ASSESSMENT OF ENERGY SAVING IN BUILDINGS BY MEANS OF HYBRID ENVELOPE SYSTEMS

I. Meroni, C. Pollastro, R. Lollini and A. De Salvia

ITC - CNR, Construction Technologies Institute of the National Research Council
Via Lombardia, 49 - 20098 San Giuliano Milanese (Milano) - Italy

ABSTRACT

Active and passive solar strategies, together with measures of energy conservation and integration of new materials and technologies, can bring a meaningful energy saving in buildings. In particular, if combined with energy saving measures, the use of solar source can strongly reduce the demand of traditional energy sources. However, the use of such technologies is not sufficient if comfort demands of people who live or will live in the building are neglected and if the proposed technologies are not studied for their real suitability. Modern buildings require integrated solutions, not only to let each component work properly, but also to minimise the global costs of the building itself. The paper presents the results of some ITC's experiences. They have allowed to design, realise and test, through specifically defined methodologies, some innovative solar envelope technologies. The experimentation has been carried out both under real and controlled laboratory conditions. Besides, experimental data have been used to validate specifically developed mathematical models, that have allowed both to optimise some of the realised systems and to extend the analysis to the behaviour of the systems themselves under conditions different from the experimental ones.

KEYWORDS

Solar energy, energy saving, comfort, envelope technologies

SOLAR APPROACH IN BUILDINGS

The need to reduce energy consumption in buildings while reducing at the same time the environment pollution, has increased the interest in the technologies able to assure good comfort conditions inside the buildings, with the minimum energy consumption and the use of the solar source. Over the last years integrated energy approaches have been developed aiming at obtaining the maximum saving of fossil fuel consumption with low additional costs; these approaches combine thermal insulation measures with a rational use of both traditional and renewable energy sources, in particular the solar one. Some envelope hybrid systems are hereafter presented. The performances of such systems can be assessed through adequate test-cells that allow the evaluation of physical parameters in an environment towards which the components itself acts as an energy-flux mediator. This procedure allows the comparison with other components and the optimisation of the component itself. By using such apparatus and a multi-floor experimental building, some analysis have been carried out to assess the performances of the above mentioned systems. To this end, energy contribution Cg* has been evaluated. Such parameter, pointing out the energy performances of the different systems, is the energy needed to keep the test-cell on which the systems are fitted, at a temperature level as similar as possible to the temperature level of a similar cell with a reference system, by means of electric heaters. During the analysis the consumption, the internal air temperatures and the climatic conditions were measured and the energy contribution Cg* of the innovative and reference systems was calculated. The energy contribution is measured over a meaningful period, lasting at least some days, and is defined as follows:

$$Cg^* = Q/(h \cdot V \cdot \Delta T)$$

Where *Cg** is the energy contribution (W/m^3°C), *Q* is the energy absorbed during the measurements (Wh), *h* is the length of the measurements (h), *V* is the volume of the cell (m^3) and *DT* is the mean difference between internal and external temperature during the measured period considered (°C).

A VIEW OF THE EXPERIMENTED SOLUTIONS

The tested solutions here presented, referred to the family of opaque and transparent components, are the ones that gave the best results both from the energy point of view and for what concerns their easy integration in traditional building typologies.

The attached sunspace

The attached sunspace consists of a prefabricated glazing system that can be extended to the desired length allowing the closing of external areas such as verandas and balconies on both new and existing buildings with the double aim of re-qualifying the building external space and contributing, at the same time, to its conditioning.

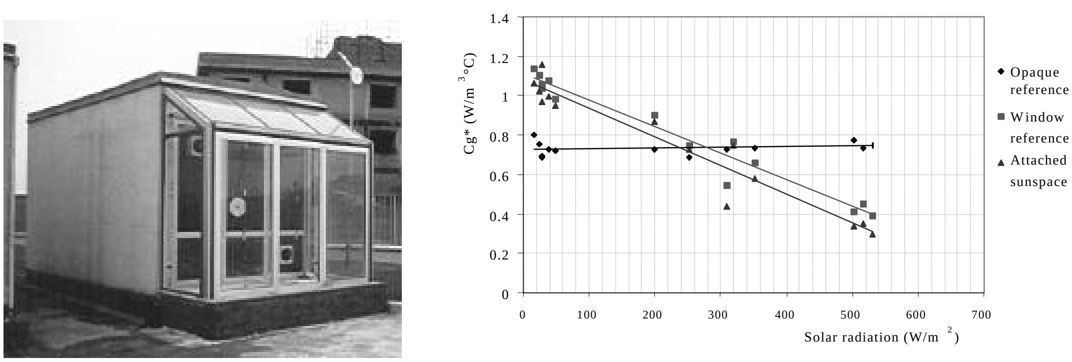

Figure 1: The attached sunspace and the trend of energy contribution

In order to understand the advantages offered by the sunspace, its performances have been compared with the ones of a window similar to the one fitted in the sunspace and with an opaque system. Whenever the air temperature in the sunspace exceeded the temperature of the test cell, the stored heat was automatically transferred from the sunspace into the cell.

Wall-chimney with radiant and ventilating ceiling

The system mainly consists of an insulated enclosure wall, a plain-sheet dark-coloured absorber, a transparent covering, a thermal ceiling, motorised valves and shutters and a window with the shutter integrated in the system. The operation of the system is programmed at fixed times according to a logic scheduled and managed by an electronic device. When the temperature difference measured by two sensors, located in the upper and in the lower part of the air-space respectively, exceeds the value set on a differential thermostat, and the air temperature in the test-cell is lower than the set one, a fan placed in the channel of the false ceiling is switched on and the relevant shutter is opened, allowing the hot air to pass from the absorber to the test-cell through the false ceiling.

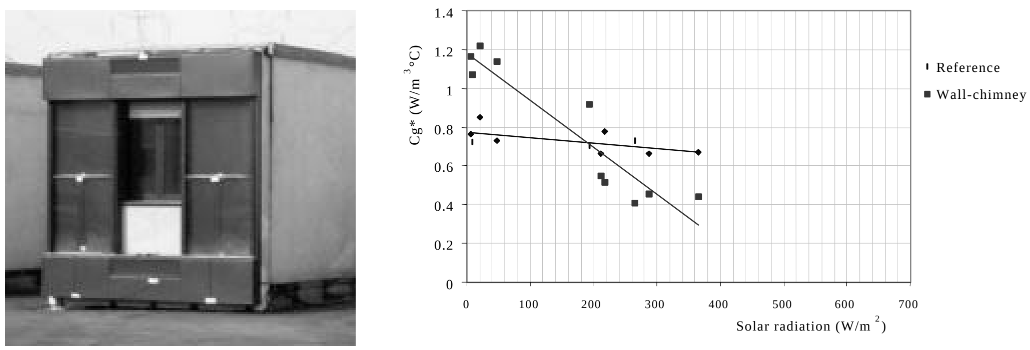

Figure 2: The wall chimney with radiant ceiling and the trend of energy contribution

When the above mentioned temperature difference is lower than the temperature set on the differential thermostat, the fan remains in the switched-off position and the shutter closed. A particular device blocks the inflow of the heated air into the cell whenever the internal air temperature of the cell itself exceeds a certain temperature value, set by an ambient thermostat.

Wall-chimney system

The system mainly consists of a solar collector, a window, a concrete panel, a system of valves for the integration of the façade with the heating plant, a fan-coil heating plant.

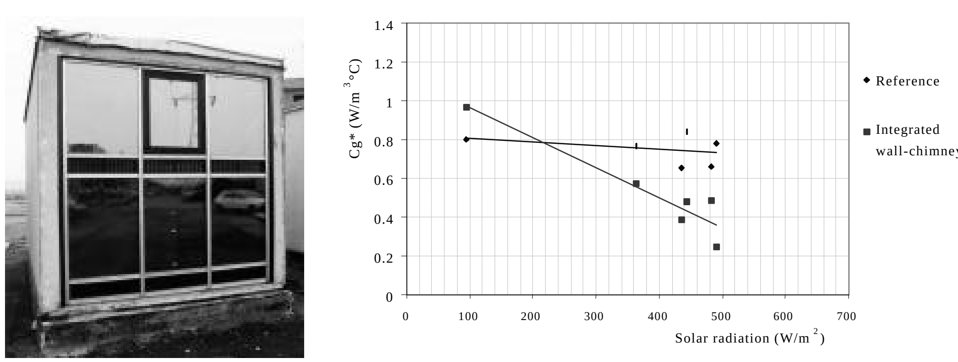

Figure 3: The wall-chimney system and the trend of energy contribution

Four kinds of conditions are foreseen.

1) *Deactivated solar collector:* such condition takes place during the night hours or when the radiation is low, when the plate temperature is lower than the ambient air one. In this case, for what concerns the heating, the fan-coil is automatically activated.
2) *Passive heating:* such condition takes place when the radiation is good, and at the same time the ambient air temperature is lower than the fixed one and the plate temperature is higher than ambient temperature but lower than the fixed one. In this case the fan-coil is off and the valve for the inflow of the air is open.
3) *In series heating*: the air, pre-heated by the chimney, is introduced into the fan-coil. Such condition takes place when the ambient temperature is lower than the one set by the thermostat and the plate temperature is higher than the ambient one.
4) *Cooling solar chimney:* such condition takes place when the plate temperature exceeds the limit temperature fixed at 65°C.

The dynamic window

It consists of a transparent system, comparable to a traditional window with double glazing, characterised by the integration of a changeable transparency glazing. In the air-space between the double glazing and the changeable transparency one, under specific conditions and thanks to the properties of the changeable transparency glazing to darken, the air is heated by greenhouse effect and put into the internal environment. The system is provided with a management logic for the ventilation and for the air fluxes of the air-space. The controlled management of the air leakage is assured both by a particular device located in the upper part of the window frame, and by other elements of the system. Properly dimensioned photovoltaic panels ensure the functional autonomy of the system.

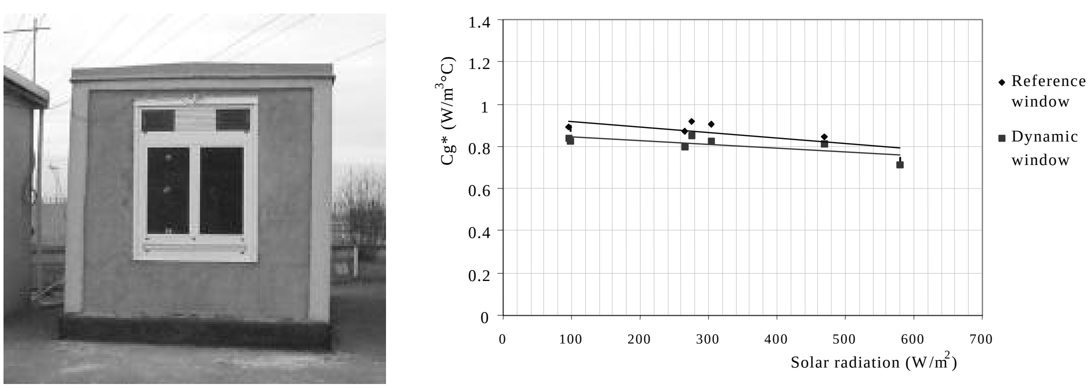

Figure 4: The dynamic window and the trend of energy contribution

Dynamic insulation prefabricated system

It consists of a multi-layer prefabricated opaque system with an air-space through which the air flow acts as an energy vector between the internal and the external environments. It is equipped with a module for the energy management making up the plant part of the system.
Such module is able to assure the management of the thermal fluxes through the dynamic system. In such module the bi-directional air flow between the internal and the external environments and

through the air-space of the system is determined allowing the selection of the flux cycles indoor-outdoor, outdoor-indoor, outdoor-outdoor. The module has been designed to be autonomous from the energy point of view and completely automated. The system works according to two functional models selected according to the seasons. In winter conditions (heat gain) the system exploits the heating of the air in the air-space and transfers such heated air inside the environment. In summer conditions (heat exhausting), the system avoids the over-heating of the internal environmental air by exhausting such heated air.

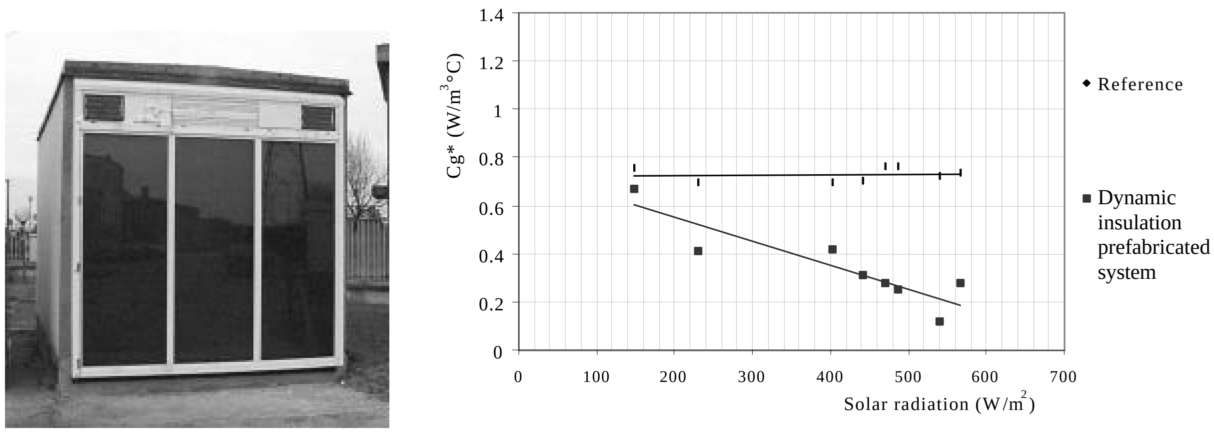

Figure 5: The dynamic insulation prefabricated system and the trend of energy contribution

The experimentation under real working conditions

To assess the performances of the last presented opaque system (see Figure 5) under real working conditions, an experimentation was carried out, which envisaged the integration of such system in a multi-floor experimental building. The results obtained during this experimentation are presented here as an example. Two prototypes of the system are fitted on the south façade of the experimental building. The volume bound by the systems is about 270 m^3. For the comparison, a similar volume of the building whose south façade was characterised by an opaque brick part and a transparent part was used.

The obtained results

Test-cell evaluation

As shown in the diagrams of the energy contribution (from Figure 1 to Figure 5) the energy contribution of each of the presented systems seems to be particularly meaningful. The energy saving obtained by using the sunspace and compared with that ensured by the window results to be within 10% under weak solar radiation conditions (< 300 W/m^2) up to 20% under good solar radiation conditions. Under each test condition, the performances of the sunspace resulted to be higher than those of the transparent reference. For the two wall-chimney systems (with and without the radiant and ventilating ceiling) the energy saving is about 30%, even with not particularly good solar conditions. The analysis of the dynamic window the results shows a meaningful contribution Also the dynamic insulation prefabricated system has given the best performances. In fact, its energy contribution reaches 60%. During the tests a 0.6 m/s air velocity inside the cavity and a mean air temperature higher than 55 °C have also been recorded..

Real working evaluation

Performances drops between tests under real working conditions and the results of the test-cell analysis were not recorded. In fact the energy contribution of the opaque system compared with the reference one, reaches 40%, as pointed out in Fig. 11. Besides, the internal air temperature stays within acceptable values considering the external temperature conditions. In particular a lower and lower internal temperature, compared with the reference, was measured, both during the day and the night. This happens also for what concerns the relative humidity in the indoor environment, lower than the one in the reference environment. With an equal air temperature, the indoor comfort is improved.

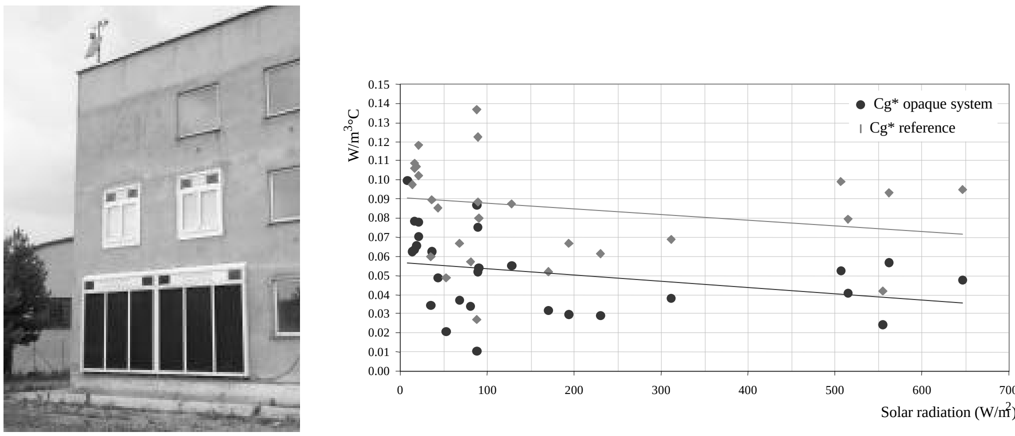

Figure 6: The experimental building with the tested system and the trend of ehergy contribution

CONCLUSIONS

The rational use of energy in buildings means preserving them in general, and using at best the renewable energy by minimising the use of fuels. In 1973 the first oil crisis drove governments to look for safe energy sources by reducing the dependence on imported oil. Some years later the need to preserve energy was forgotten. Nowadays the general crisis of the environment in which we live cannot be ignored. The present energy situation binds us to consider once again the use of renewable sources, alternative to oil fuels and petrol by-products, which have become a not much sustainable source, in particular in countries in which traditional primary sources are poor. Many initiatives have been promoted in the building sector. In fact, it must be considered that buildings are responsible of a great part of the consumption in the national balance and even today a part of the energy used for cooling is uselessly wasted. From the environmental sustainability point of view, the use of renewable sources plays a primary role and the energy consumption control in buildings exploiting at best solar gains, should be one of the objectives to be pursued.

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