Energy Rating Concept and Retrofit of Building Envelopes

JITKA MOHELNÍKOVÁ, ONDŘEJ MIŠÁK
Institute of Building Structures
Brno University of Technology
Veveří 95, 662 37 Brno
CZECH REPUBLIC

Abstract: - The paper deals with energy renovation of residential buildings in climatic conditions of the central Europe region. The energy balance assessment of selected buildings before and after renovation was carried out. The renovation of building envelopes could bring significant energy savings not only from the point of view of low energy consumption and reduction of heating cost but it also represents positive environmental impacts.

Key Words: - Sustainable buildings, Energy efficient buildings, Low-energy buildings, Energy renovation, Thermal protection of buildings, Thermal insulation, Heat losses, Energy savings.

1 Introduction

Energy saving demands brought standard requirements and legal regulations for the reduction of heat consumption in buildings. The goal of this paper focuses on the renovation of selected types of residential building envelopes from energy saving point of view.

Many renovations in spite are not efficient because of lack of energy rating concept. This concept should consist of many improvements for energy savings.

The main tasks include the regulation of heating system in buildings and monitoring of heat consumption in individual flats and service rooms. Window retrofit is also necessary because of inconvenient properties of existing glazings and window frames. After the window renovation the design and completion of additional thermal insulation system for building envelopes (peripheral walls and roofs) are required.

In addition to these main renovation steps further improvements are recommended as the glazing of loggias and balconies. Glazed external parts of building loggias create buffer zones which reduce heat losses and extend the living area of individual flats.

The retrofit of buildings completed in accordance with above mentioned steps could significantly reduce heat losses and diminish heat consumption in buildings. The energy renovation could also bring improvement in indoor thermal comfort not only in winters but also during summer seasons (limitation of overheating of interiors).

2 Building envelopes for renovation

The residential building with eight over-ground floors and one basement was investigated. The structural height of individual floors equals 2.85 m, the building floor area is 353.16 m^2, the total building volume is 9058.6 m^3.

The building peripheral walls were constructed from prefabricated reinforced concrete panels. The building envelope does not satisfy present thermal insulation requirements. For this reason the additional thermal insulation from foam polystyrene was completed (thickness of 150 mm). Windows with U-value = 2.7 $Wm^{-2}K^{-1}$ (wooden frame, two separated glazed panes) were replaced by new ones with U=1.4 $Wm^{-2}K^{-1}$ (plastic frame, double glazed unit with low emissivity glazing, argon filling).

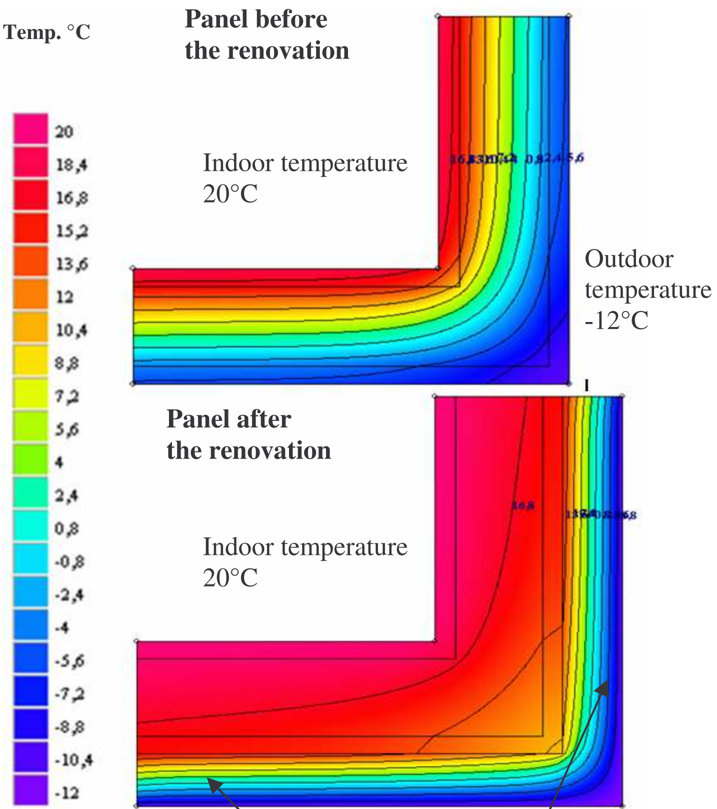

Fig.1 Temperature profile of characteristic details
The corner of the building peripheral wall before and after the renovation (simulated in Therm, LBNL)

The temperature profile of cross section of the corner of the peripheral wall without and with the thermal insulation layer is shown in Figure 1. Thermal resistance of the panel (reinforced concrete panel with lightweight concrete core) equals value of R=0.42 m^2KW^{-1}, U=1.7 $Wm^{-2}K^{-1}$(determined for surface resistances: internal R_i=0.13$Wm^{-2}K^{-1}$, external R_e=0.04$Wm^{-2}K^{-1}$) [6].

The computer simulations have proven that temperature in the corner is less than 10.7°C. This temperature is lower than the dew point temperature that is characteristic for indoor climate conditions (design indoor temperature 20°C, design indoor relative humidity 50%).

The temperature in the corner between two panels with additional thermal insulation is about 15°C. That means that the thermal insulation improvement of the building envelope could eliminate condensation problems.

2.1 Heat losses

The assessment of heat loss reduction for the renovation of the panel-block building envelope was carried out for design values of boundary conditions as: indoor temperature 21°C (residential area) and 15°C (ground floor), indoor relative humidity 50%, outdoor temperature -12°C, outdoor relative humidity 84%.

Heat transmission losses from the above mentioned constructions were determined for the studied building (in the initial and renovated state) and compared with requirements for the thermal protection of buildings in accordance with standard regulations [2].

Table 1 Determination of heat transmission losses for the initial and renovated building

Construction	Initial building		Renovated building	
	U-value	Heat loss	U-value	Heat loss
	$W\,m^{-2}K^{-1}$	kW	$W\,m^{-2}K^{-1}$	kW
Walls I	1.7	72.54	0.25	10.67
Windows I	2.7	36.27	1.4	18.81
Walls II	1.7	9.12	0.25	1.34
Windows II	2.7	1.01	1.4	0.52
Floor	1.7	6.0	1.7	6.0
Roof	1.8	19.81	0.25	2.91
TOTAL heat loss [kW]	**144.76**		**40.26**	

Note: Walls II, Windows II are in basement.

The reduction of heat transmission losses after the building envelope renovation (additional thermal insulation for walls and roof and new windows) is more than 100 kW.

Façades of investigated buildings in the initial and renovated state were monitored by the thermo-camera. Thermo-photographs show the façade temperature profiles (see figure 2). Better thermal properties of new windows and the façade with the additional thermal insulation significantly reduce heat losses. It is obvious in figure 2 that the insulated façade has lower external surface temperature compare to the envelope of the initial building. It practically means lowering of heat losses during winter heating season.

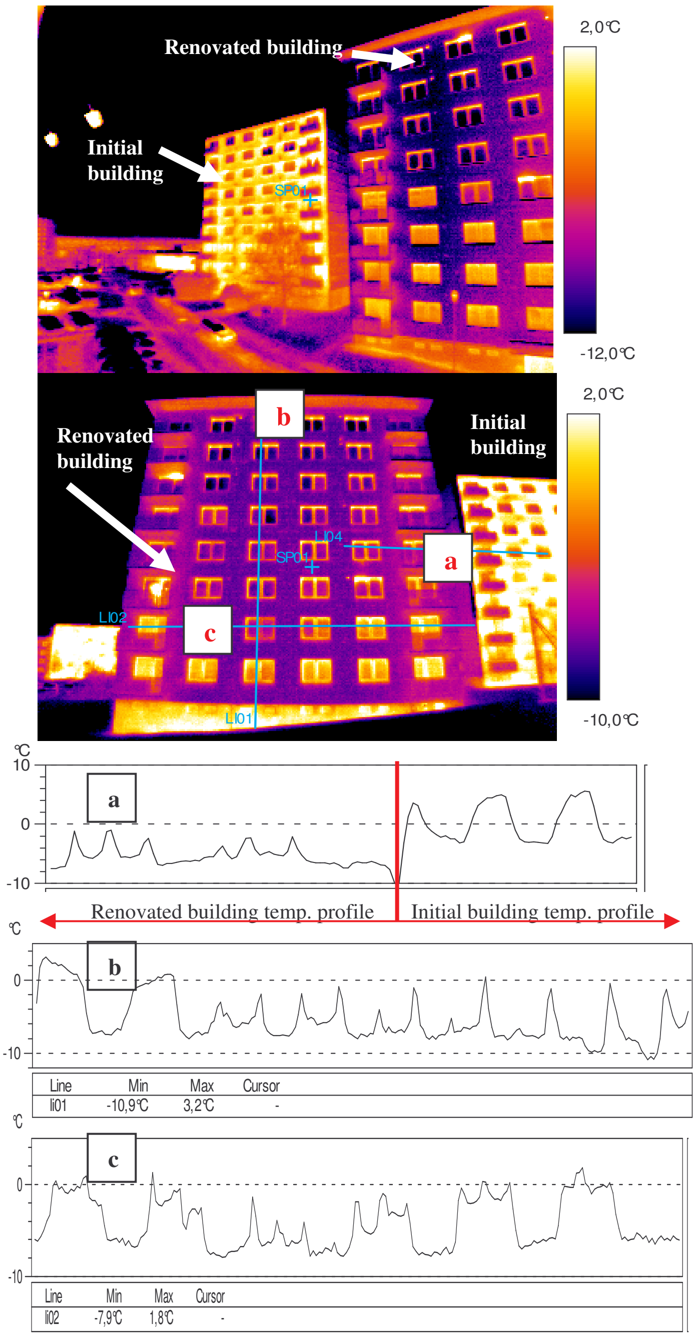

Fig. 2 Thermocamera photograph (thermocamera Thermacam): **a**) temperature profile at the boundary between initial and renovated building, **b**) vertical temperature profile, **c**) horizontal temperature profile

3 Energy savings after the renovation

The energy evaluation of the renovated building and the energy balance of the building before the renovation were calculated [3] for given climatic conditions [4].

Average monthly values of global solar radiation energy in kWhm^{-2} for north N, south S, east E, west W and NE/NW, SE/SW orientation were selected from standard data [4] for the energy balance calculations.

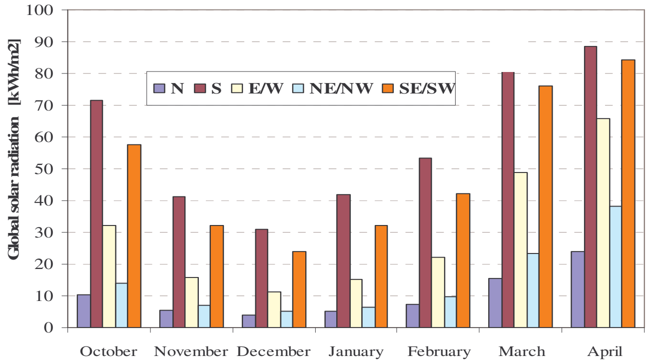

Fig. 3 Global solar radiation energy
Energy of solar radiation per heating season [kWhm^{-2}]
N 77.02, **S** 416.99, **E/W** 211.23, **NE/NW** 103.65, **SE/SW** 348,32

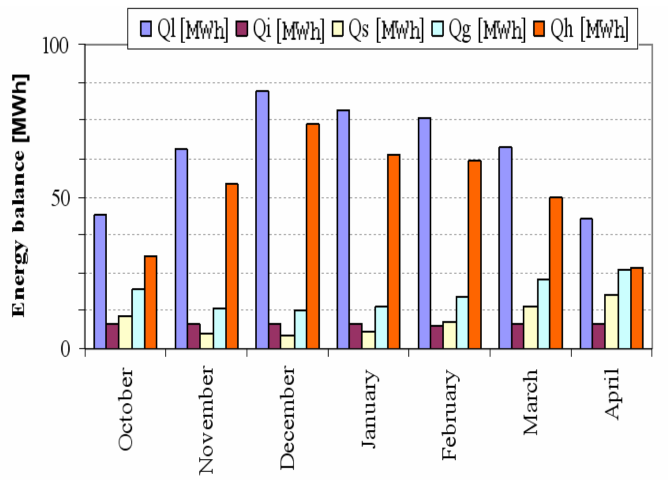

Fig. 4 Energy balance of the initial building
Ql…total heat conductive and ventilation losses, Qi…internal heat gains in the building, Qs…solar gain, Qg…total heat gain (Qg = Qi + Qs), Qh…heat consumption for heating (Qh = Ql – Qg).

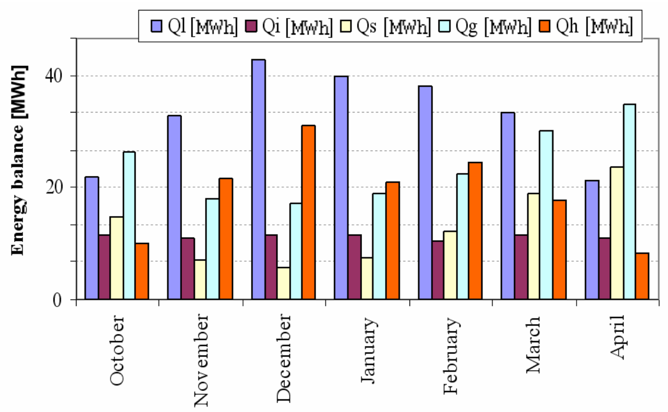

Fig. 5 Energy balance of the renovated building
Ql…total heat conductive and ventilation losses, Qi…internal heat gains in the building, Qs…solar gain, Qg…total heat gain (Qg = Qi + Qs), Qh…heat consumption for heating (Qh = Ql – Qg).

The energy balance was done for the reference heating season (from October to April). The results of this evaluation are shown in Fig. 5, Fig. 6. The figures compare total heat losses and gains of the investigated building in the initial (Figure 5) and renovated state (Figure 6).

The renovated building represents a significant reduction of heat consumption. The total energy savings resulting from the renovation and also annual specific heat consumption relating to the building volume are presented in the following table.

Table 2 Total heat consumptions and energy savings in the renovated building

Heat consumption per heating season				**Energy savings**
Total heat consumption	I	1533.7 GJ	426.024 MWh	**304.3** MWh
	R	438.24 GJ	121.734 MWh	
Specific heat consumption	I	47.03 kWhm^{-3}		**33.58** kWhm^{-3}
	R	13.44 kWh/m^{-3}		

Note: I-initial building, R-renovated building

Energy savings could bring also reduction of carbon dioxide emissions. The following table shows result of the study aimed at the determination of CO_2 emission reduction due to energy savings for gas heating.

Table 3 Carbon dioxide reduction [6], [7]

Building	**Heating demand**	**CO_2 emissions**
	MWh	t
Initial state	426.02	106.51
Renovation	121.73	30.44
CO_2 emission reduction		**76 t**

The housing estate with 20 renovated panel-block buildings during 5 year-long utilisation could bring important energy savings and reduction of emissions as: energy savings for heating demands 30.43 GWh and reduction of CO_2 emissions from gas heating 7 600 t.

4 Building simulation

The simulation of the annual energy balance of heat losses and gains in the investigated building was carried out in the computer program BSim [1]. The simulations were completed in three different variations:
- the building in the initial state,
- the renovated building – the case study I,
- the renovated building – the case study II.

The results of the simulated variations of the investigated building facade and its renovation in the two case studies are presented in figure 2.

The simulation of the renovated building in the two case studies was completed for the compositions of building constructions and their overall heat loss coefficients U-values which are summarisede in table 4.

Table 4 Overall heat loss coefficients of building constructions in the renovated state

Construction	Case study I U-value [W m^{-2} K^{-1}]	Case study II U-value [W m^{-2} K^{-1}]
Walls I	0.38	0.25
Windows I	1.8	1.2
Walls II	0.38	0.25
Windows II	1.8	1.2
Floor	1.40	1.37
Roof	0.3	0.2

The better thermal insulation parameters were achieved with an additional thermal insulation of roof, walls and floor (foam polystyrene was used for facades, mineral fibre insulation for the roof). The low-emissivity glazing and new frames were used for the window retrofit.

The presented results of the BSim simulations were taken as input data for the following evaluation. The new software module was completed for the optimisation of individual design variations. The program module calculation results compare the annual energy balance of all designed case studies.

The estimation of price of the building renovation in individual case studies and economical evaluation with respect of investment price – energy savings – heating cost saving - pay back period are very important for the design process. The mentioned program module was developed for the evaluation of energy savings and the optimisation of energy saving building retrofit. The program compares investment price and savings of design case studies.

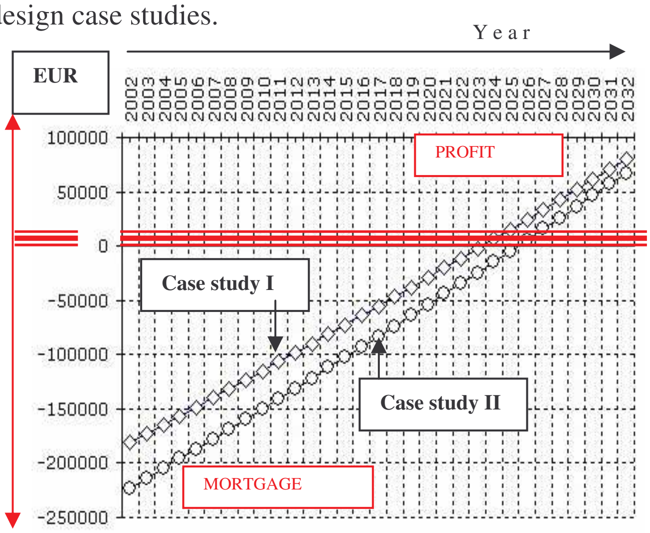

Fig. 6 Mortgages and profits of the building investigated in the case studies

The example of graphical results of the program module for energy balance simulations is presented in figure 7.

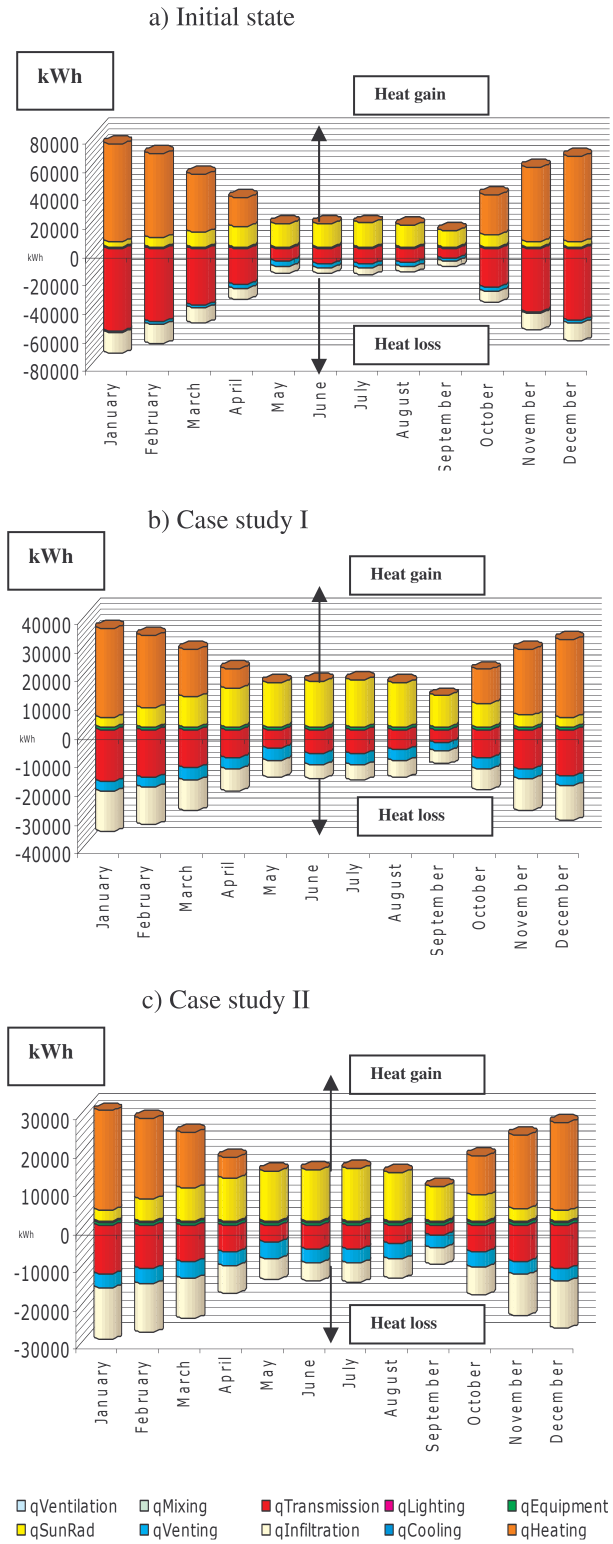

Fig. 7 Building energy balance simulations
a) Building simulation in the initial state
b) Building simulation in the case study I
c) Building simulation in the case study II

5 Conclusion

The results of the energy assessment of the investigated buildings have shown that the energy renovation of building envelopes could bring not only low energy consumption and reduction of heating cost but also positive environmental impacts.

The design optimisation has to be based on energy rating concept. The recommended energy rating process in the case of building renovations is following:

- renovation and regulation of building heating and ventilation services,
- installation of energy efficient lighting and building services,
- window retrofit, facade and roof thermal insulation facing designed and completed with respect of reduction of heat losses, elimination of thermal bridges and exclusion of condensation problems.
- recommended energy saving improvement is also installation of solar thermal and photovoltaic collectors or heat pump systems.

References:

[1] J. Duffie, W.A. Beckmann, *Solar Engineering of Thermal Processes*, John Wiley & Sons, New York, 1991.

[2] F.P. Incropera, D.P. Witt, *Fundamentals of Heat and Mass Transfer*. John Willey & Sons, New York 1996.

[4] E.T. Johnson, *Low-E Glazing Design Guide*. Butterworth Architecture, Boston 1991.

[3] EN 832:1998/AC:2000 *Thermal performance of buildings - Calculation of energy use for heating*

[4] CSN 73 0542:1995 *Method of estimation of energy balance of glazed area in external building constructions*

[5] Regulation 213/2001 of *Ministry of industry of the CR*

[6] *Energy audit of panel-block buildings* (Obla14, Brno), Brno University of Technology, 2003

[7]*http://www.hnutiduha.cz/aktivity/energetika/emise_form.html, http://www.tzb-info.cz*