DEVELOPMENT OF LOW-COST PHOTOTHERMAL EXTERIOR CLADDINGS

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ABSTRACT

As a design concept, buildings and annexed exterior spaces should be developed with the aim of reducing energy consumed for lighting, central heating, hot water, refrigeration and ventilation to a minimum while making the most of solar energy. The rest of the necessities will be covered following the criteria demanded for general energy balance and by finding solutions that comply with the most advanced level of technology through the use of low environmental impact energy. For this reason the new Spanish Technical Building Code requires the introduction of photothermal solar solutions.

However, the new regulation has introduced one problem. We see these installations on the roofs or terraced roofs of buildings and apart from their novel attractiveness they almost always look harsh, like something alien to the building and unfortunately they constitute a destructive element in the profile of the urban landscape, similar to the reckless installation of TV aerials, whether they be the traditional mast or the more modern satellite dish.

In order to avoid this they have developed solar panels that act as another element of the composition and construction of buildings. It has become as integral part of the buildings as brickwork, windows, walls, roofs etc. They are polyfunctional tiles that are integrated into the design of the roof.

On the other hand, the durability of the solar collectors is a decisive factor in their selection, especially if they should last at least 20 years. These days, there is enough information and experience on the subject and there are totally reliable collectors on the market.

A new mixed collector has been developed between the tile and the hydraulic circuit. The flat collector operation is conceptually simple. Most of the radiation captured by the collector is absorbed through a surface that appears black in solar radiation (i.e. it absorbs practically all the radiation and reflects very little). Part of the energy absorbed is transferred to a circulating fluid while the rest is lost in the transmission of heat to the environment.

1. INTRODUCTION

The current available solutions to undertake the regulated installation of solar exploitation in thermal applications are a long way from satisfying the architectonic plans and functions desired.

In effect, the most exploited industrial solutions lack a sufficient degree of architectonic integration, double the encapsulation of the functional elements by creating double cladding and generate higher costs that limit the advance of future energy solutions.

Taking the market information shown in table I as a starting point, this study presents an original contribution to low cost towards the integration of a new innate function in the roof-panelling which, through its materials and polyvalence, allows both functional and aesthetic integration at a much lower cost than what is currently available on the market.

	Weisshaupt	Isofotón	Solex
Useful Area(m²)	2'58	2'20	0'37
Material	Glass-Cu	Glass-Cu	PC-Cu
Fluid capacity (l)	2'3	200	0'42
Flow (l/h)	5	6	3
Loaded weight (Kg)	7'1	232	3'6
Maximum pressure (bar)	6	8	3
Loss of charge (mbar)	46	52	164
Max. output (w/m²)	698	650	430
Price (€/m²)	236'4	387'2	520'3

Table 1. Comparative of commercial solar thermal collectors.

2. CONCEPTUAL DESIGN

Any thermal solar exploitation is transfers the solar energy to a conventional thermal circuit through the solar collectors. The essential parts of any thermal solar collection are (see figure 1):

- Absorbent plate: collects the solar radiation and absorbs it in heat form by simultaneously transferring it to a fluid heat transporter. It is constructed in copper plating. In order to increase the solar radiation absorption effect the absorption must be maximised. This is achieved through coating.
- Transparent surface. This is placed on the absorbent plate to create a greenhouse effect while at the same time protecting it from atmospheric elements. It allows the solar radiation through but is opaque to the radiation emitted by the absorbent plate. Warm glass is often used for maximum transfer as it is economical, resistant and long-lasting.

- Exchanger: the hydraulic circuit guarantees a suitable circulation speed in order to extract the heat that accumulates in the absorbent plate. It should maximise the exchange surface while at the same time minimising the loss of charge in the hydraulic circuit.
- Encapsulation: The container in the previous assembly with mechanical support functions and thermal insulation.

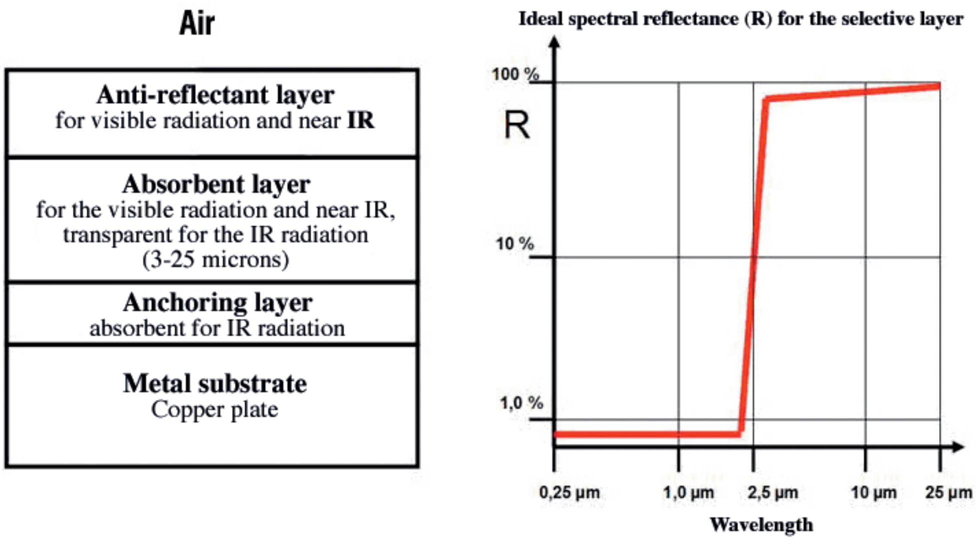

Figure 1. Design specifications.

Due to regulatory restrictions [1] the materials in contact with the hydraulic fluid can only be copper or stainless steel. This restricts the exchanger development field and must be kept in mind at all times. The rest of the development should be focussed on increasing the functionality of the ceramic cladding, the main function of which is to act as insulation, so that it is fully developed for construction solutions for roofs.

3. COLLECTOR DESIGN

In the first phase a simple pilot assembly was used in order to test the effectiveness of the thermal exchange both in materials and geometry. Figure 2 shows this system.

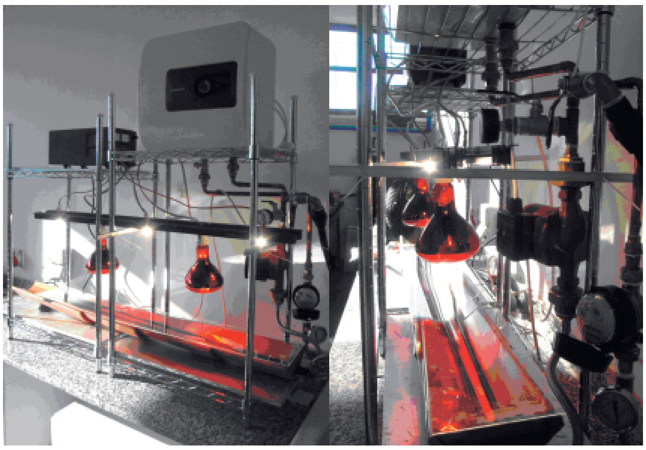

Figure 2. Pilot system.

This assembly allowed us to draw the following conclusions:

- The concentration geometry of a traditional roof had a thermal efficiency yield rate of less than 5%.
- The greenhouse effect of any material with a transmittance of more than 90% at incidence angles of more than 40º can reach a thermal yield equivalent to the industrial exchangers. The critical functioning region is shown in Figure 3. Additionally, this efficiency should be maintained over time with abrasion and aging which limits the glass material to appropriate conditions.

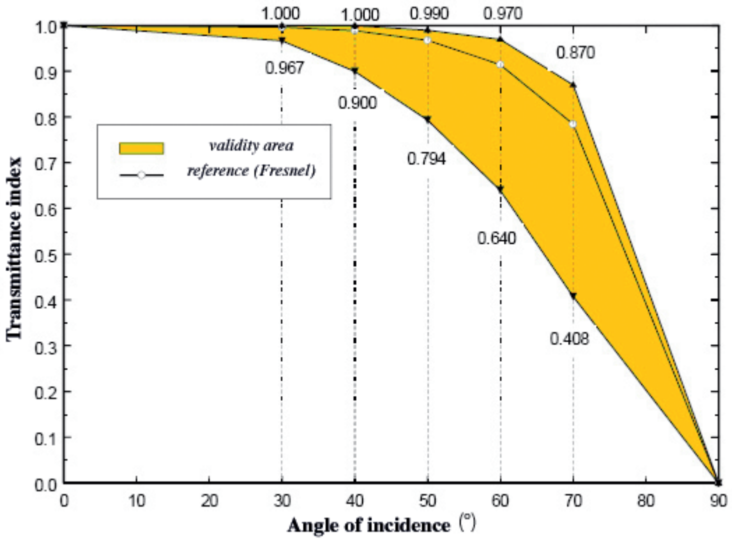

Figure 3. Transmittance of the selected glass with incident solar angle.

- The absorbent finishes provide a leap of more than 20% in energy absorption by the fluid. These finishes are always dark or black. For the optimum construction typology of the exchange and to obtain the minimum thermal loss in the absorbing plate in addition to stability in time for these properties, the electrolyte treatment was optimized with Co on a Zn plate. The absorption results for this material compared with the other solutions are demonstrated as follows:

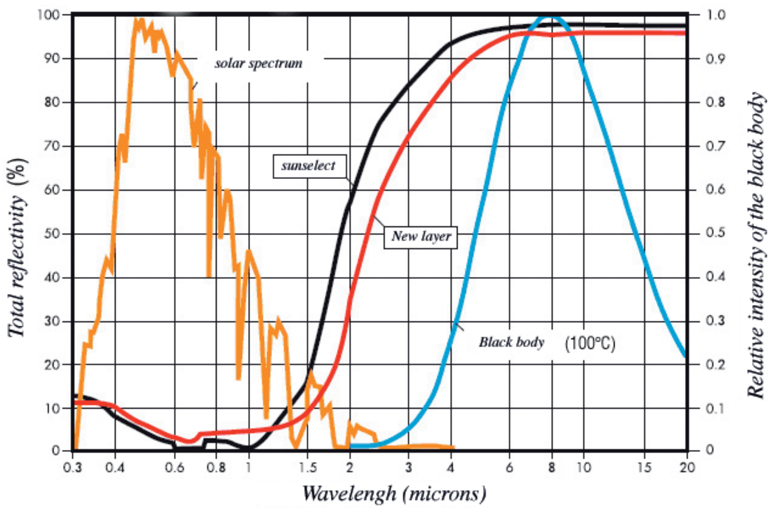

Figure 4. Spectral reflectivity of the new copper electro-deposited layer.

Finally, the insulating capacity of the roofs was shown to be the same or superior to the material used in the commercial solar collectors, which offers additionally, a magnificent opportunity for architectonic integration. The effect of which is the roof design as shown in the next figure.

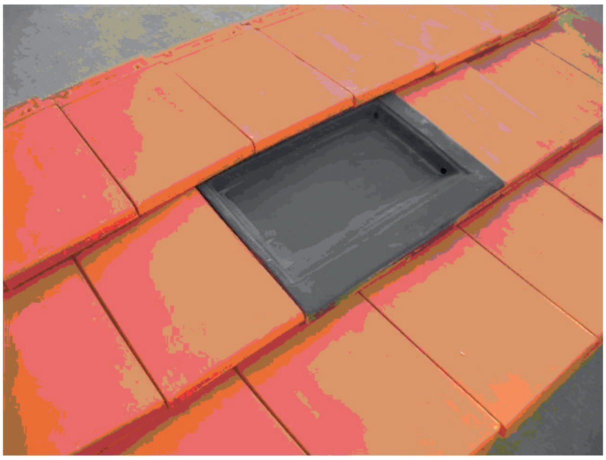

Figure 5. Designed encapsulating roof tile.

4. INDUSTRIAL PROTOTYPE

After the theoretical design and the selection of materials it was confirmed in a laboratory prototype that the selection and assembly of the best materials consists of using a flat surface with a maximum absorbency facing south at 45º to the horizontal. The surface should be covered with the best selected glass creating a chamber with no contact or ventilation. The pre-selected materials for this assembly have had their optimum performance tested and checked in a laboratory prototype.

In this way, the maximum efficiency for collecting solar radiation will be achieved. The rest consists of evacuating this thermal energy through a water exchange circuit with maximum efficiency and a maximum design flows of 20 l/m^2h therefore not exceeding the laminar regime in the fluid circulation which would deteriorate the thermal exchange.

Additionally, it is advisable that the loss of charge in the exchange should be as low as possible in order to avoid excessive consumption of the recirculation pump. As we should obtain a maximum contact area it is advisable to design rectangular sections of the ducts with the longest sides that are in contact with the hot surface. These ducts will be joined together through wide collectors in order to minimize bends and other charge losses.

These circumstances are ideally resolved by employing a flat collector made from sheets that act like a sandwich. Effectively, the flat plate acts as a distributor and by just cutting it and adhering the sheets you can configure a collector that fulfils all the restrictions. The following figure presents some of the collectors prepared for assembly.

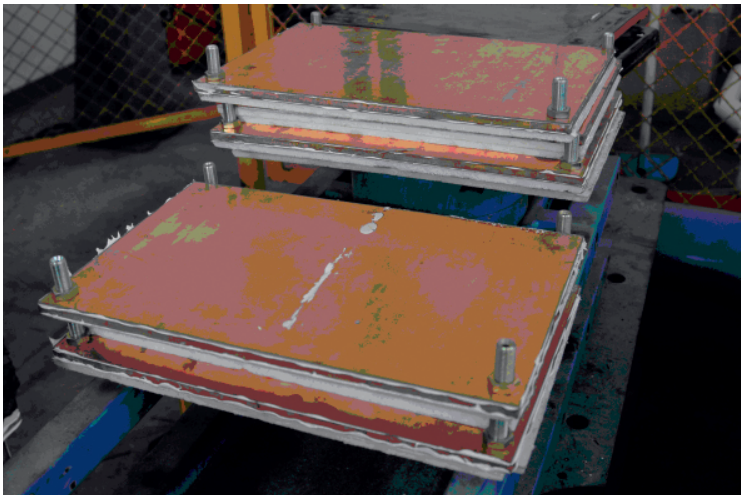

Figure 6. Pre-assembled collectors.

5. RESULTS

The pre-industrial designed and assembled collectors were mounted on an experimental roof that is shown in the following figure. This assembly incorporated the collectors and circuit elements in the lower part of the roof necessary for the operation of the closed circuit.

The thermal evolution of the water was evaluated through the use of an exchanger and an immersion pump that simulated the consumption circuit.

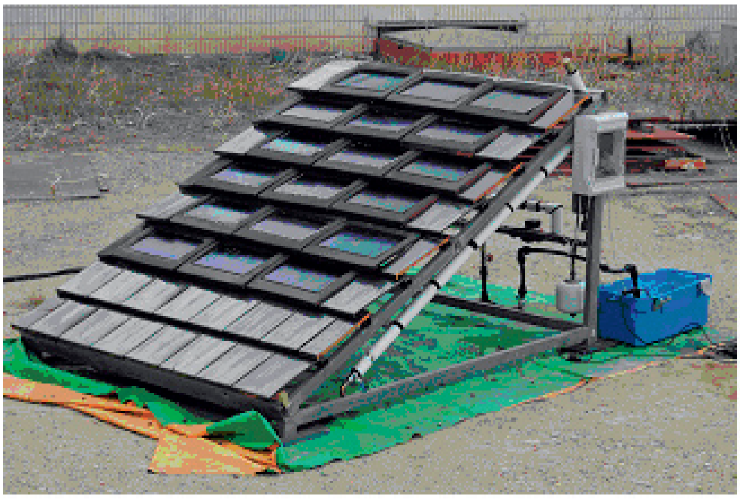

Figure 7. Complete test prototype.

With the temperature data (Fig. 8) and with the solar irradiation information obtained with a commercial pyrometer the average global thermal result of the 712 w/m assembly in a week of total sun. The data for temperature and volume of flow was duly recorded and evaluated, and, having repeated the test 5 times in periods of 48 hours, an efficiency level for the collector of 61% was obtained for the overall surface. This value is equivalent to the most efficient flat collectors on the market.

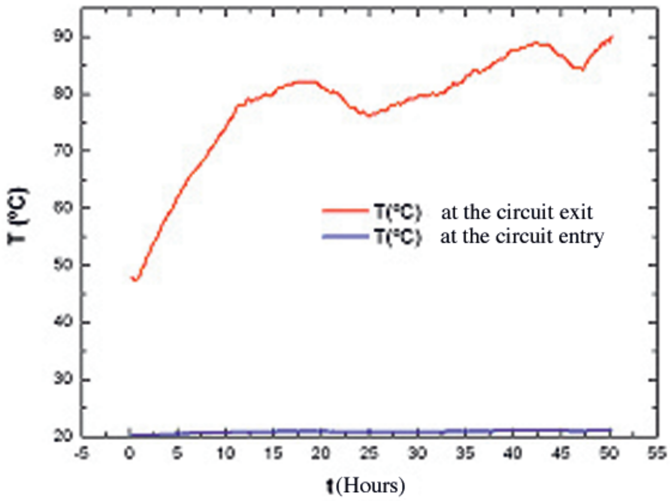

Figure 8. Average thermal response curve for the collector.

6. CONCLUSIONS

The cladding developed for solar thermal collectors yields a performance equivalent or superior to the market solutions while achieving an excellent architectonic product integration and minimising hydraulic losses in the circuit. In tandem with this, the industrial redesign of the heat exchanger is being worked on in order to obtain a product cost that significantly reduces the market solutions for solar thermal collectors.

After verifying the originality of the solution through carrying out a searching in the patents library of the above proposed product, a patent application has been submitted for the collector design.

Furthermore, a prefabricated alternative is being developed that includes the assembly of all the elements that are included in the work through using a crane on pillars in order to execute the envelope.

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