Energetic rehabilitation of an office building in Barcelona by use of passive ventilation strategy and active solar technologies as shading device and corporate identity element

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ABSTRACT

The present paper shows an example for an integrated design process combining the design work of the architect, the use of simulation tools and applied research on new combinations of materials, with the aim of the energetic optimization of an architectonical project.

This integrated design approach is promoted and applied by CISol- Centre for Solar Research at the School of Architecture ETSAV as a method for a sustainable building design.

1. INTRODUCTION

The presentation shows the case study of an energetic rehabilitation of a five-story staircase and the adjacent zones that suffered sever problems of overheating and cold due to an insufficient ventilation, the lack of sun shading, and an overall deficient thermal behaviour.

Industrial fixed glazing elements are substituted by a multifunctional double-glazed facade consistent of a combination of transparent PV panels and coloured and printed glass elements.

An intelligent natural ventilation strategy is developed to cope with the special condition of the staircase as intermediate space between the air-conditioned office space and the exterior.

Thermal measurements were made before and after the intervention. Simulation tools were used to define the right combination of materials in terms of sun shading, daylight use, electricity production and architectonical quality.

Design, technologies and concepts were further developed and validated by design studies and measurements realized as applied research activity by CISol.

Base for this work is the concept of a Solar Network (Fig. 1), seeing research centres like CISol in the important role as connecting elements between the different entities working in the field of architecture, solar energy and sustainability.

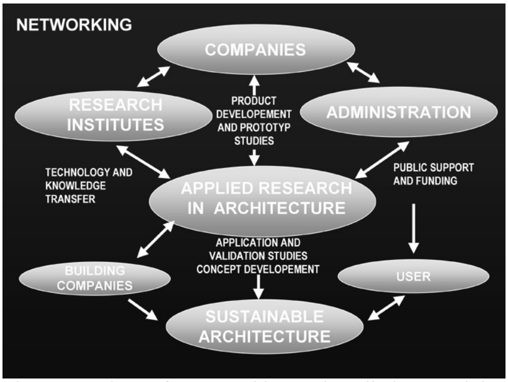

Figure 1: Scheme for networking and applied research in solar architecture.

2. SITUATION

SCHOTT Ibèrica SA is a glass manufacturing company situated in Sant Adria del Besos, a small community beside Barcelona, within a mixed-use residential and industrial area, approximately 500m from the seaside.

The office building, constructed in 2001 is located within the site, touching one of the manufacturing halls.

It is northeast/southwest orientated with a totally glazed staircase on its southwest façade.

This staircase suffered a severe overheating problem in summer, due to the fixed, industrial glazing element without openings and without any shading device. Poor thermal behaviour due to thermal bridges and high U-values of the glazing created discomfort also in winter with very low temperatures inside.

3. OBJECTIVES

The overheating problem had to be solved, at the same time, as the companies own products should be applied for this purpose. In total the situations of discomfort in summer and winter had to be smoothed, as the occupants of the building to move between different offices frequently use the staircase.

4. APPROACH

The idea was to develop a corporate identity concept for SCHOTT, bringing together different of their products in new combinations, solving in an innovative way existing climatic problems.

5. DESIGN PROCESS

In a first stage, a preliminary study was made, defining the above mentioned problems of overheating, missing sun protection, deficient natural ventilation possibilities, glare problems, thermal bridges and deficient overall thermal behaviour (Fig. 2).

Monitoring was done by use of TESTO data loggers in 6 different points of the building, recording values of air temperature and relative humidity every 30 minutes for about 40 days in July and August and 40 days in December and January.

Results showed that in some parts of the staircase temperatures of about 50ºC were reached in August, and air temperature of the staircase in summer could easily be 10 to 15 degrees above ambient temperature.

A second step was the study of the sun situation of the façade, defining the amount of incident solar radiation throughout the year and the shading situation due to the adjacent building.

According to radiation data for Barcelona, there is a maximum amount of 1600kWh/m^{2}a inciting on a south orientated and 40º inclined plane.

Due to the verticality of the façade and the southwest orientation the incident radiation on the façade is reduced to approximately 67% of this amount, which means around 1060kWh/m^{2}a.

A 3D modelling of the building with a sun study was realized for different moments of the year to define approximately the influence of shading on the façade and a possible photovoltaic installation (Fig. 3).

As a result, a diagonal distribution was proposed, dividing the façade in two parts, one upper part, appropriate for a PV installation as receiving sun throughout the whole year, and one lower part, recommended to be realized without a PV installation, due to the shading caused by the adjacent building.

In a third step this result were translated into a first design proposal with different materials in the façade.

For the upper part there was recommended the use of ASITHRU semi transparent PV panels, product of RWE SCHOTT Solar, in a double glazing element, whereas for the lower part

Figure 2: Building analysis and description of deficiencies.

Figure 3: Sun study and evaluation of shadowing by adjacent buildings.

a combination of IMERA coloured glass, product of SCHOTT AG, as double glazed element with an white screen printing as additional sun protection and design element was foreseen (Fig. 4).

For ventilation there were proposed glass louvers in different elements of the coloured glass façade and additional ventilation openings in the upper part, to create a chimney effect within the staircase.

An additional entrance hall was proposed as a climatic buffer space between the staircase and outside.

From the architectonical point of view, this proposal created a new corporate design for SCHOTT Ibèrica SA, combining there own products in their building facade like two hands reaching each other representing two (product) lines of the company coming together to form one combined element.

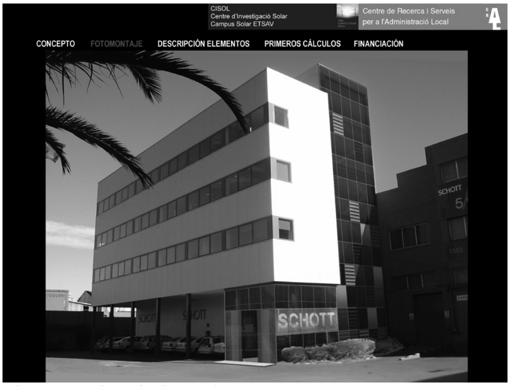

Figure 4: First design scheme.

As final step of the design process, a combination of PV panels and coloured glass sheets was proposed to explore ones more the creative potential of the companies products.

6. PROTOTYPES

As there was so far no experience in the combination of IMERA coloured glass with ASITHRU transparent PV panels, prototypes of different colours and glass combination have been produced, to evaluate their architectonical potential (Fig. 5).

The semi-transparency of ASITHRU in combination with coloured glass showed a promising effect of light and shadow (Fig. 6).

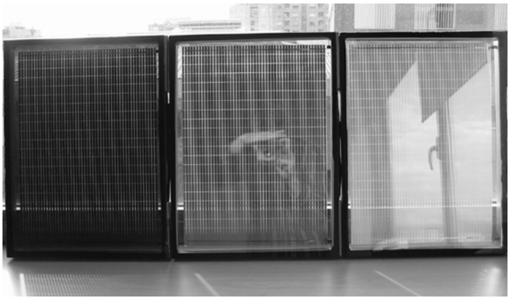
Figure 5: Prototypes of ASITHRU PV Elements with coloured IMERA glass.


Figure 6: Double-glazed IMERA element with screen printing as sun protection and design feature.

Also for the IMERA double glazed elements prototypes were produced with different kinds of screen printing, finding a compromise between the sun shading properties and design aspects in terms of the play of light and shadow, opacity and transparency.

7. THERMAL SIMULATION

A thermal simulation with TRNSYS was made to evaluate the effect of the proposed design on the thermal behaviour of the building and to optimize the proposed strategies in the field of sun protection and natural ventilation.

Different sizes of openings were simulated to define the requirements for sufficient natural ventilation.

The overall performance of the proposal showed to be promising. Maximum temperatures in the staircase could be dropped in summer to just 2-3ºC above the ambient temperature (Fig. 7).

In winter maximums on the other side

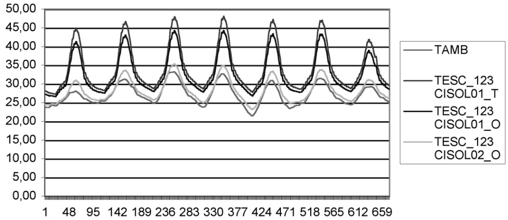

Figure 7: Simulation results air temperature summer reference week before and after the intervention.

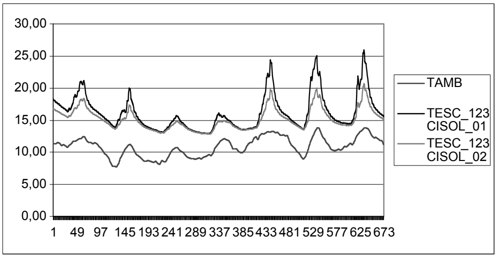

Figure 8: Simulation results air temperature winter reference week before and after the intervention.

dropped also from about 26ºC to about 21ºC, due to the improved sun protection, which limits in winter the desired direct solar gains, but the minimum temperatures did not change (Fig. 8).

The chosen construction system, a semi-structural curtain wall façade, already conditioned the possibility of integration of openings. For design reasons there was a first decision for Italian windows, opening towards the outside, and in closed position almost invisibly integrated like fixed glazing elements.

This façade system showed to be a problem in terms of shadow projection on the PV panels in the upper part of the façade. Even a 15-degree opening would have caused shadow on some part of below installed ASITHRU photovoltaic elements, causing a notable loss of productivity of the whole PV installation.

So finally the decision was made to introduce a line of windows in the upper part of the façade, which open to the inside, permitting fully opened a free ventilation opening of 1,6m^2, required minimum according to the TRYNSIS simulation results.

For visual aspects, but also as a weather protection, fixed metal lamellas are used to cover these openings towards the outside, reducing only slightly the free ventilation opening.

The effect of vegetation in front of the lower openings in the façade was simulated and found as little significant.

One concern for safety reasons was the temperature that could reach the semitransparent ASITHRU PV elements as well as the screen printed coloured glass panels, as they are in direct contact with the staircase.

Simulation showed that the surface temperature of PV panels would not get higher than 48ºC, and the temperature of coloured glass panels would be limited to a maximum of 43ºC.

According to simulation results, with the new facade the overall heating and cooling demand of the office building could be reduced by 8%, dropping from about 87kWh/m^{2}a to approximately 80kWh/m^{2}a.

8. RESULTS

Results of thermal simulations have been introduced into the project, finding an architectonically attractive solution for each parameter (Fig. 9).

The ASITHRU PV installation has a potential of about 1,5kWp, which is a rather small installation, but the project has to be understood as an integrated answer to a whole row of necessities. In this sense the PV installation contributes positively in the field of daylight use, sun protection, visual relation to the exterior, thermal behaviour of staircase and building and last but not least as a corporate identity element for the company (Fig. 10).

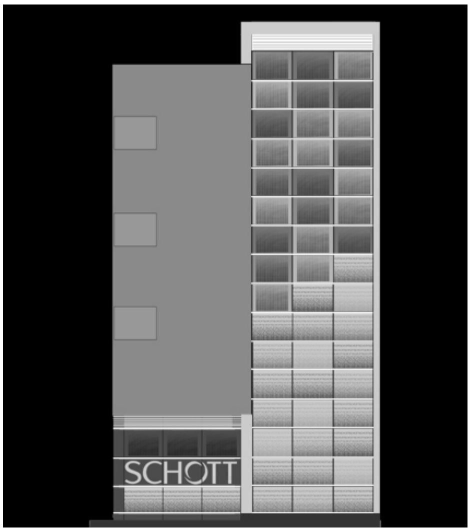

Figure 9: Final design scheme.

Figure 10. Interior of staircase.

The project is now under construction. Final results will be presented at the conference.

9. CONCLUSIONS

The presented project reflects the philosophy of the integrated design approach, which the CI-Sol- Centre for Solar Research ETSAV, tries to implement into the architectural education at the Polytechnic University of Catalonia (UPC) but also in its work as a service and research centre, offering services in the fields of energy consultancy, technological education, solar design and applied research on new solar building elements to public and private entities.

The example of the Solar Façade for SCHOTT Ibèrica SA shows how this concept can be put into practice by a close and interdisciplinary collaboration between industry, research centres and university.