HYBRID SOLAR SYSTEMS IN BUILDINGS: TWO CASE HISTORIES

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ABSTRACT The utilization of Hybrid Solar Systems in buildings allowed a rational use of energy required to obtain proper comfort conditions inside the building itself. During some research programmes carried out at ICITE, prototypes of test cells capable of supplying significant information on the energetic behaviour of technologically innovative building envelopes for passive and hybrid solar control, have been designed and built. Using these test cells several studies have been carried out on different systems and components; two of these have been perfected: an opaque multilayer system and a ventilated dynamic window.

Afterwards, it was believed convenient to rely on a practical tool to be used to assess the different systems' typologies under different working and climatic configurations. This is the reason why a mathematical model was studied, optimized and validated on the basis of data obtained from experimentation carried out in real working conditions on the opaque multilayer system and on the ventilated dynamic window.

The paper presents the analysis and optimization of two solar systems from an energy point of view, by using a finite element simulation model.

1. THE FINITE ELEMENT MODEL

A finite element simulation and analysis model with a computational fluidodynamics module has been used to assess the behaviour of dynamic external wall components. In considering geometrical and thermophysical properties and after setting thermal and fluidodynamical boundary conditions with known meteorological data, a steady-state analysis has been performed through the finite element model for the two components.

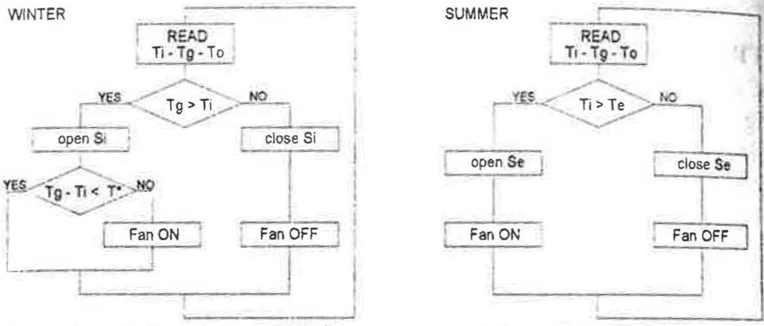
Input files have been suitably filled in for the program used which is able to create the model relating to the geometrical configuration to be analyzed. It was possible then to compare the efficiency of the component modeled according to the variation of some geometrical parameters which were considered to be essential for the improvement of energy performances of the component itself.

The meaningful quantities used for the definition of the models are the in[illegible] air temperature (Ti), the outdoor temperature (To), the air gap temperature (Tg), [illegible] output temperature (Tu) and solar radiation (I).

Energy Q supplied by the air heated in the air gap is calculated starting fr[illegible] the difference ΔT between output temperature (Tu) and input temperature and fro[illegible] some characteristics of the system, such as air-flow rate (m) and air specific heat (Cp) as follows:

$$Q = m\,Cp\,\Delta T \qquad (1)$$

2. THE VENTILATED DYNAMIC WINDOW



Figures 1 and 2. Cycles of winter and summer working of the dynamic window.

The component consists of a dynamic double window employing solar photovoltaic cells as energy supply for management devices integrated in its frame. Both external and internal windows are provided with a standard double glazing. The air-flow occurs in the gap between the internal and the external glazing. Fans and shutters (one of them towards the outside Se and the other are towards the inside Si) placed on the window upper box manage the air flow used to heat or cool the internal environment according to the following operation modes. In winter time (fig. 1), under conditions of good solar radiation, the internal glazing gets dark; the air in the space warms up due to the greenhouse effect and transfers heat into the internal environment. In summer time (fig. 2) the air in the air gap causes a convective flow and the warmed air is moved from the inside to the outside helping this way to cool the internal environment.

This system is entirely autonomous as regards its installation and operation and does not interfere with the installation of the building.

3. OPTIMIZATION OF THE DYNAMIC WINDOW

The model regarding the prototype installed in the test cell, which was previously validated, has then been simplified and parametrized.

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Kg/s).

COND	1	2	3
Ti (°C)	20	20	20
To (°C)	12	11	9
I (W/m²)	683	576	473

Table 1

The efficiency η o[illegible]
and is defined as:

where S is the glass[illegible]
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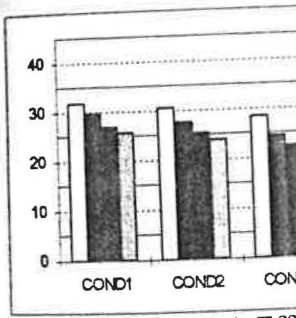

Figures 3 and 4. Eff[illegible]
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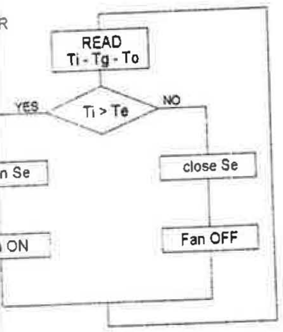

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As concerns the winter case, the analysis was focused on a situation with internal opening in an open position and with the fans running. The parameters concerning air gap width and the fan air-flow rate were changed.

Four values were studied for the air gap length: 16 cm (actual value of the prototype), 12 cm, 8 cm and 5 cm. Thickness values less than 5 cm were not considered for they cannot be practically realized. For all these values the model was solved with two different air-flow rates (0.018 Kg/s, equal to the real one, and 0.036 Kg/s).

COND	1	2	3
Ti (°C)	20	20	20
To (°C)	12	11	9
I (W/m^2)	683	576	473

Table 1

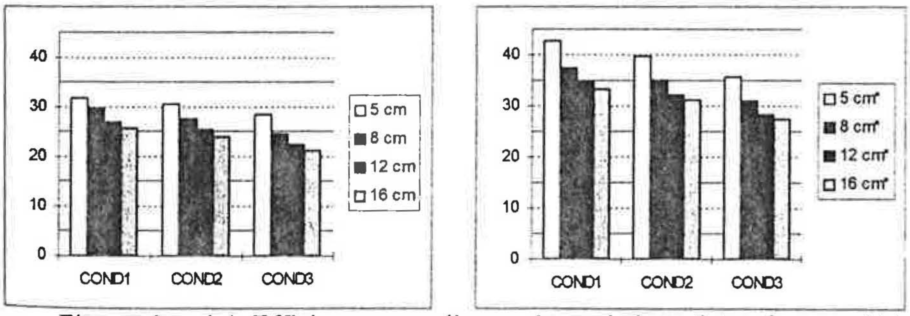
The boundary conditions employed are schematized in table 1; the chosen values correspond to the average over a 11-13 hourly interval of three winter days characterized by a different average value of radiation.

The efficiency η of the considered system was calculated starting from Q (1) and is defined as:

$$\eta = Q/(S\ I) \quad (2)$$

where S is the glass surface.

The efficiency, reported in figure 3 and 4, is strongly affected both by the air gap width and by the fan air-flow rate. The most effective air gap is the one having the smaller width especially if the air-flow rate is doubled. As to the component that has actually been realized, the efficiency could then increase more than 15%.



Figures 3 and 4. Efficiency according to the variation of the air gap width with air-flow rates of 0.018 Kg/s and 0.036 Kg/s (*).

In considering the summer working condition, a natural convection motion is brought in the air gap in order to dispose of the overheating due to solar radiation. The holes made on the prototype, as noticed during the modeling and experimental phase, proved to be insufficient. Two studies were then executed with a 1.5 cm-high continuous longitudinal opening in one case and a 3 cm-high one in the other case.

The study was executed for the same values of air gap width as for the winter case (Ti = 27°C, Te = 34°C, I = 590 W/m^2).

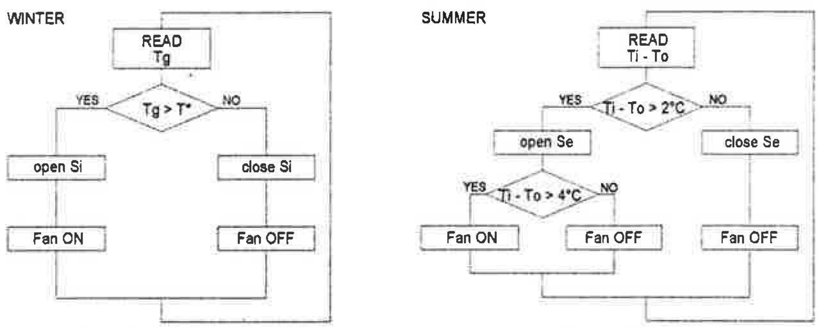
L	opening 1.5 cm		opening 3 cm	
(cm)	m (kg/s)	Tu (°C)	m (kg/s)	Tu (°C)
5	0.020	315	0.026	314
8	0.028	312	0.035	311
12	0.029	311	0.039	310
16	0.030	311	0.057	308

Table 2

In this case it is meaningful to analyse each obtained value about the air temperature going out from the air gap and about the air-flow rate, related to the different air gap width values (L).

The air gap width value is no longer so meaningful, since the real "obstacle" to the beginning of the natural convective motion is represented by the opening letting air out. In particular, when the opening is 1.5 cm high, a variation of air-flow rate is recorded only with a 5 cm air gap, while the other three types give results that are substantially similar since the ratio between the air gap width and this opening is great. By bringing the opening to 3 cm, this ratio reduces and the air gap dimensioning affects the air-flow rate values. It is possible to notice that the outgoing air temperature Tu do not differ in a considerable way the component's overheating is avoided.

4. THE DYNAMIC INSULATION OPAQUE SYSTEM



Figures 5 and 6. Cycles of winter and summer working of the opaque system.

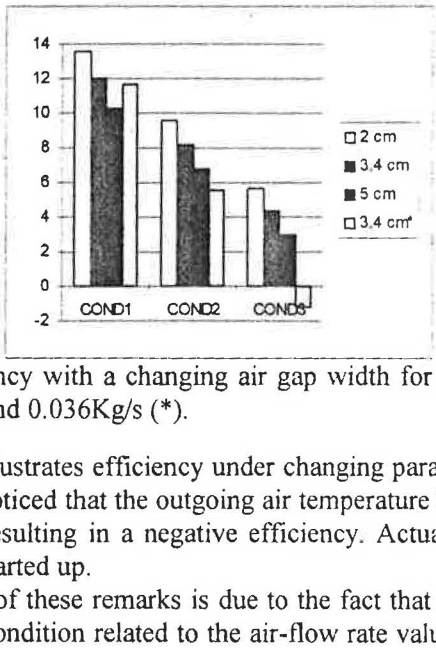
The component consists of a sun-operated prefabricated modular system for air-conditioning of buildings; it can be assembled with equal systems up to achieving the desired façade dimensions both in the vertical and horizontal direction. It is composed of a multi-layer prefabricated element which has, from inside to outside, a loadbearing layer, an air gap and an external screen that can be made of both opaque and transparent material. It is surmounted by a module for energy management, which causes a bi-directional air flow between the internal and the external environment and though the air gap of the prefabricated element. The system is autonomous as regards its installation and its functionality.

5. OPTIMIZATION OF DYNAMIC INSULATION OPAQUE SYSTEM

This panel creates less problems than in the previous case both because from a design point of view there are no severe restrictions and because experience was acquired during previous experimental works.

Also in this case the analysis was focused on different geometrical configurations corresponding to different air gap width values: 2 cm, 3.4 cm (actual value) and 5 cm. The conditions employed are still those of table 1.

In this case, to calculate efficiency (2), the S value employed was that of the panel's surface. This system, contrary to the previous one, takes air from the outside at temperature To, heating it in the air gap; therefore, the actual saving has to be assessed relating to internal temperature. The Q value (1) is obtained by using as ΔT value the difference between the outgoing air temperature and the internal temperature. In this way, the situation changes to a great extent, for, by doubling the air-flow rate, the values of the outgoing air temperature are smaller and they are not balanced by the air-flow rate increase.



Figures 7. Efficiency with a changing air gap width for air-flow rates of 0.018 Kg/s and 0.036Kg/s (*).

Diagram 7 illustrates efficiency under changing parameters. When radiation is not great, it can be noticed that the outgoing air temperature becomes lower than the internal temperature, resulting in a negative efficiency. Actually, the system, in this case, would not have started up.

A limitation of these remarks is due to the fact that the model was used by imposing a boundary condition related to the air-flow rate value. In this case, the best performances of the 2 cm air gap might not be found in real conditions even using the same fan since the fan itself might not be able to actually produce the same air-flow rate in two channels having different features. In fact, the 2 cm-value proves to be critical and friction can no longer be ignored.

L (cm)	opening 10 cm m (Kg/s)	Tu (°C)
2	0.025	326
3.4	0.027	323
5	0.057	317

Table 3

The outlet hole was under-dimensioned also for the panel considered in the summer case; in this connection, the experimentation did not outline a convective motion having meaningful speed values. This is the reason why the analysis was carried out on an opening able to produce interesting results. The opening used for the analysis is continuous and 10 cm-high. In this case, temperature is higher than in the previous case, since the system inputs external air.

6. CONCLUSIONS

The employed model proved to be an effective tool to study new configurations of prototypes that had already been experimentally tested.

In particular, the results pointed out that, in order to considerably improve the performance of the dynamic window, it is necessary to reduce in a drastic way the air gap with respect to the already existing prototype. This way, efficiency related to the active working time of the component would be improved by 15%.

In the summer case, the study executed on both components pointed out that the openings towards the outside envisaged for natural convection had been underestimated. In order for the natural convective motion to be started, it is in fact necessary to considerably increase the above mentioned openings. This leads to a remarkably increased efficiency since, at present, prototypes, due to this very reason, do not actually benefit from natural convection.

7. REFERENCES

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LIFE TIME E

ABSTRACT The building's back to nature, consists of th balance is to be analyzed for embodied and operational er price are only partly related energy consumption can be e values for different climatic z consumption is primarily dete

1. INTRODUCTION

In order to ensure the w appropriate temperature and a is possible either by using a sc flows, or by controlling energ and the environment by arch again material and energy, emb materials and elements, erect optimization of life cycle energ

- market conditions do not pr regular maintenance is prop
- operational energy saving p

2. EMBODIED ENERGY

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