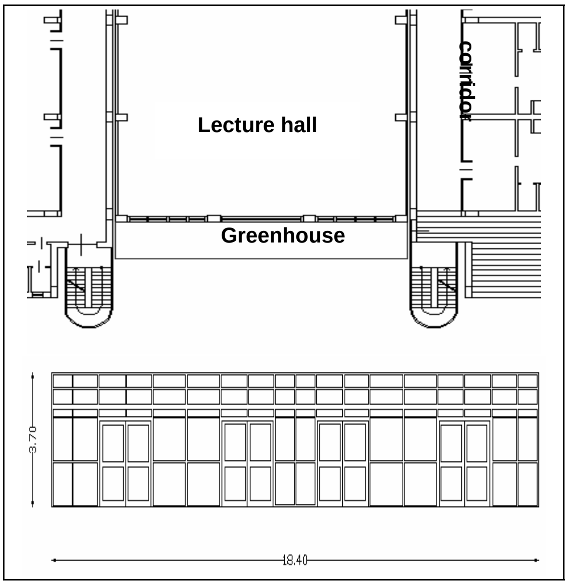

Fig. 4 – Layout of Montessori lecture hall

The main technical and geometrical characteristics of greenhouse are explained in Table 1

Table 1: Characteristics of glazed surface

Glass Enclosure					
Vertical Surface (β= 90°) Double glazed with tinted panel outside			Vertical Surface (β= 90°) Double glazed with tinted panel outside		
Frame m²	Glazed m²	SGHC	Frame m²	lazed m²	SGHC
10,65	39,00	0.56	5,50	40,6	0.86

During heating period, from November to April, the thermal needs and the variation of temperature of this passive element have been calculated using the Energy Plus tools. The solar radiation striking the glass enclosure of the greenhouse is showed in the following figures for two different weather condition: a) sunny day; b) cloudy day .

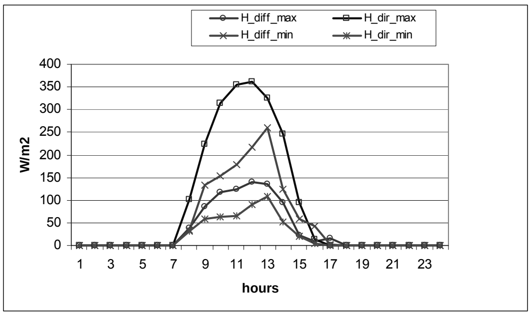

Fig. 5 –Incident Solar radiation (January)

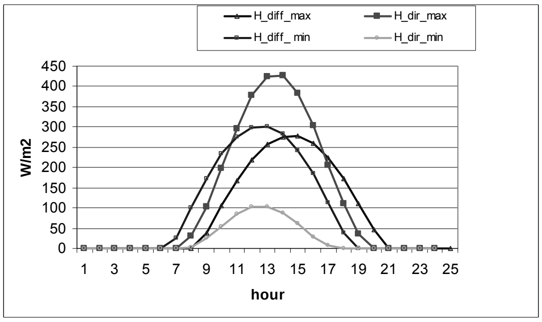

Fig. 6 –Incident Solar radiation (March)

The main data of calculation are summarized in Table 2

Table 1: Solar flux transmitted by the glass enclosure of the greenhouse

	H_h	H_d	$H_{\beta(90)}$	$H_{\beta(30)}$	$G_{s\beta(90)}$	$G_{s\,\beta(30)}$
	MWh	MWh	MWh	MWh	MWh	MWh
Jan	5,6	3,3	7,21	7,24	32,65	52,29
Feb	7,7	4,2	8,25	9,34	37,36	67,46
Mar	10,6	5,5	8,70	11,83	39,39	85,44
Apr	14,6	6,5	8,70	15,11	39,40	109,4
Nov	6,7	3,4	8,89	8,86	40,25	63,99
Dec	4,9	3,0	6,55	6,42	29,66	46,37

The energy saving achievable from the greenhouse has been evaluated considering the following operative conditions:

a) lecture hall without any HVAC plant
b) lecture hall with an HAVC plan

The following figures show the variation of daily temperatures inside the greenhouse (Ts) and inside the lecture hall (Ta) for the two model days analysed

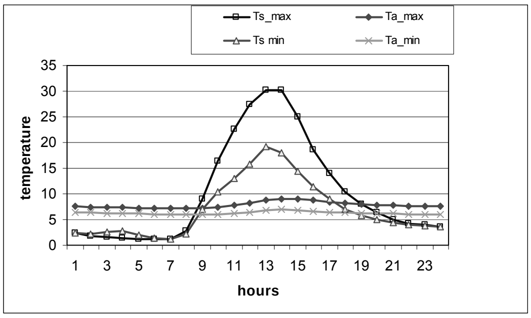

Fig. 7 – Variation of daily temperatures (January)

The achieved results show that the temperatures inside the greenhouse during the period of interest (8.00 -18.00) vary from minimum of 10° and maximum of 30° in sunny days (T_{s_max}) and from minimum of 7° and maximum of 18° in cloudy days (T_{s_min}). Otherwise the temperature inside the lecture hall is always less of 10°C.
Obviously this typology of heating regime can't satisfy the energetic needs of the lecture hall

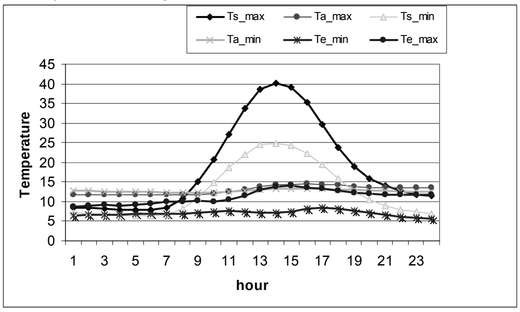

Fig. 8 – Variation of daily temperatures (March)

In March the temperature inside the greenhouse grew until 25° c and 40° c respectively in cloudy days and in sunny days; moreover the temperature inside the lecture hall increase until 15° c. Also for this month the energetic contribution of the solar gains in not sufficient to satisfy the energetic demand.
Case b)
The following figures show the variation daily temperatures in the hypothesis that the lecture hall is kept at minimum temperature of Ti = 20°C by a heating system.

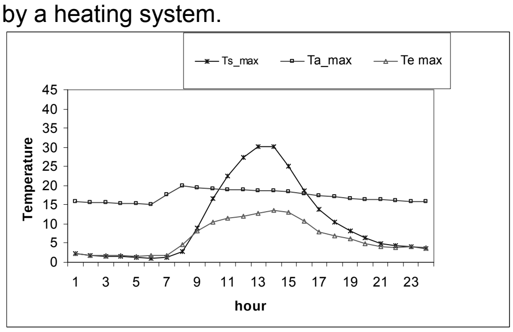

Fig. 9 – Variation of daily temperatures (January)

The achieved results show that the temperatures inside the lecture hall are more less 20°C, so the energetic contribution of the solar greenhouse satisfy the energetic needs of the lecture hall during the sunny days

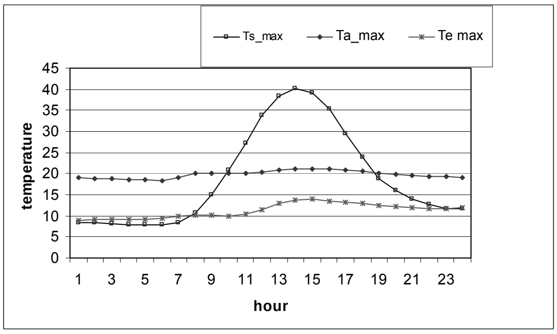

Fig. 10 – Variation of daily temperatures (March)

In March the temperature inside the greenhouse is always up 20° c and the energetic contribution of the solar gains fully satisfies the energetic demand.

3.Experimental Validation

In this section, It is reported on experiments designed to test the effectiveness of our approach. On January 5th and 10 th , experimental temperature measurement, under clear-sky condition, have been executed in the solar greenhouse and in the lecture hall .
During the monitoring phase of indoor temperature, the terminal devices of heating system have been disabled so that it has been possible to estimate the solar gains and thermal balance of.
Fig. 11 and Fig.12 show the values of temperature measured in the lecture hall and in the greenhouse the surveyed period.

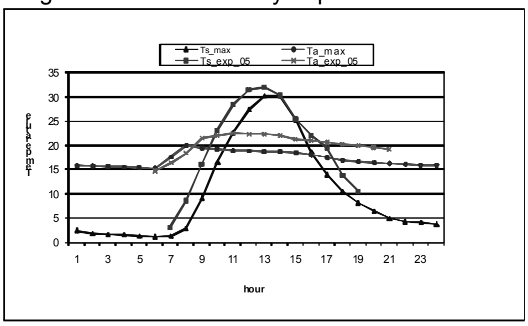

Fig. 11 – Comparison of experimental and predicted data (05/01)

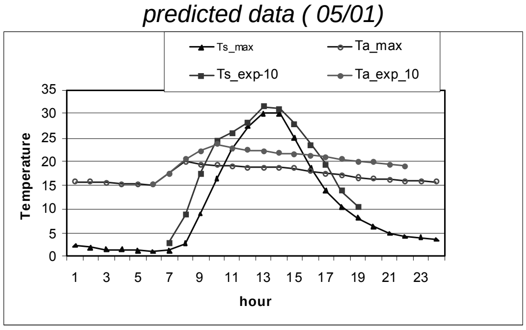

Fig. 12 – Comparison of experimental and predicted data (05/01)

It is possible to observe that the measured temperatures of greenhouse are slightly different from those calculated. Otherwise the temperatures measured inside the lecture hall are always more higher than those predicted (about 2°÷ 3° C). This difference is probably due both to the presence inside the lecture hall of more less one hundred students which contribute to the heating and the difference between meteorological condition predicted in comparison to those effectively surveyed

With reference to the measurements of 10/01 it is observed that the temperature in the lecture hall increase over the temperature of 20°C fixed for the simulation. However the temperature trend follows the predicted values

Globally, results show a really good agreement between experimental and calculated data, showing an average error equal to ± 2°C.

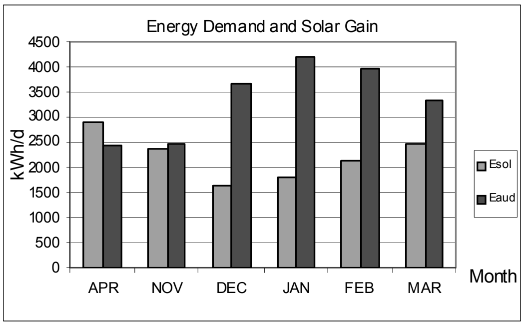

Fig. 13- Comparison of thermal requirements of the auditorium (E_{aud}), related to the period of occupancy, and energy gains (E_{sol})

The seasonal energetic savings achievable have been evaluated in 13300 kWh (479000 MJ) , value that, represents approximately the 66% of energetic demands of lecture hall**.**

4. Conclusions

On the ground both of results achieved by proposed method an experimental measurements, it is possible to notice:

- A substantial good performance of approached methodology to obtain both trend of temperature in the greenhouse environment and heat gains
- For whole diurnal period of investigated months, the air temperature, in the greenhouse, rise up more than 20°C, and in that period it is strongly reduced the thermal dispersion
- The greenhouse reduces about 65 % of the consumption of not-removable energy used to heating Auditorium.
- The results show that, just for this typology of application, it is possible to built one design index (I_G), in function of to the ratio of the surface of the greenhouse A_{GH} , and external surfaces of room $\sum A_e$:

In our case $I_G = (A_{GH}/\sum A_e) = 1/8$. By the value of this index in the other similar cases will be possible to evaluate if the application of solar greenhouse in building renovation could carry real benefits about save energy.

5.Reference

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