

## Innovative low energy renovation of a single family dwelling for summer comfort

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### ABSTRACT

A single family detached dwelling was partly renovated for structural reasons. This was an opportunity to rethink the concept of the living space with adjacent sunspace.

The new structure is flexible, to take account for the varying occupation, by a sliding separation wall. A balanced ventilation system with heat recovery must guarantee good indoor air quality at a minimal energy cost. The external construction is equipped with a sloped green roof, a high glazed facade with innovative framework and triple Argon filled glazing ( $U\ 0.8\ \text{W/m}^2\text{K}$ ) with warm-edge spacer. To control solar gains, a shading device with large inclinable lamellas has been designed. These lamellas are equipped with PV solar cells. To optimise the position, spacing and inclination of the shading and of the PV cells, a model study was performed in the daylight laboratory of BBRI under the direct sun simulator for various moments of the day and the season.

Summer comfort conditions can be further improved by a system of night time ventilation via large louvers both in the sunspace and in the living room and an exhaust chimney equipped with a low pressure fan to support the natural ventilation whenever needed (hybrid ventilation).

Monitoring results are not yet available at the moment of publication, but are envisaged in the near future.

### 1. THE BUILDING DESIGN

A 20 year old dwelling is partly renovated due to structural problems in the support beam of an

attached sunspace. This sunspace was designed as a single glazed double envelope covering the living area of the dwelling, and facing South (SE-SW). The dwelling was at its conception in 1984 an example of energy conscious design: located on a south sloping hill, well oriented and open to the South, unheated spaces located at North-East and North-West with closed facades, a sunspace, strictly separated from the living area by insulated walls and windows, as buffer for preheating of ventilation supply air and a solar hot water system. Summer comfort is fairly well realised by an external roller screen on the glazed roof and natural ventilation via the staircase and roof lights. Results of an energy rating exercise show that the annual energy consumption is very moderate: 37.2 to 45.7 kWh/m<sup>2</sup>.year for heating, 63.7 to 72.5 kWh/m<sup>2</sup>.year for total energy consumption (Santamouris, 2004).

Since there was an urgent need to reconstruct the sunspace part of the house, there was an opportunity to adapt part of the living space as



Figure 1: View on the house before renovation (design: ir. L. Vandaele).

well. The following philosophy was used for the renovation design:

- flexible living area: shrinking size of family during the week, growing during weekends,
- adaptable for elderly people, with possibility to split the building in 2 independent dwellings,
- good physical and visual connexion to the garden and the landscape, with respect for the original design and the location,
- no additional energy consumption,
- good summer comfort and air quality,
- innovative technologies for sustainable building and living.

After several years of difficult balancing between urban planning limitations and functional, aesthetic, physical and economical design considerations, a compromise was found in the design as presented in the drawings of Figures 2 and 3.

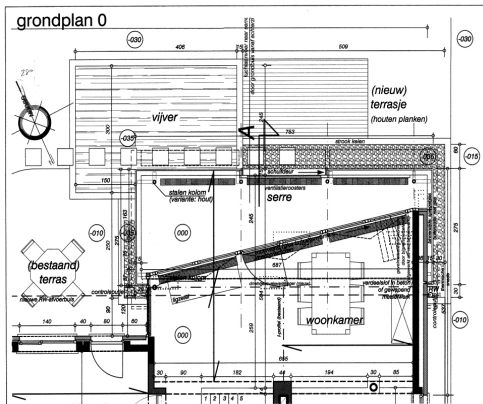


Figure 2: Groundplan of the renovated part.

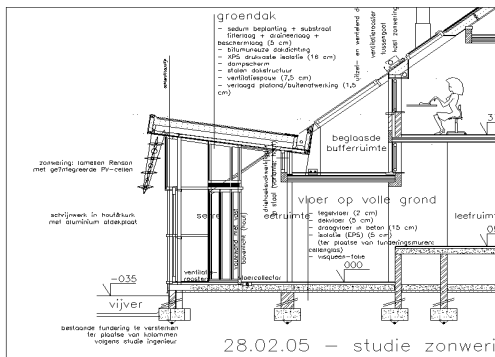


Figure 3: Section (design: ir.-arch. F. Dobbels).

The sunspace and the separating wall between sunspace and living room were pulled down. The ceiling of the living room and the new roof are supported by a steel truss of 7m by 0.8 m.

The steel framing for the roof is supported by four steel poles and the truss. Also the horizontal wooden beams of the window frame construction are supported by these poles. The roof is well insulated (27 cm,  $U=0.12 \text{ W/m}^2\text{K}$ ) with a green roof on top, giving additional insulation and heat buffering (cooling). At the inside, an acoustical ceiling compensates for the larger reflecting surface due to the glazing.

The new construction is a glazed box slid over the old part. The NW façade is an insulated sandwich panel with opaque glass at the outside and a wood covering at the inside. The SSW and ESE facades are in low-e argon filled triple glazing with Swisspacer warm-edge spacer by Sain-Gobain Glass,  $U=0.8 \text{ W/m}^2\text{K}$ .

The living room and the sunspace are separated by a folding/sliding wall in wooden frames with low-e glazing ( $U=1.1 \text{ W/m}^2\text{K}$ ). This construction allows for the living room being seamlessly expanded for larger occupation. Although the volume of the living space has been expanded, the installed heating power is reduced by 2kW.

## 2. SUN SHADING

### 2.1 The design

Since the south façade (SSW) is fully glazed, it is necessary to provide shading, without obstructing too much the view to the surroundings. Therefore the choice was made for the ICARUS shading system (Renson), a motorised solar shading made of inclinable lamellas (aerofoil blades of 360 mm wide). A priori, the upper part of the glazed façade was equipped with 3 such lamellas. The exact inclination was not yet known. Moreover the lamellas will be equipped with a strip of solar cells (12.5 cm wide), a new development of the companies Renson and Soltech. To fully assess the effects of shading in summer, solar penetration in winter, daylight and glare, and optimal solar exposure for the PV cells, and to adjust the design and the position of the sun shading device, simulations on a scale model were proposed.

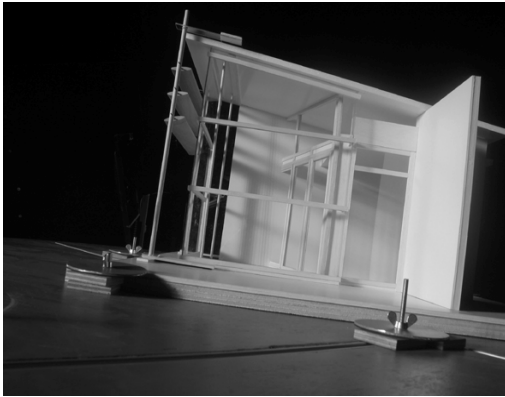


Figure 4: Scale model on the turn table, sun at 21 December 12 a.m., lamellas 30° inclined.



Figure 6: Inside view on 21 December, 12 a.m. lamellas at 45°.

## 2.2 The test facility

The simulation was set up under the solar simulator at the daylight laboratory of BBRI (Deneyer et al., 2002). The solar simulator is constructed as a fixed 'one-lamp' parallel beam light source with the relative movement of the sun being simulated by rotating the model table around two rotation axes (Fig. 5). It can be used for the analysis of shading and sun patch patterns for measurements of sunlight in the model and for the simulation of the dynamic sunlight penetration over a longer period.

## 2.3 The model

A scale model of the building was constructed (credits to arch. C. Heather Moore) with movable lamellas in an adjustable position. To keep the dimensions reasonably fitting to the test facility, only half of the new construction was modelled on a 1/5 scale. (including the SE-SW facades). See Figure 5.

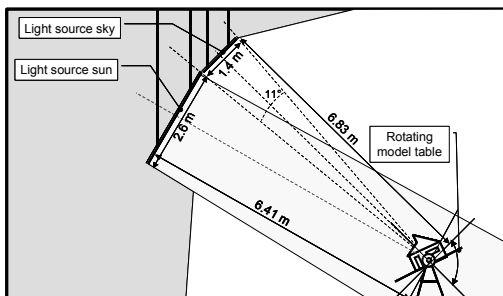


Figure 5: The one-lamp artificial sky and sun at the BBRI daylight laboratory.

## 2.4 Simulations

The sun's position was simulated for December 21 at 12 a.m., March 21 at 9 a.m., 10:30 a.m., 12 a.m., 3 p.m. and June 21 at 9 a.m., 10:30 a.m., 12 a.m. Pictures were taken from the outside and the inside of the model. Inside views as e.g. in Figure 6 show that the view to the outside is almost unobstructed by the lamellas from the rear side of the room and that their effect on the direct shading in winter is rather limited.

Figure 9 shows a solar beam penetrating on top of the lamellas. Another phenomenon is the shading from one lamella on the other, which may harm the output of the electricity production by the PV strips. Therefore the position of the support structure of the lamellas was altered such that there is no longer shading from the

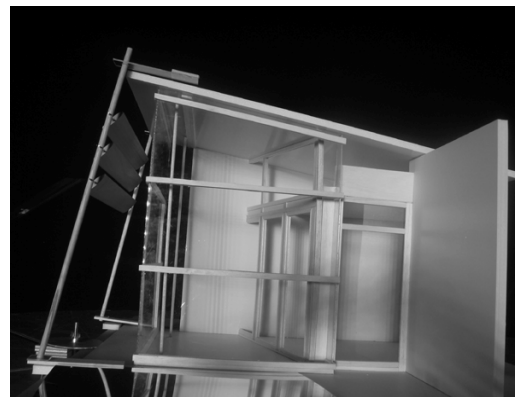


Figure 7: Exterior view, 21 March 10:30 a.m.: structure 90° to roof, lamellas 80° inclined.

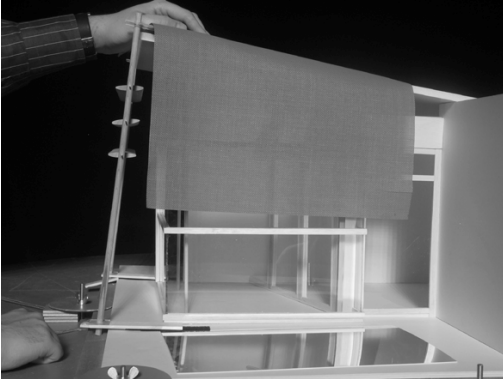


Figure 8: Exterior view, 21 March 9 a.m.: structure 90° to roof, lamellas at 0° with water surface and solar screen on ESE façade.

lamellas on the PV strips. This position has also an awning effect on the lower part of the façade, giving good solar protection in summer.

2.5 Conclusions from the simulations

In general terms, the simulations allowed to draw the following conclusions on the design:

- the position of the lamellas is correct,
- to avoid the solar spot indicated on Figure 9, a shading element should be added close to the ceiling,
- inclining the structure on which the lamellas are mounted up to a position perpendicular to the roof slope and starting on the roof edge provides an awning effect and full shading on the whole façade in most cases,
- it also improves the exposure of the PV solar cells to the sun,

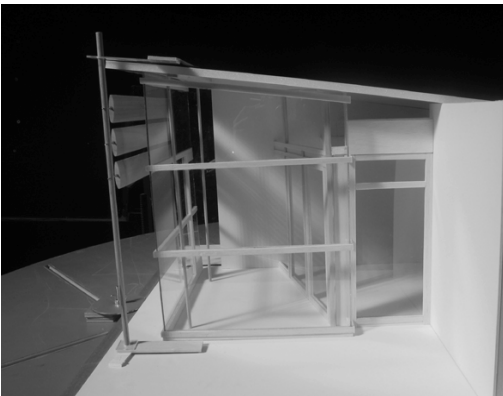


Figure 9: Outside view, March 21 at 12 a.m., structure parallel to facade, lamellas 90° inclined.

- the opening between the lamellas and the façade on the E and W edges may cause a sun spot in the morning and the evening,
- on the East façade a roller screen seems the most suitable shading device,
- the location of a water surface close to the house is in most case not a problem but may cause hindering reflections in some positions inside.

The final design was adapted accordingly. The system consists now of 4 lamellas of 360 mm on an axis perpendicular to the roof. To avoid the thermal bridge effect of the structure with lamellas (cooler fins), the support frames are mounted on the roof steel structure using insulating mounting blocks.

On the East façade roller screens are mounted.

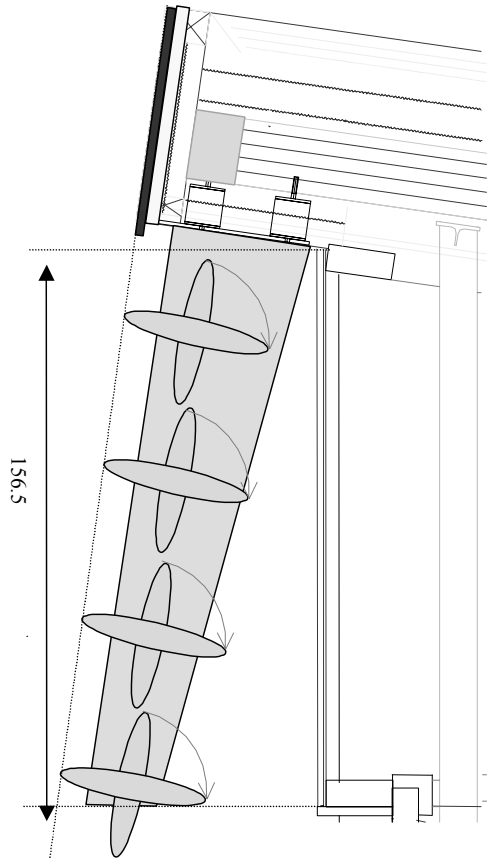


Figure 10: Final design of the shading device.



Figure 11: Louvre for night time ventilation at lower part of the West façade.

### 3. NIGHT COOLING

#### *The design*

To avoid overheating in summer, a night ventilation system has been designed. It allows both the sunspace and the living room to be cooled by night with outside air.

Air supply is provided via a large louver on the West façade, as shown in Figure 11. At the inside this louver is shut off by a window with insulating panel in the sunspace. For the living room, the louver is connected to the cavity between the old brick wall and the new opaque façade covering. On top of the wall, the cavity is closed by a motorised sliding ventilator.



Figure 12: View from inside on the neighbourhood.



Figure 13: Status of the renovation works in April 2005, still without shading.

The air in the sunspace is collected via the perforated ceiling panels into a roof cavity leading to the glazed buffer space on the 1<sup>st</sup> floor. The connection between the cavity and the buffer space is controlled by a motorised sliding ventilator. The air in the living room is evacuated to the same buffer space via a motorised internal window.

From the buffer space the air is evacuated to the outside via a hybrid ventilation system. On top of the exhaust chimney a 14 W low pressure fan of 315 m<sup>3</sup>/h can assist the evacuation of the air in case the thermal draught should not be sufficient.

Moreover the glazed roof of the buffer space can be opened for additional exhaust ventilation.

### 4. CONCLUSIONS

An integrated approach has led to an innovative energy conscious design which takes account for summer comfort by an innovative shading device and natural (hybrid) night time ventilation. The use of the solar simulator has proven, to be a very helpful design support tool. Results of occupation, user satisfaction, improvement of the total energy performance and indoor climate monitoring are not yet available but will be reported in due time.

### ACKNOWLEDGEMENT

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