IMPROVEMENT OF HEAT BALANCE OF FAMILY HOUSE

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Abstract. The paper describes the problems of improvement of heat balance in family houses. The majority of local buildings used for housing of inhabitants in villages and small towns are family houses constructed during the previous periods without the respect to energy consumption for heating and air-conditioning. High prices of energy and protection of environment are the main reasons for improvement of heat balance during the recent years. On the other hand, many solutions of heat balance improvement constitute big investment, not available for many owners of buildings. Problems of humidity of construction materials must be in many cases respected in old buildings. A special construction method with a ventilated gap was applied on a normal family house, modernized with the aim to decrease energy consumption by external insulation improvement without high investment costs. This paper describes the results of calculation and also of measurement provided in that building to confirm the final results of modernization during the winter and summer periods.

Keywords: heat balance, family house, insulation, modernization.

Introduction

New modern buildings are currently usually constructed as low-energy buildings, or passive, or alternatively zero energy buildings. In some countries this terminology relates to specific building standards. The Czech definitions [1] are based on the principles, that low-energy buildings are those that need very low consumption of energy for heating, which should be lower than 50 $kWh \cdot m^{-2} \cdot a^{-1}$, passive houses with specific consumption of energy used for heating lower than 15 $kWh \cdot m^{-2} \cdot a^{-1}$ and zero (nearly zero) houses with specific consumption of energy lower than 5 $kWh \cdot m^{-2} \cdot a^{-1}$.

There are several, transformed from the international (European) standards, which are used for ventilation, heating and air-conditioning design, used in the Czech Republic, e.g., [2 – 4]. The most important regulation used in the Czech Republic is [5], as a source of information for evaluation of buildings from the point of view of energy consumption. It is based on legislation of the EU [6; 7].

There is a different approach in the designing method. According to the heat losses and gains a suitable heating system of the building is proposed and designed, where the capacity, efficiency and control of the whole system is the main priority. The main parameter of ventilation is the quality of indoor air. Hygienic conditions [8] must be respected during the whole year.

The research was applied in the modernization of a normal family house. The improvement of thermal insulation by external construction without high investment costs and the heat pumps and biomass burning for heating are used.

Materials and methods

The calculation of winter heat balance was based on the main equations of the sensible heat balance for steady-state stationary conditions. The total heat losses Q_c are:

$$Q_c = Q_p + Q_v - Q_z \tag{1}$$

where Q_c – total heat losses, W;
Q_p – heat losses by transfer through the surrounding constructions, W;
Q_v – heat losses by ventilation, W;
Q_z – heat gains of the building in winter, W.

The summer heat balance was calculated for a sunny day on July 21, in the afternoon time, when the highest heat gain is expected. The heat balance of each room in the building was calculated individually. Total heat gains of sensible were calculated as a summary. The general equation is expressed by the formula:

$$Q_t = Q_l + Q_{sv} + Q_e + Q_f + Q_{ok} + Q_{ov} + Q_s + Q_{ve} \tag{2}$$

where Q_t – total sensible heat gains in summer, W;
Q_l – heat produced inside by the people, W;
Q_{sv} – heat from the lights (illumination), W;

Q_e – heat produced by machines and equipment, W;
Q_f – heat gains from fans, W;
Q_{ok} – heat gains from the windows by convection, W;
Q_{ov} – heat gains from the windows by radiation, W;
Q_s – heat gains from the walls, W;
Q_{ve} – heat gains by ventilation, W.

The modernized three floor family house has external dimensions 10.70 m x 8.05 m. The 1st floor (ground-floor) includes the entrance, hall, cellar, boiler room, store and garage. The 2nd floor (Fig. 1) includes two rooms, bathroom with toilet, kitchen and hall. The 3rd floor has the same arrangement as the second one. Improvement of the thermal insulation by external construction without high investment costs and the heat pumps and biomass burning for heating is used. There are installed five heat pumps (Split air-air) on the flat roof.

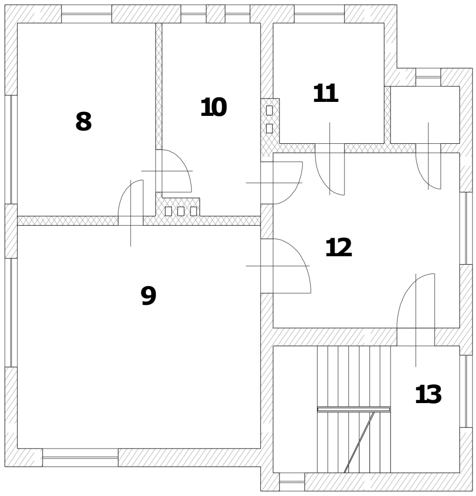

Fig. 1. **Ground plan of the 2nd floor:** 8 – bedroom; 9 – living room; 10 – bathroom; 11 – kitchen; 12 – hall; 13 – stairs

The heating system is hot water central heating with a boiler for combustion of biomass with power 25 kW, which is used also for hot water. The gas boiler 18 kW is used as a reserve source of power. The other source of energy are five heat pumps air-air with cooling power 3.52 kW and heating power 3.99 kW, which are used only occasionally. Ventilation is natural, by the windows. The walls (thick 300 mm) are constructed on the 1st floor from brick-concrete blocks, from hollow cinder blocks on the 2nd floor and from the calcium-silicate bricks on the 3rd floor.

The surface of the whole building was thermally insulated by the mineral insulation Rockwool 80 mm thick and special Belgian bricks 80 mm thick (Fig. 2). The ventilated gap 40 mm was created between the thermal insulation and the new surface wall from Belgian bricks.

Fig. 2. **Insulation of surface walls:** 1 – mineral Rockwool; 2 – Belgian bricks

The measurement was important for verification of the theoretical calculations. The instruments and measurement techniques were used for this purpose: Ahlborn measuring instrument ALMEMO 2590-9, temperature sensors with NiCr-Ni thermocouples, Pt100 and NTC, thermowires and compensation lines, capacitive humidity sensors FHA646-E1, thermovision camera IR FLEXCAM

Pro, data loggers ZTH65 for temperature and humidity registration, sensors FQ90 for measuring of thermal transmittance and heat flow for building physics and standard programs for PC and instruments Flex View1.2.2, MathCad, and Excel.

Results and discussion

The winter heat balance and heat losses were calculated both for original former construction and also for the new, improved one. Table 1 presents the results. The heat losses were reduced from 17.37 kW to 9.73 kW. The summer heat balance was strongly influenced by the position of the house to the South and large part of the walls with windows, which caused intensive solar radiation during the summer days, so the reduction of the heat gains was smaller than we expected. The heat gains decreased from originally 12.41 W to 11.5 W. The results are presented in Table 2.

Table 1

Winter heat losses, kW

Part of building	Original construction	With new insulation
1st Floor	3.34	1.32
2nd Floor	7.65	4.34
3rd Floor	6.38	4.07
Total	17.37	9.73

Table 2

Summer heat gains, kW

Part of building	Original construction	With new insulation
1st Floor	3.78	3.56
2nd Floor	4.39	4.15
3rd Floor	4.24	3.79
Total	12.41	11.50

Control of indoor microclimatic conditions by measurement was provided during the winter and summer period. The temperature and humidity were measured and registered by dataloggers in selected rooms of each floor in 15 minutes intervals during several days. The results are presented in Table 3 and Table 4.

Table 3

Temperature and relative humidity in winter

Part of building	Average temperature, °C	Standard deviation, °C	Average relative humidity, %	Standard deviation, %
1st Floor stairs	16.66	0.59	48.58	5.18
2nd Floor living room	21.18	0.87	52.67	5.10
2nd Floor hall	22.40	0.70	54.37	2.26
3rd Floor bedroom	21.87	0.67	49.92	4.02
3rd Floor living room	22.69	1.06	46.96	2.97
Average	20.96	0.78	50.50	3.91

The overall heat transfer coefficient was calculated and measured for several important selected parts of the building. The results of the calculation and measurement are compared in Table 5. Using the degree-days method, the theoretical consumption of energy for heating was calculated. The results of the supposed consumption of energy during several seasons are summarized in Table 6. The seasons are different from the point of view of duration and also the different coldest days of the season.

Table 4

Temperature and relative humidity in summer

Part of building	Average temperature, °C	Standard deviation, °C	Average relative humidity, %	Standard deviation, %
1st Floor stairs	21.18	0.63	60.54	4.65
2nd Floor living room	22.24	1.19	56.23	5.90
2nd Floor hall	23.05	1.17	53.97	5.42
3rd Floor bedroom	23.84	1.14	49.94	6.33
3rd Floor living room	23.99	1.36	50.21	6.34
Average	22.86	1.10	54.18	5.73

Table 5

Overall heat transfer coefficient

Part of building	Overall heat transfer coefficient, $W \cdot m^{-2} \cdot K^{-1}$	
	Calculated value	Measured value
Wall originally	1.27	1.39
Wall insulated	0.32	0.36
Windows	1.80	1.60

Table 6

Consumption of energy for heating

Season	Number of heating days, days	Average temperature, °C	Original building, MWh per year	After insulation, MWh per year
2006/2007	201	7.3	22.14	12.4
2007/2008	238	7.2	29.4	16.5
2008/2009	137	1.1	25.03	14.0

The theoretical seasonal financial costs of energy for heating are presented in Table 7. The financial costs are calculated in the comparable prices of the energy, to avoid the problems of changes of the price. Currently, the influence of the increased prise could cause bigger difference between the financial costs for heating in the original building and the house with improved insulation.

Table 7

Theoretical financial costs for heating, CZK per year

Season	Source of energy	Original building	After insulation
2006/2007	Wood	6 422	3 594
	Gas	36 457	21 614
	Heat Pump	20 303	11 874
2007/2008	Wood	8 541	4 786
	Gas	47 579	27 873
	Heat Pump	26 618	15 428
2008/2009	Wood	7 252	4 061
	Gas	40 813	24 067
	Heat Pump	22 776	13 267

Conclusions

The modernization of the surface thermal insulation resulted in improvement of the winter heat balance with reduction of the heat losses from 17.37 kW to 9.73 kW, which is approximately only about 56 %. Thanks to the ventilated gap between the new thermal insulation and outside surface brick layer there were not problems with humidity in the construction.

The comparison of the measured data with the demands of the Hygienic standards confirmed, that the indoor microclimate was during the whole year optimal in all living rooms, only the temperature in the stairs space was during some days lower by 2 or 3 K.

The sunshine, which has a positive influence on the improvement of the winter heat balance during the autumn, winter and spring, can have a negative impact on the heat balance and thermal comfort inside the house during the summer.

Generally the modernization of the house can be evaluated as successful, beneficial, contributing to the important savings of energy consumption and therefore saving of costs for heating.

References

1. Tywoniak, J.: Nizkoenergeticke domy. Grada Publishing. Praha, 2005. 193 p. (in Czech).
2. CSN EN 12831 Tepelne soustavy v budovach – Vypocet tepelneho vykonu. (in Czech).
3. CSN EN ISO 13789 Tepelne chovani budov – Merne tepelne toky prostupem tepla a vetranim – Vypoctova metoda. (in Czech).
4. CSN EN ISO 13790 Energeticka narocnost budov – Vypocet spotreby energie na vytapeni a chlazeni. (in Czech).
5. Vyhlaska c. 148/2007 Sb. o energeticke narocnosti budov (in Czech).
6. COM 2002/91/EC: Directive on the Energy Performance of Buildings.
7. COM 2010/31/EC: Directive on the Energy Performance of Buildings.
8. Narizeni vlady 361/2007 sb. kterým se stanovi podminky ochrany zdravi pri praci. (in Czech).