Advanced Building Construction and Materials II

Edited by
Milan Palko

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Fax: +41 (44) 922 10 33
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Trans Tech Publications Inc.
PO Box 699, May Street
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USA

Phone: +1 (603) 632-7377
Fax: +1 (603) 632-5611
e-mail: sales-usa@ttp.net

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Preface

Development of the material-technological base in the field of construction is progressing faster than in the previous periods. Based on the potential of new materials and technologies, it is possible to create advanced engineering building systems. Integration of advanced materials, technologies and construction systems creates a high-quality construction with optimum performance in the presence as well as in the future. Nevertheless, improper application of high quality materials in the wrong environment may cause a defect.

Research in the field of building materials, technologies and construction is currently primarily driven by energy efficiency, ecology and quality of the human environment. The importance of energy efficiency is affected secondarily by limited resources of fossil fuels. Another significant moment in this part is the price of energy and forecasts of its growth. Ecology of environment enters the problem through the external environment and ecology of artificially produced human environment. An important factor in terms of ecology is a comprehensive view of the construction work and its segments in the context of the production of pollution produced in the manufacture, transport, installation, exploitation and recycling or removal (rated as for example: primary energy of the material). Construction is currently focusing on higher energy standards using environmentally friendly materials and energy based on renewable resources. The quality of the internal environment has a direct impact on the users, on their health, abilities, well-being and safety.

Saving energy and increasing energy standard applied to buildings entails numerous problems related to energy and economic efficiency, thermal and technical features of building materials and construction, built-in moisture with operational moisture regime, indoor air quality connected with aerodynamic characteristics of the construction. By using a high-performance insulation, which is often flammable, fire safety problems may arise. By changing the scope and material-design solutions form different acoustic parameters of the works. Energy optimization of proportionality, transparent and non-transparent container structures housing brings light and technical problems.

For solutions to these issues is important choosing the right methodology solutions whether in the form of experimental verification, surveillance or computer modeling.

The aim of this journal is to inform the general public with the results derived from research and practices related to the above-mentioned issues.

Topics:
- Energy Saving and Ecological Buildings
- Thermal Performance of Building Materials and Constructions
- Aerodynamic Characteristics of Buildings and Construction
- Fire Safety Materials, Spaces and Construction
- Noise Protection and Daylight Conditions

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CHAPTER 1:

Energy Saving and Ecological Buildings

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Operation Energy Consumption after the Renewal of an Elementary School

Ivan Chmúrny

Technical University, Radlinského 11, Bratislava, Slovakia

ivan.chmurny@stuba.sk

Keywords: energy use, heating, ventilating, operational rating

Abstract. Analysis of energy consumption during the operation of the renewed elementary school in Lietavská Lúčka, which uses renewable energy sources. The results are based on the consumption of natural gas and electricity according to data from the meters of market suppliers of energy from 2006 to 2013.

Intoduction

The pilot project aimed at the elementary school Lietavská Lúčka [1] placed emphasis on the progressiveness of solutions, energy savings by improving the thermal protection of buildings as well as the use of renewable energy sources. The project was supported by the former Ministry of Construction and Regional Development of the Slovak Republic. The following were chosen as the basic principles of the solution:

- superior thermal insulation properties of building structures in comparison with STN 73 0540-2: 2002 valid at the time of the preparation of the project,
- the diversification of sources of energy (solar energy, electric energy, natural gas, energy from the environment)
- minimizing energy losses by ventilation (ventilation system with heat recovery).

The project also addressed the research and development tasks [2], which aimed to document and evaluate the measured data from operation after the renewal of the elementary school. Thus, to prove the results of the saving measures on the basis of the measurements of the real operation of the building. *Fig. 1* and *Fig. 2* show a view of the facade of the renewed elementary school.

Fig. 1 View of the entrance to the elementary school building

Fig. 2 View of the facade of the building

Thermal protection of building

The thermal performance of the building structure in its original condition is listed in *Table. 1* while the performance after restoration is listed in *Table 2.* During the restoration of the building by improving the thermal protection, EPS-Neopor gray foam polystyrene was used as additional thermal insulation. A thickness of 140 mm. was used on the walls. 300 mm. was used on the flat roof construction

Table 1 Thermal performance of the structure in its original condition

Building construction	U in W/(m^2 K)
Exterior wall thickness 270 mm	1.69
Exterior wall thickness 400 mm	1.4
Roof of the school	1.16
Roof of the dressing rooms	0.95
Floor on the ground	1.87
Wooden double windows	2.85
Double glazing	$g = 0.75$

Table 2 Thermal performance of building structure after renewal of the school building

Building construction	U in W/(m^2 K)
Exterior wall thickness 270 mm + ETICS with 140 mm EPS-Neopor	0.19
Exterior wall thickness 400 mm + ETICS with 140 mm EPS-Neopor	0.17
Roof of the school + 300 mm EPS	0.095
Roof of the dressing rooms + 300 mm EPS	0.093
Floor on the ground	0.33
Plastic windows with insulating double glazing	1.30
Double glazing	g = 0.63

This change in the thermal protection of the building means a significant reduction in the heat loss of the building. Computed, this represents a reduction of heat loss from the value of 242.6 kW to 92.4 kW, hence a reduction of heat loss by 61.6%. Theoretically, under standard conditions of evaluation and in the project energy evaluation, a theoretical energy savings in energy need for heating of 74.4% was achieved, as shown in *Fig. 3*.

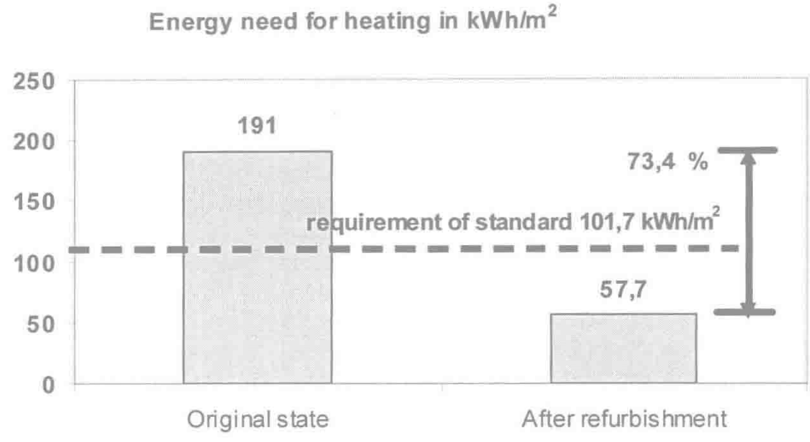

Fig. 3 Energy need for heating in project evaluation

Energy supply of the elementary school

After the renewal of the building structures and technical equipment of the building, it is provided with energy from market suppliers and renewables:

- 30 pieces of solar collectors with an absorption area of 69.6 m2
- heat pump water - water, total of 10 ground bores
- condensing gas boilers with a heat input of 3 x 49 kW
- controlled ventilation system

The installed air handling unit has a high efficiency heat recovery system, the declared value of the efficiency is 80%. The device enables:

- variable air flow,
- operation controlled by a time program,
- setback mode outside of operating hours,
- thus, savings of electricity and heat for heating the air is assumed.

The determining factor for the operation of the BTE equipment, which uses electricity, is its price and tariff. The fundamental attitude of the operator of the elementary school is to save fees for electricity. Thus, the starting point is that the technology systems be operated only during low tariff times. Low tariffs are during the periods:

Mo ...Fri 00:00...9:05; 10:05...12:15; 13:15...16:05; 17:05...19:35; 20:35...24:00;
Sat ...Su 00:00...2:45; 3:45...10:00; 11:30...15:20; 16:50... 24:00;

The operation of the heat pump is only during low tariff periods. Ventilation / without heater, only heat exchanger / operated only during low tariff periods and according to the time program, but only if the desired air quality is not achieved. Air quality is controlled by the built-in sensors for the concentration of carbon dioxide in the exhaust air. Time program for ventilation:

Mo ...Fri 7:00...9:00; 10:15...12:00; 13:30...15:05; 17:30...19:00; 20:45...22:00;

The air handling equipment is operated in an intermittent manner, which may affect the indoor air quality at the time of interruption.

The ventilation system provides quantitative and qualitative criteria in supplying fresh air to the treated areas. Quantitative indicators are given for the planning and designing of this system, which considered these parameters. The designed ventilation system of the building is equipped with a highly efficient heat recovery capable of heating up the air supply through waste heat from exhaust air to a temperature of + 16 ° C without additional heating. The designer thought that reheating the air supply would not be needed, and that it would be offset by the increased output of the existing radiators. An additional power supply for heating the air is not installed. The required thermal power of the ventilation system was designed for 20 kW.

The electricity consumption for the operation of the air handling equipment is low compared to other electricity consumption. This is especially due to the time program, which ensures the operation of the ventilation equipment only at the time of low tariffs. In times of high tariffs, the ventilation equipment is not in operation. Thus, the operation of the ventilation without a heater, the heat exchanger is operated at the time of low tariffs and only if the desired air quality of 800 ppm is not achieved. In the operation of the classrooms, air quality varies from 600 to 1200 ppm, representing a class of air quality in the 2nd and 3rd category according to STN EN 15251. According to the records of the activities of ventilation, air quality did not fall to the 4th class, which is considered to be outside the parameters of acceptable quality and could be tolerated only for a limited part of the year. During such operation of the air handling equipment, ventilation by opening windows is also used, however, it is difficult to quantify. Air quality according to the records of the air handling equipment itself is acceptable and energy efficient. The subjective evaluation of students and teachers, however, reported up to 25 % dissatisfaction with the ventilation system on the basis of a questionnaire survey. They felt a slight discomfort due to the cold air falling on the heads of students and reported feeling a swirl of air and sometimes a draft of wind (breeze) through the hair. *Fig. 4* shows the concentration of carbon dioxide during teaching in three classes in the elementary school. Deductions are based on carbon dioxide sensors from the air handling control system, located at the diffuser of exhaust air.

Experience has shown and a questionnaire survey confirmed that even ventilation with a high efficiency of heat recovery heat can cause feelings of discomfort. Of particular concern is also the avoidance of the use of the ventilation system on the grounds of the tariff pricing policy of the market electricity supplier. It is therefore disadvantageous to run the ventilation system in times of high tariffs. However, intermittent operation of the ventilation system while saving energy can cause thermal discomfort in winter.

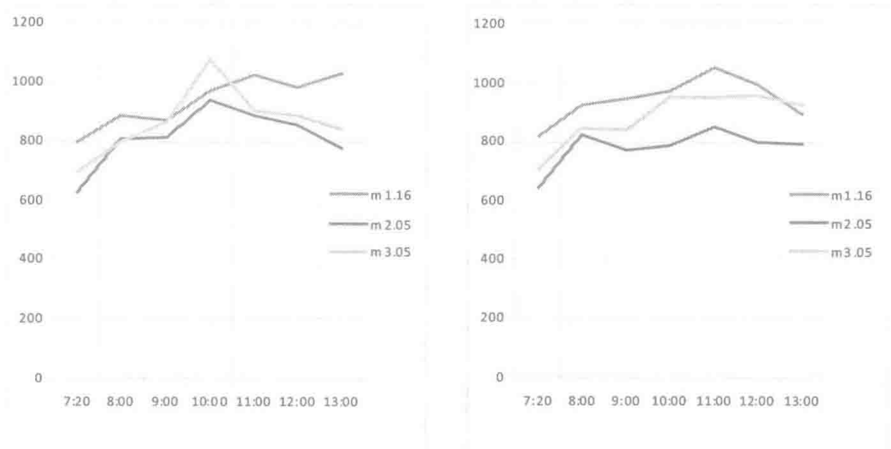

Fig. 4 Carbon dioxide concentration in ppm in three classrooms during class

Evaluation of energy consumption according to energy carriers

The documentation of data on energy consumption in this analysis is based on the measured data from operation. The reported energy consumption from different places is recorded on the meters of the market energy suppliers:

- natural gas consumption in kWh or m^3,
- electricity consumption in kWh.

A presentation of the data on energy consumption in a comparison of individual years and the condition of the building in these years mainly concerns whether such a comparison of the condition makes sense, namely, if comparable data is being compared. Given the changing situation in the BTE systems in the past, this condition was not always respected. In the past, the building was still running the old atmospheric boilers until 2006 and later new gas condensing boilers in 2007. This change of the heating source was not associated with the recovery pilot project of the school at all. The status of the BTE systems and building structure modifications took place continuously and thus easy comparisons between the years always requires an explanation on what is actually being compared. Until 2006, old atmospheric boilers were installed. We assume that this is a typical situation which could occur in several elementary schools in Slovakia. In 2007, new boilers were installed without connection with the elementary school renewal project under the pilot project of the MCRD of Slovakia. The efficiency of the heat source was increased and changed the energy consumption: both gas and as well as the total energy consumption. There is also a big influence from the thermal properties of the windows. The windows were changed before the overall renewal of the elementary school, namely before starting work on the pilot project. In addressing the pilot project in view of the existing state of the windows, it was stated that they conform to STN 73 0540: 2002, and it would be uneconomical to have them again changed for the new higher standard with even better properties. Thus, in the history of energy consumption for the years 2008 to 2009 we have a situation where the windows had already been replaced, although the building had not yet been completely restored. However, the window replacement appears in the measured data from operation. This problem occurs to the greatest degree when we want to express the percentage of energy-savings for the easy management and evaluation of the data. We see the way out from this ambiguous comparative situation in this simple reasoning. The technical condition of the building of the elementary school varied and a detailed description of the various changes in the building structures and building equipment and their influence on the operating consumption values is ambiguous to exactly express, also due to the fact that these changes were never implemented at the beginning of the year or the beginning of the heating season. What is clear, however, is the consumption of energy that appears on the billing meters of market energy suppliers. Thus, we will document the evaluation of energy consumption data for electricity and gas consumption in the individual years of operation after the final building approval of the elementary school with respect to year 2006. The operation of the elementary school in the years 2010, 2011, 2012 and 2013 is evaluated and documented in *Table 3*. However, 2010 is not typical, because this year the restoring of the building was still being finished.

Table 3 Energy consumption of the Lietavská Lúčka elementary school (year-round consumption) for conditioned area A_b = 2 154 m2

Year	Gas consumption in m^3	Gas consumption in kWh	Electricity consumption in kWh	Total energy consumption in kWh
2 006	38 727	399 990	4 122	404 112
2 007	24 767	255 805	2 872	258 677
2 008	21 657	223 704	6 115	229 819
2 009	9 418	97 273	2 161	99 434
2 010	5 257	54 297	42 218	96 515
2 011	1 570	16 216	38 289	54 505
2 012	2 211	22 836	39 456	62 292
2 013	2 140	22 106	40 101	62 207

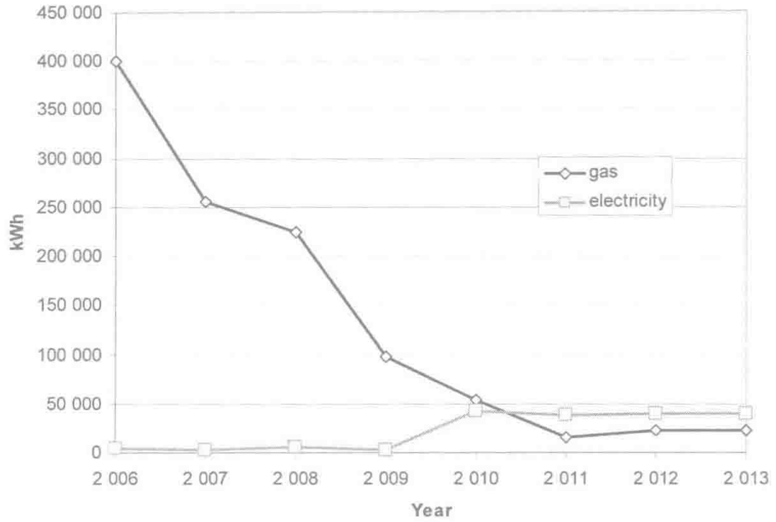

Fig. 5 The reduction in natural gas consumption and increased electricity consumption

The energy use

The energy use is the sum of the energy use for the different points of consumption. In the overall need for energy use, energy is required for heating, hot water, ventilation, lighting and use of the building. Therefore, this value also includes the electricity consumption for the operation of computer classrooms. Thus, in general electricity associated with the use of the building. This item is not usually considered in the energy certification of buildings. However, we cannot separate the measured data from the operation since we do not have electricity sub meters. Therefore, this item is also considered.

An indicator of the total energy requirement in kWh / (m^2.a) from the measured data from the operation of the elementary school in Lietavská Lúčka, based on unadjusted data from operation (we could have used the term total energy consumption) in the years 2011-2013 is shown in *Fig. 6* ranging from 25 to 29 kWh / (m^2.a). Compared with 2006, the savings in energy consumption is between 85-87%.

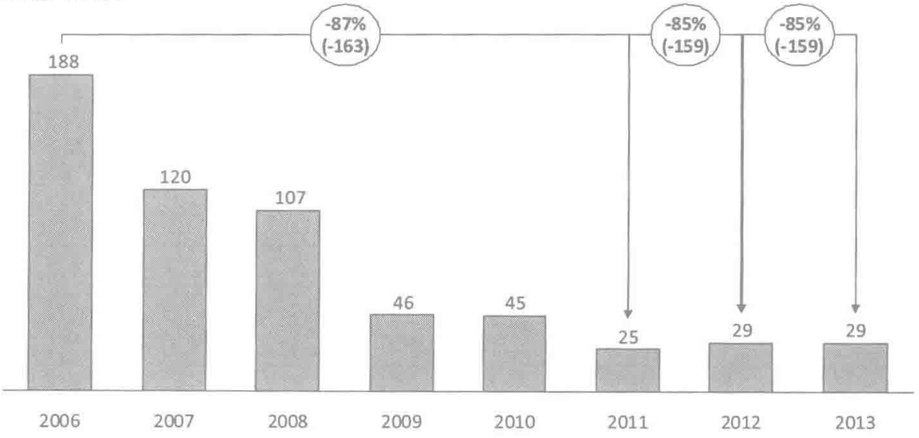

Fig. 6 The total energy use compared with respect to 2006

Primary energy

The savings expressed in terms of primary energy in *Fig. 7* are lower than in the use indicator of the total energy use. This is due to:

- higher primary energy factor for electricity in Slovakia (2,764),
- higher share of electricity on total consumption in buildings with modern BTE systems (heat pumps, heat recovery ventilation, etc.).

Savings in primary energy range from 70 to 72 % compared to 2006.

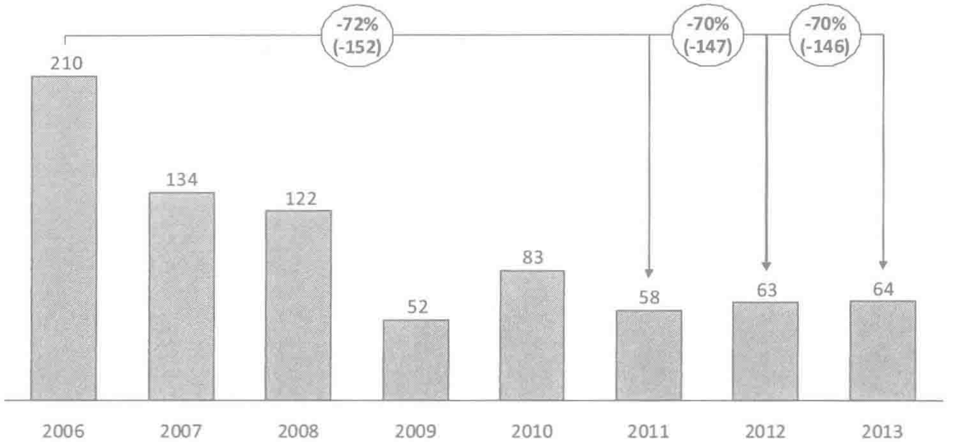

Fig. 7 Primary energy compared with the consumption in 2006

Conclusion

The renewed elementary school in Lietavská Lúčka is probably the only elementary school in Slovakia where the higher standard of renewal of a building in technical and investment terms is applied. A superior thermal insulation thickness was used in the reconstruction of walls, roofs and floors. For heating and hot water preparation, energy from the environment and a heat pump were utilized. In ventilation, an additional ventilation system with heat recovery was installed. These modern technologies increased the investment intensity [2]. If we subtracted the cost of the equipment of the school that was not directly related to the renewal of building structures and building equipment, the cost of 1 m^2 of floor space was: EUR 881.60. Then the operation of the building was able to achieve a total energy use below 30 kWh/m^2 and the need for primary energy less than 65 kWh/m^2.

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