Integration of Active Solar Thermal Collectors with Coloured Absorbers in Façades

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ABSTRACT

Even if the quality and durability of active solar systems equipments are henceforth ensured, there are still some considerable barriers to the development of their market, in particular their architectural and technical integration to the buildings. Our research aims at studying, designing and realizing a structural component of building ensuring in a permanent and integrated way the set of functions normally provided by elements of façade and by thermal liquid-cooled collectors. The product is intended to be distributed and implemented by building professionals.

KEYWORDS

Thermal solar collectors, façade integration, coloured absorbers.

INTRODUCTION

By signing the Kyoto Protocol, France has engaged a strong reform of its policy of control of energy and development of renewable energies. In the Climate Plan 2004, it registered the application of the "factor 4" which aims at dividing by four, from here 2050, the emissions of greenhouse gas. Thus, a 50% increase of the heat production of renewable energy origin in 2015 appears among the main objectives of the national energy policy, from where the growing interest in thermal solar systems.

The alternative offered by the thermal solar systems proves to be relatively attractive, more especially as it has two fundamental advantages: solar energy provides an inexhaustible source of energy and its use produces neither emission of pollutants, nor waste [BAL 2006]. But, the development of the French market indeed seems to be facing different constraints:

- Architectural: the aesthetics perception of these systems within the buildings, and the quality of their integration to the buildings architecture and their environment, are major elements of reserve of architects and building owners towards the use of solar active thermal components;
- Political: Some policies encourage the use of solar energy by means of various incentives (tax deductions, help with the investment), but it is essential that these policies to engage in duration, which is seldom the case;
- Economical: The free cost of the resources is counterbalanced by the high cost of the installations.

Thus, the "integration of active solar components to the building" must be a major concern for the years to come in order to avoid unaesthetic implantation solutions

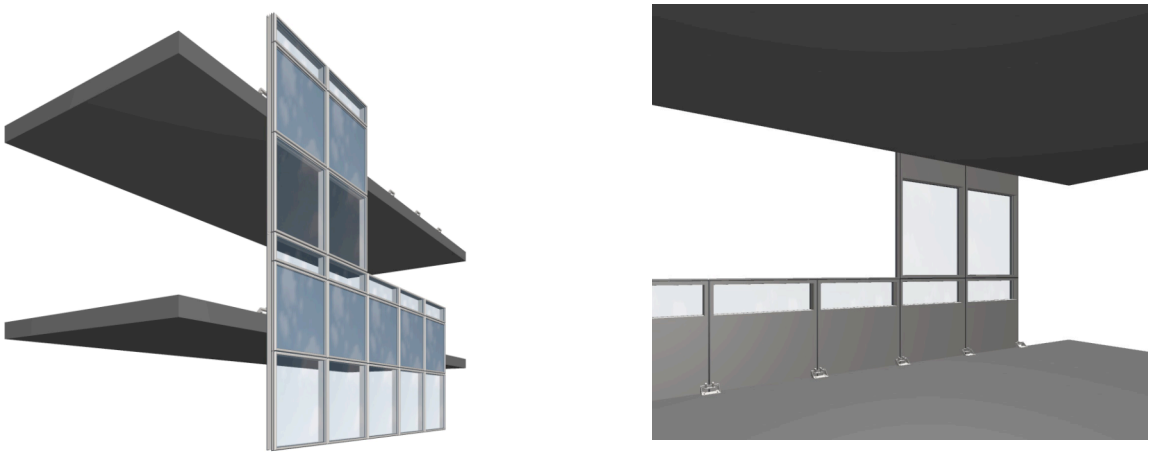
and significant realization over costs. Moreover, unsuited solutions could lead to devaluate the buildings or to threaten its integrity.

METHODS

A preliminary market inquiry led to a feasibility study intended to evaluate the relevance of the approach and technical choices. A functional analysis of active solar systems and of building envelope guided us with the elaboration of the proposal. A prospective method based on structural analysis was used in order to evaluate the quality of the integration. Numerical simulations were carried out to estimate the energy productivity of the design. Real size prototypes were constructed and installed on a real building, and the solar system has been tested over 48 days.

DESIGN OF PROTOTYPE

Façade collectors are used as an element for design for buildings. By varying the surface grid dimensions, the kind and colour of the cover strip and the colour of the absorber the look of the façade can be changed. In this context, the work on the development of a solar component for façade integration has been carried out. The design of the component was based on lightweight façades. The concept was to directly incorporate a collector absorber element in a breathing façade component with respect to the norms NFP 28-001, NFP 28-002, NFP 28-003, NFP 28-004 and DTU 33 [
Figure 1].



a – Front side view

b – Back side view

Figure 1 : Design of the façade collector.

Heat insulation is a component both of the building as well as the collector. The component comprises a transparent glazed part and an opaque solar collecting part. The collector part is composed of a glass cover, an absorber copper plate, fluid collectors, insulation, a metal box and the frame. A functional analysis of the solution before and after the integration is presented in the following table:

TABLE 1
Functional analysis of the façade before and after the integration of the solar component

Function	Before	After
water tightness	Waterproof joint	Waterproof joint
Heat insulation	None	Collector insulation
Sound insulation	Double glazing	Collector insulation
Solar collector	none	Absorber

This shows that on the one hand the façade has conserved the main functions of a lightweight façade; on the other hand it has gained new functions (heat insulation, solar energy). This multifunctional component is an integral part of the architecture and an energy converter.

PROSPECTIVE EVALUATION OF THE COMPONENT

The proposed design was evaluated with "SISBAT-01", which is a prospective method developed in the Building Sciences Laboratory (LASH) and is intended for building actors in order to help them in their design and to guide them with a systemic approach towards better solar integration solutions [Salem, 2006]. This method is based on economical, technical, architectural and environmental criteria, and is covering the life cycle of the product. On a scale varying from 0 (very bad) to 3 (very good), the proposed solution showed a global good result (2,12) [Figure 2].

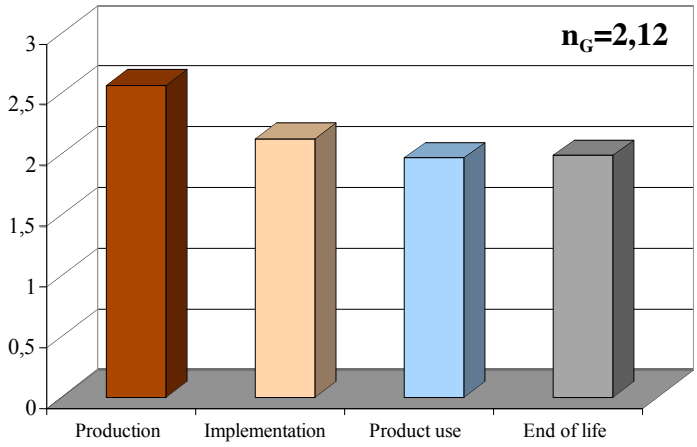


Figure 2 : Evaluation of the façade collector.

The analysis of the results showed the concept to be very satisfactory according to some criteria such as the choice of the raw materials, aesthetics, durability, maintainability and deconstruction; each corresponding evaluation result was higher than 2,5. The qualitative evaluation was then completed by a series of numerical simulations.

SIMULATIONS

Transient System Simulation Program (TRNSYS) was used to develop a model taking into account the solar component/building couple. This has the advantages of considering the thermal interaction between the component and the building and making it possible to optimize the integration of the collector in the building envelop. Simulations were carried out for different orientations (South, East and West) and several geometric configurations (with and without shading effect), to obtain the collector yield of façade integrated collectors compared to collectors facing south with a tilt angle of 45°. The calculations have been done for a domestic hot water system (DWH).The DWH system has 14 m² of solar collectors integrated in the façade of light structure building composed of two zones of 110 m^3 each, and a 1000L DWH storage tank. The system is regulated with a differential controller. For architectural reasons, three colours were chosen for the absorbers of the façade collectors, taking into account the absorptivity and emissivity factors as shown in table 2:

TABLE 2
Absorptivity and emissivity factors of the absorbers coating

Colour	Absorptivity	Emissivity
Black chrome	95,6	7,7
RAL 7021 (Grey)	95	86
RAL 6009 (Green)	94	95

Figure 3 shows the ratio of the additional collector area needed in the façade to reach the same energy productivity as in a system with a tilt angle of the collector of 45° facing west. The results show the needed integrated collecting surface to be increased by small ratios, where surface is available. They also show the components with coloured absorbers to have a thermal behaviour close to those with selective black absorber coating.

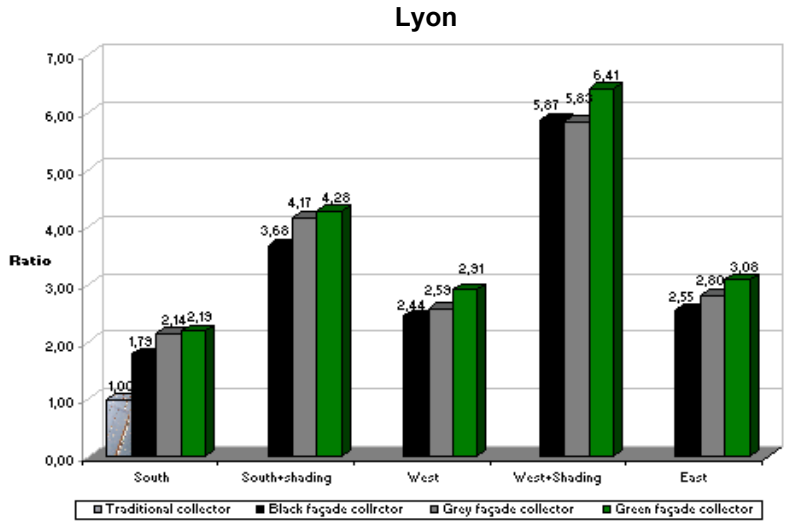


Figure 3 : Ratio of needed surface façade collectors to reference collector surface.

A parametric analysis based on the thickness of the collector insulation, showed that 120 mm of mineral insulation to be the most appropriate for the design. Indeed, simulations were carried for four different values of thickness in order to investigate the impact of the integration on the temperature of air in the building, in winter and summer. Comparisons were made to the temperature of air in a building without any integrated collector. The results showed significant impact for small insulation

thickness on the temperature where the solar system was under stagnation conditions [Figure 4].

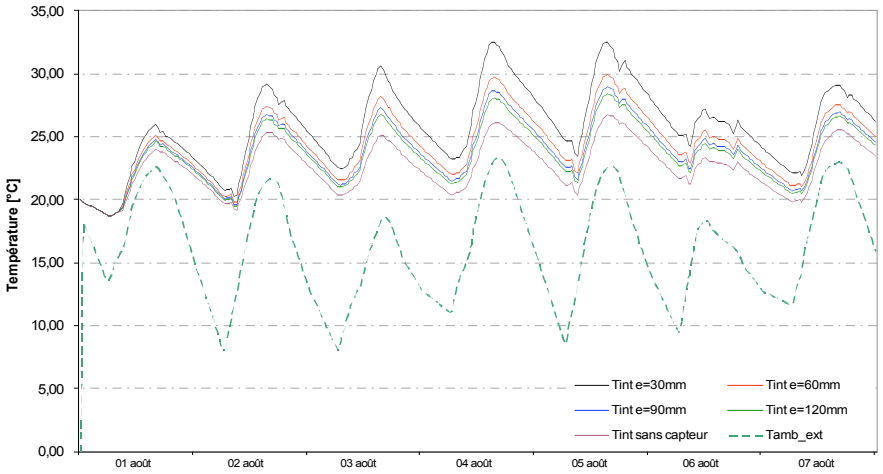


Figure 4 : Room temperatures for different collectors' insulation thickness for a solar system in stagnation.

EXPERIMENTS ON REAL SIZE BUILDING

Three prototypes of 2,1 m² each were installed on the façade of an experimental building located in Isle d'Abeau near Lyon :

- The west collector is the reference collector with a selective black coating;
- The absorber of the central collector is covered with grey painting and the absorber of the east collector is covered with green painting.

The prototypes were connected to a DWH system of 150L storage tank and a regulation unit [Figure 5]. A series of experiments were conducted on each of the three prototypes and a computer based real time monitoring system has been installed to measure the thermal behaviour of the system.

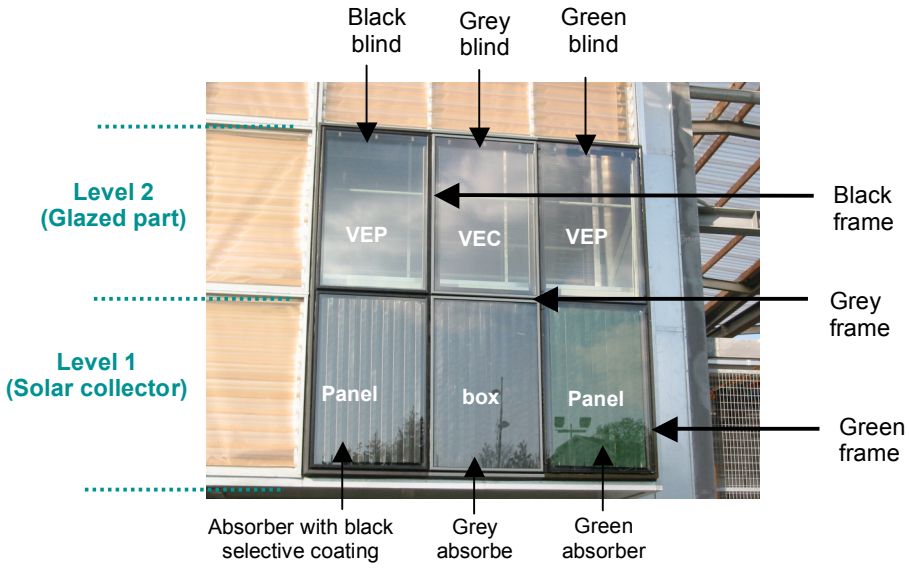


Figure 5 : Room temperatures for different collectors' insulation thickness.

The results of the measures conducted on several days show that the collectors with black and grey absorbers have close behaviour. Worst results were obtained with green absorber. When the system is under stagnation conditions, the maximum recorded values of the absorbers temperatures during test period are: 101°C for black absorber, 93°C for grey absorber, 89°C for green absorber.

The measurements during stagnation period show that the joint temperature in the air gap does not exceed the 70°C, the blind temperature 95°C, and the external glazing of the double glazed window 87°C.

CONCLUSION

Integration of active thermal solar components in buildings is opening a new field of application for solar thermal systems. The results of computer simulations show that we can largely win in architecturally and aesthetically by integrating solar components in building façades. The loss in thermal productivity can be largely compensated by a small increase of collecting area. Since façades represent the largest part of the building envelop, this problem can be easily surmounted.
The interaction of integrated solar components with the building was investigated. Building behaviour is not strongly affected by the solar component when sufficient insulation layers are present.
Coloured absorbers offer to architects new possibilities and advantages for using thermal solar collectors. Thus, by considering the non optimized position for façade collectors, the coloured components showed good thermal performances relatively to those with selective black absorber coating. The development of selective colours for absorbers is an essential step in order to construct visually attractive systems with thermal performances identical to the state of the art absorber coatings [Müller, 2004]. This will help in a broad dissemination of solar thermal systems. Fields of application can be seen in newly constructed houses as well as in retrofits [Matuska, 2006].
The experiment permitted to test the operation and the behaviour of the prototype solar components in time under ordinary and stagnation conditions.

ACKNOWLEDGEMENTS

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