Energy performance of a retrofitted pilot building made with industrialized technology

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ABSTRACT: Buildings made with prefabricated technology face significant problems in the building stock of Eastern-Europe. In Hungary 20 % of the dwellings belong to this category. The buildings represent a low quality standard regarding energy consumption, operating cost, thermal comfort and fabric protection. The international Solanova project aims at the realization of the renovation of a demonstration building with passive house measures. The construction of the pilot building was finished in October 2005 in Dunaújváros, Hungary. A survey about the project idea was presented in the PLEA 2005 conference in Beirut. Present paper summarizes the steps of the building construction from beginning to the technical handover and the experienced performance of the renovated building during the first heating season.

Keywords: low-energy architecture, retrofit, buildings made with industrialized technology, prefabricated building panels, monitoring

INTRODUCTION

The construction of buildings with industrialized technology dominated the housing sector from the middle of fifties till the end of eighties all over Europe, but especially in Eastern Europe and the Sowiet Union. Only in Hungary there are 780 thousand of these kind of flats (20% of the building stock), which is lower than the average of the post communist countries. In the former Eastern Germany there are appr. 2,2 million such flats.


Figure 1: The Solanova building before renovation

The category of buildings made with industrialized technology contain the so called “panel buildings”, but also those living-houses, which were built by other type of industrialized technology (e.g. block-, cast-, tunnel-shuttered-, ferro-concrete skeleton-houses). For simplifications in the paper the name “panel buildings” will be used for all these categories.

Panel-rehabilitation is currently a most actual question of the region, because the expected lifetime of the holding structures are still above 50-100 years, whereas the windows, building finishes and building service systems have reached the end of their physical lifetime. [1]


Figure 2 The Solanova building after renovation

Furthermore the panel buildings are criticised for their high heating energy consumption, uncontrollable heating systems, very poor thermal comfort especially in summer, low acoustic value, untight building envelope and building physical problems. All these result in the most pressing problem: the declining welfare of the inhabitants.

The Solanova project aims at the demonstration of the energy conscious renovation of an existing panel building (in the followings the building will be called as “Solanova building”, see Fig. 1 and Fig 2) using passive house measures and solar energy support. In the German-Austrian-Hungarian project the special characteristics of the panel buildings are examined and the already worked out passive house measures are applied. The original state and the impact of the renovation are examined by a scientific supervision and a computer aided monitoring.

The renovation process ended in October 2005, but the scientific research and the demonstration are running until December 2006.

2. SOLANOVA – PROJECT AIMS AND RESULTS

2.1 Heating energy consumption

The heating energy consumption of the original building was 210 kWh/m^2/year in the heating season 2004-2005. It is a measured value corrected for a mean winter season. The contractual Solanova aim is to decrease this value under 45 kWh/m^2/year. Considering the planned measures a value between 20 and 30 kWh/m^2/year were expected.

During the first heating season after renovation the measured heating energy consumption was 25,3 kWh/m^2/year, but the heating period is still not over, therefore it has to be corrected for the mean winter season. The corrected value is 31,1 kWh/m^2/year that is far beyond the contractual aim. The saving is 85 %.

2.2 Summer thermal comfort

The climate in Hungary is continental, the winter is cold, the design temperature for heating systems is from –15 to -11 °C depending on the region. On the other hand, the summer is hot and dry, the temperature can exceed 35 °C and the yearly solar radiation is 4,42 GJ/m^{2}year.

A social research made among the dwellers in the Solanova building before renovation proved that the biggest problem after the high operation costs was the poor summer comfort. Fig. 3 shows measured results in a hot summer week. The room temperatures often exceeded the outdoor air temperature, 30-33 °C is a usual value. At night the temperature were mostly above 27 °C.

The flats with the most unfavourable position are located on the top floor on the southern side. These flats do not have a possibility for cross ventilation, because all windows look to the South. The surface of the flat roof is dark and there is no ventilated air gap, therefore it behaves as “roof heating”.

Thus, the improvement of the summer comfort was essential in the Solanova renovation concept. After 2006 summer measured results and the opinion of users will be known.

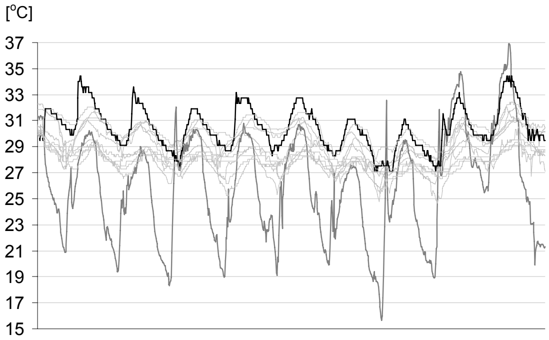

Figure 3: Measured air temperatures in 11 rooms of the Solanova building with different locations before renovation. The grey line with highest amplitude is the external temperature, the black line is the hottest room on the top floor, southern side

2.3 Winter thermal comfort

Due to the uncontrollable heating system of the original building the difference in the mean indoor air temperatures in the flats with different locations was very high before renovation.

In the rooms located at the end facades having two or three exposed surfaces the air was 5-6 °C colder than other rooms with more protected position (see Fig. 4).

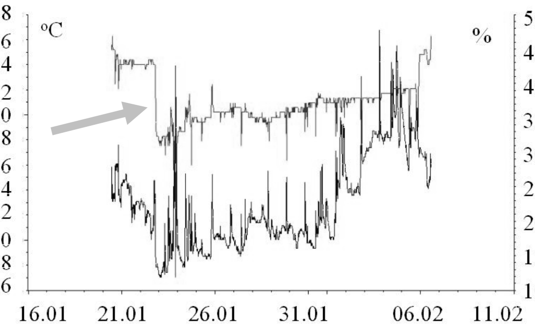

Figure 4: Above curve: measured indoor air temperature before renovation in two rooms with different locations in winter. The sensor was moved to the other room at the moment marked by the arrow. Below curve: registered relative humidity in the same rooms.

Heat cost allocators were not installed in the renovated building, because the significant internal heat flows would have significantly disturbed the measured values. Unfortunately the monitoring results from the first heating season proved that it was a mistake, because most of the dwellers are keeping very high temperatures (23-28 °C) causing much energy waste. They are not motivated for energy saving and prefer having high thermal comfort. For the next heating season the installation of heat cost allocators is planned.

2.4 DHW and solar energy use

If the heating energy consumption is reduced with 80-85 % the heat demand of the domestic hot water would have a significant share. It would be approximately double of the heat demand. Therefore measures were made to reduce the DHW consumption and to support the DHW production with renewables.

The location of the building is ideal for using solar energy, because one main façade faces to the South and there are no shading obstructions in front of the façade, only a one-storey nursery school.

2.5 Eco-efficiency, social research

The project can be successful only if the measures are replicable, therefore low cost solutions were developed during the optimisation process. Ecologic aspects were also in focus, all measures were analysed for a whole life cycle.

Finally, a social research follows the demand of the dwellers and the acceptance of the low-energy concept.

3. THE OPTIMISED CONCEPT

2.1 Measures reducing the transmission losses

In order to achieve the targets the building envelope had to be insulated and new energy efficient windows were installed. A special feature of the panel buildings is the sandwich structure: the original prefabricated panels consisted of two reinforced concrete layer and 5-8 cm thermal insulation in between. Therefore the major heat loss related to the joints, in fact the thermal bridge losses were generally higher than the losses calculated from the U-value.

Figure 5: The facades were covered with 16 cm polystyrene thermal insulation

It means that the external insulation of the facade has much more impact on the thermal bridge losses than on the U-value. Therefore less thermal insulation was enough than in other low energy buildings. In the Solanova building 16 cm PS thermal insulation were applied on the facades, more wouldn't have had much sense (Fig. 5).

The flat roof was covered with 21-34 cm thermal insulation and the cellar ceiling 10 cm (Fig 8).

For architectural reasons and to create a recreation area for the dwellers a green terrace roof was constructed aiming an additional positive effect on summer comfort in the top floor dwellings (Fig. 6 and 7).

The old, extremely bad revolving windows were installed to new good quality, but not passive house windows.

Figure 6: Planting on the green roof

Figure 7: View from the neighbouring building

Figure 8: Insulation of cellar ceiling with 10 cm PS

Calculations proved that on the southern side the energy balance for the whole heating season is approximately the same for double and for triple glazing, because although the heat losses are higher for double glazing the solar gains are higher, too. For the northern side the triple glazing is definitely better.

Nevertheless, for cost restrictions on the northern side double glazing windows will be installed with a U_w-value of 1,4 W/m^{2}K. Contrarily on the southern side for summer protection reasons triple glazed windows with integrated shading devices are to be applied with a U_w-value of 1,0 W/m^{2}K, due to the higher priority of summer comfort.

Thermal bridge free installation of windows is essential (Fig. 9).

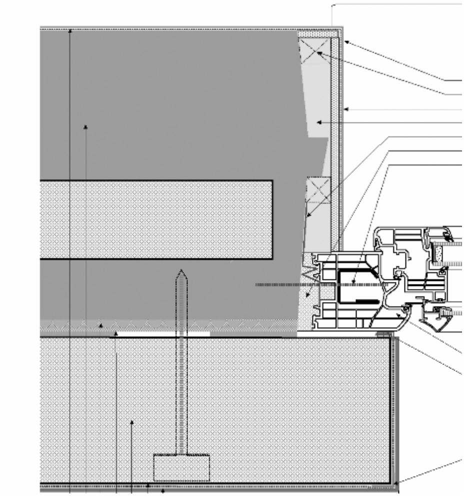

Figure 9: Thermal bridge free installation of the triple glazed windows on the southern and western side. [4]

2.4 Air tightness

If the building envelope is well insulated further savings can be achieved by decreasing the ventilation losses. In the Solanova building a balanced ventilation system with heat recovery will be installed. It can work at the design efficiency level only if the building is extremely air tight. In passive houses the n_{50} value must be lower than 0,6 h^{-1}.

Contrarily, in the Solanova building the air tightness was very poor. The blower door tests measured n_{50} = 7,1..12,0 h^{-1}. In the near future the blower door test results of the renovated buildings will be available.

2.3 Windows and summer protection

As it was proven by the social research and the opinion of the dwellers, a good summer indoor climate is perhaps more essential than the energy saving. Although the yearly cooling load is usually moderate compared to the heating load, air conditioning units use electric energy which has a triple primary energy coefficient than gas or heating oil.

Dynamic simulation models [3] (Pleiades+Comfie and Dynbill) have proved that the application of efficient shading devices and natural night ventilation is enough to keep the daily peak indoor air temperature below 24 °C; which is a moderate level (Fig. 10).

Analysing different shading possibilities, internal shading was excluded, due to the poor efficiency or high price. External shading didn't seem to be optimal either, because the thermal bridge free installation would have increased the price and there is a strong wind in the area.

The final solution was a movable shading device with lamellas integrated between the two external glass layer of the window. It is almost as efficient as the external type and there are no problems of wind and installation.

After summer 2006 there will be data about the real summer performance of the building.

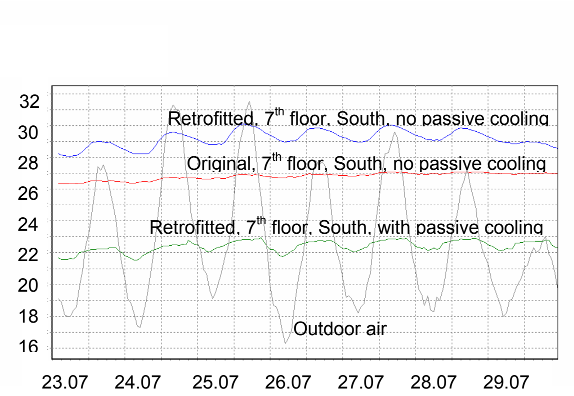

Figure 10: Indoor air temperature during a hot summer week showing the effect of passive cooling (efficient shading and night ventilation).

2.4 Heating and ventilation system

As mentioned, the ventilation losses will be decreased by a flatwise balanced ventilation system with heat recovery. The remaining heat demand will be covered by a new traditional radiator system. The new concept is a double pipe system with minimised total pipe length, small radiators and roomwise control.

Figure 11: Installed ventilation heat recovery units under the ceiling of the hall. Now they are covered with gypsum board suspended ceiling.

The optimisation process highlighted that the main problem of designing a heating system in a low-energy building is the avoidance of overheating.

2.5 Solar collectors and water saving devices

Without any measures the heat demand of the DHW would be dominating after the retrofit. Therefore water saving equipments were installed and 72 m^2 solar collectors support the DHW production. The collector field serves double function: in addition to the DHW production they perform as a canopy for the southern ground floor shops providing shadow and rain protection (Fig. 12) [5].

Figure 12

4. CONCLUSION

The two major problems of panel buildings are the high operation costs and the poor summer thermal comfort. Therefore when designing a renovation with passive house measures, special attention must be taken to the summer protection and to the avoidance of overheating.

The Solanova building design is based on these two principles and for replicability reasons optimised, cost efficient, ecological solutions have been developed.

The results of the long-term monitoring will soon be available, but according to the preliminary results the heating energy saving is approximately 85%.

ACKNOWLEDGEMENT

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