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ENERGY RETROFITS OF SCHOOL BUILDINGS

Purpose. *The evaluation of the structure of heat losses through the thermal envelope as well as ventilation heat losses of a typical low energy performance school building and the selection of the most effective energy retrofitting measures.*

Methodology. *The annual method according to ISO 13790 was used to determine the space heating demand of the building.*

Findings. *The research defines and virtually implements an intervention strategy, which incorporates modification of ventilation system as well as upgrade of windows for the school building.*

Scientific novelty. *The structure of heat losses of the existing low energy performance school building was determined and analyzed. On the basis of the analysis the relative energy retrofitting approaches were proposed.*

Practical value. *The proposed energy retrofitting measures may be applied as the first retrofitting steps in thermal modernization of school buildings stock in Ukraine.*

Key words: *energy retrofit; very low-energy houses; energy balance; school buildings.*

Introduction. Sustainability in the building sector is a concept that considers the impact of the building with respect to the environment and energy generation and usage, but also considers the well-being of the people living inside the building and the economic aspects.

According to the International Energy Agency, buildings are responsible for 32% of the total final energy consumption and around 40% of the primary energy consumption in most of its member countries.

The importance of these issues increases further when referred to school buildings, in which the occupants are students/children pursuing a learning activity.

The issue of energy performance and energy management in public buildings has been the subject of several significant publications. Many authors have carried out research addressing the different aspects of improving energy efficiency in existing school buildings, considering also issues related to the internal air quality: Butala and Novak [1], Santamouris *et al.* [2], Dimoudi and Kosterala [3], Theodosiou and Ordoumpozanis [4], Becker, Goldberger and Paciuk [5], Butala, Gričar, and Novak [6].

The problem of conservation of energy in existing buildings is of great importance for Ukraine as well. The most part of the building stock is outdated [7]. A lot of school buildings, especially located in rural areas, have very low thermal performance. The acuteness of the energy supply problem for school buildings is related to such issues: 1) the low energy efficiency of the most existing buildings and (2) insufficient budget financing of expenses.

So, it is important to evaluate the influence of heat losses through various building thermal envelope components as well as ventilation heat losses on total heat losses and then select the most efficient energy retrofitting measures.

The objectives of this study are as follows: 1) to evaluate the current thermal performance of a typical school building with high energy consumption; 2) to assess the impact of the thermal upgrade of windows and ventilation system on space heating energy consumption.

Research results. The building under study is a 3-storey school building , located in Kyiv (Ukraine) and built in 1960. The projected building footprint is 1453 m^2 (Fig. 1). The heated area is 3780 m^2, and the heated volume is 13130 m^3.

Fig. 1**. The 3-storey school building constructed in 1960**

The external walls of the building consist of interior plaster (20 mm) and brickwork (510 mm) with their corresponding U-value of 1,15 W/(m^2K). The top floor ceiling is composed by a concrete slab (220 mm) as well as a bed of gravel and its relative U-value is 0,544 W/m^2K. The floor on grade consists of such components: linoleum, sand-cement screed (40 mm), concrete slab (300 mm). The corresponding U-value of it is 2,02 W/(m^2K). The windows have double glazing in timber frames (Fig. 2). The U-value of the existing windows is 2,78 W/(m^2K). The building includes 7 exterior doors. The U-value of the doors is 2,65 W/(m^2K). The ventilation type of the school building foresees only window ventilation.

Fig. 2. **The low energy windows of the school building**

Based on the above reported materials, the next phase of the study was the calculation of the building energy losses and gains with the Passive House Planning Package (PHPP), the Excel spreadsheet-based design tool. It calculates building components' U-values, heating, cooling and primary energy demand, ventilation rates for comfort as well as the risk of overheating in the warmer season. Moreover, it compiles climate data from many locations worldwide, including Kyiv (Ukraine).

For this study, the new PHPP 9 was used, which allows the direct comparison of different variants, together with their economic evaluation.

As a first step, the thermal performance of the original school building was studied. The annual heating demand of the existing school building determined with PHPP9 calculation tool is 139 $kWh \cdot m^{-2}a^{-1}$.

The magnitudes of heat losses and heat gains of the existing school building are shown in Table 1.

Table 1.

Heat losses and heat gains of the existing school building (before retrofitting)

The type of heat losses	Heat losses and heat gains	
	Annual values, kWh/a	Annual values per m^2 of treated floor area $kWh/a \cdot m^2$
Transmission heat losses through the building thermal envelope:		
External walls	61279	16,21
Roof	68090	18,01
Floor slab	51288	15,57
Windows	240144	63,53
Exterior doors	17481	4,62
Ventilation heat losses	210528	55,7
Total heat losses	686914	181,7
Available solar heat gains	109342	28,9
Internal heat gains	53665	14,2
Total heat gains	162913	43,1
Annual heating demand	524001	139

The results of calculation showed in Table 1 indicate that the most significant heat losses are that through windows as well as ventilation ones. So, it was decided to implement such innovative technologies: to install mechanical ventilation system with heat recovery units (Fig. 3) as well as modify windows using double low-E glazing in PH-frames with good thermal quality.

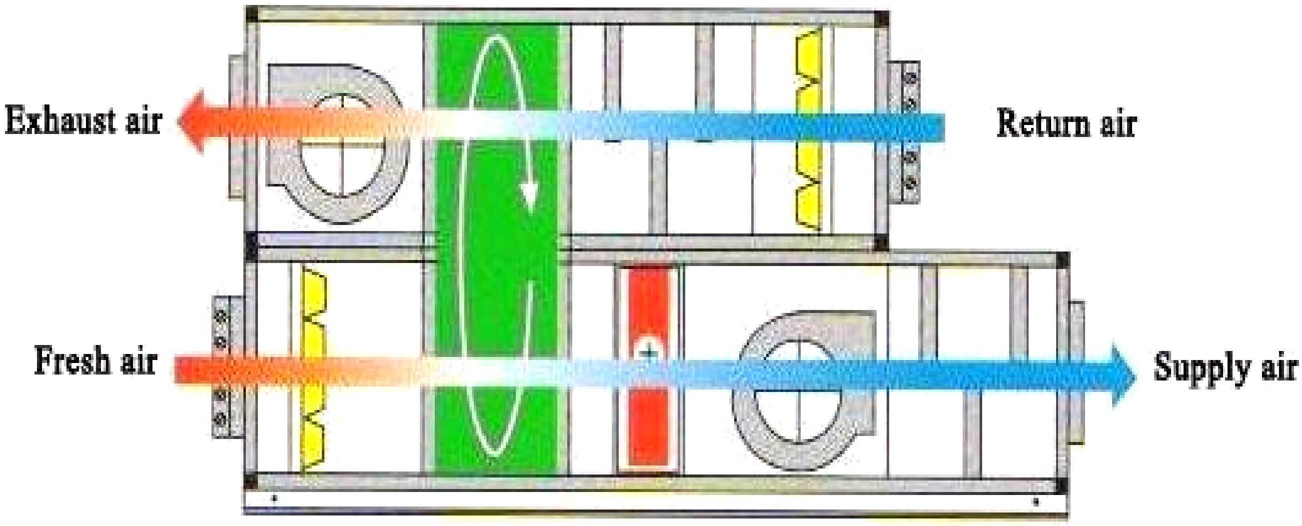

Fig. 3. **Heat recovery ventilation unit**

The heat losses and heat gains of the retrofitted school building were evaluated using energy balance calculation tool PHPP9.

The results of calculation are shown in Table 2.

Table 2.

Heat losses and heat gains of the school building (after retrofitting)

The type of heat losses	Heat losses and heat gains	
Transmission heat losses through building thermal envelope	Annual values, kWh/a	Annual values per m^2 of treated floor area, kWh/a·m^2
External walls	61279	16,21
Roof	68090	18,01
Floor slab	51288	15,57
Windows	110230	29,6
Exterior doors	17481	4,62
Ventilation heat losses	75189	19,9
Total heat losses	421661	111,6
Available solar heat gains	90881	24
Internal heat gains	53665	14,2
Total heat gains	144096	38,1
Annual heating demand	277569	73

The results of energy balance calculation shown in Table 2 demonstrate that replacement windows by more efficient ones and installing mechanical ventilation system with heat recovery units allow to reduce the specific annual energy heating demand almost twice (from 139 to 73 kWh/a·m^2).

Finally, a complete assessment should be made on the expenses of the upgrades and a cost-benefit analysis of the investments over a long-term period.

Conclusions.

1. The evaluation of the structure of heat losses through the thermal envelope as well as ventilation heat losses of a typical low energy performance school building was carried out. It is shown that the heat losses through windows as well as ventilation losses are the most significant ones.

2. It was decided to implement such innovative technologies: to install mechanical ventilation system with heat recovery units as well as modify windows using double low-E glazing in PH-frames with good thermal quality.

4. The two energy retrofit measures allow to decrease the school building space heating demand from 139 to 73 kWh/a·m^2 and may be used as the initial retrofitting steps in thermal modernization of school buildings stock in Ukraine.

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ЭНЕРГЕТИЧЕСКАЯ МОДЕРНИЗАЦИЯ ЗДАНИЙ ШКОЛ

КУЗНЕЦОВА Е.А.
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Цель. *Оценить структуру теплових потерь через внешние ограждающие конструкции, а также вентиляционные тепловые потери типового здания школы, имеющего низкую энергетическую эффективность, а также выбрать наиболее эффективные меры для термомодернизации школы.*

Методика. *Для определения потребностей в тепловой энергии на отопление здания была использована методика, изложенная в ИСО 13790.*

Результаты. *В исследовании предложен и виртуально реализован подход, который состоит в модификации системы вентиляции и замене окон на новые со стеклопакетами с низкоэмиссионным покрытием.*

Научная новизна. *Была определена и проанализирована структура тепловых потерь здания школы низкой тепловой эффективности. На основе этого анализа были предложены соответствующие варианты энергомодернизации.*

Практическая значимость. *Предложенные варианты могут быть использованы в качестве начального этапа в проведении энергомодернизации зданий школ Украины.*

Ключевые слова: *энергетическая модернизация; здания с низким потреблением энергии; энергетический баланс; здания школ.*

ЕНЕРГЕТИЧНА МОДЕРНІЗАЦІЯ БУДІВЕЛЬ ШКІЛ

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Мета. *Оцінити структуру теплових втрат через зовнішні огороджувальні конструкції, а також вентиляційні теплові втрати типового будівлі школи, що має низьку енергетичну ефективність, а також вибрати найбільш ефективні заходи для енергетичної модернізації школи.*

Методика. *Для визначення потреб у тепловій енергії на опалення будівлі була використана методика, викладена в ІСО 13790.*

Результати. *У дослідженні запропоновано і віртуально реалізований підхід, який полягає в модифікації системи вентиляції та заміні вікон на нові зі склопакетами з низькоемісійним покриттям.*

Наукова новизна. *Була визначена і проаналізована структура теплових втрат будівлі школи з низькою тепловою ефективністю. На основі цього аналізу були запропоновані відповідні варіанти енергомодернізації.*

Практична значимість. *Запропоновані варіанти можуть бути використані в якості початкового етапу в проведенні енергомодернізації будівель шкіл України.*

Ключові слова: *енергетична модернізація; будівлі з низьким споживанням енергії; енергетичний баланс; будівлі шкіл.*