The use of decentralized ventilation systems with heat recovery in the historical buildings of St. Petersburg

Vera Murgul\textsuperscript{1,a}, Dusan Vuksanovic\textsuperscript{2,b}, Nikolay Vatin\textsuperscript{3,c}, Viktor Pukhkal\textsuperscript{4,d}

\textsuperscript{1,3} St. Petersburg State Polytechnical University, Politekhnicheskaya ul., 29, 195251, Saint-Petersburg, Russia
\textsuperscript{1}Faculty of Architecture in Podgorica, University of Montenegro, Cetinjska br.2 81 000, Podgorica, Montenegro
\textsuperscript{4} St. Petersburg State University of Architecture and Civil Engineering, 2-Krasnoarmejskaja ul. 4, St. Petersburg, 190005, Russia

\textsuperscript{a}october6@list.ru, \textsuperscript{b}dusan.vuksanovic@gmail.com, \textsuperscript{c}vatin@mail.ru, \textsuperscript{d}pva1111@rambler.ru

\textbf{Keywords:} mechanical ventilation; heat recovery; air-to-air plate heat exchanger, energy efficiency, reconstruction, thermal balance, building.

\textbf{Abstract.} Historic apartment buildings in Saint-Petersburg no longer meet today’s energy efficiency standards and need upgrading to achieve lower energy-consumption. The possibilities to upgrade old buildings – historic and cultural monuments – are initially limited. A controlled heat recovery ventilation system is considered to be an integral part of energy efficient building. Provided engineering facilities of a building are updated and reequipped energy performance increases without any impact on building exteriors. Different types of decentralized intake and exhaust ventilation systems with heat recovery based on various types of heat exchangers are considered in a detailed way.

\textbf{Introduction}

There is a range of aspects forming a ground to implement complex energy efficient reconstruction of old buildings as follows: growth of deterioration of old buildings, aging of engineering equipment, non-compliance with the existing rules and regulations related to energy consumption [1, 2, 3]. Dwelling historic buildings are considered to be specific objects with particular requirements for reconstruction and renovation. First and foremost exteriors of historic buildings should be remained the same since they are distinctive ones and recognized as historical and cultural monuments. Another reason is a must to leave authentic urban environment of a historical center as it is [4, 5].

Reconstruction is a seldom used activity in a life cycle of a building. Planned reconstruction and renovation of old buildings should be combined with a set of measures to be taken to improve energy performance [6, 7]. State and value of structural members of old buildings set the limits on possible changes and modifications to be implemented in the course of energy efficient reconstruction [8].

A set of measures for energy improvement of existing buildings includes a range of basic aspects. Energy efficiency concept is presented in the Figure 1.
It's often impossible to make changes to walling when upgrading historic buildings. First of all it is related to supplementary technological equipping of building envelopes, for instance solar power supply modules [9, 10]. However a range of measures can be taken in most cases: thermal insulation of walling, elimination of thermal bridges, air sealing of joints in all the envelopes, installation of heat recovery ventilation systems, use of energy efficient equipment [11, 12, 13].

According to studies [14, 15, 16, 17, 18] nearly half of heat losses are caused by filtering through building envelopes, and the other half of heat losses occur due to ventilation emissions (Figure 2). A significant influx of heat can be reached due to passive solar heating and domestic heat recovery in ventilation systems.

Energy efficiency classes in terms of thermal energy consumption for heating buildings are set by existing Russian rules for thermal protection of buildings (Figure 2). It is possible to reach energy efficiency class ‘A’ provided the whole set of measures to improve energy performance are taken. In particular heat recovery is a must. Besides, sealing of buildings sets
the grounds for a controlled ventilation system to be used with the purpose to ensure appropriate air exchange rate.

Conventionally, natural ventilation systems were arranged in historic buildings. The background of their usage gives the evidences of negative impacts related to deterioration of air quality (especially in the case of buildings supplied with gas), thermal and humidity abuse in rooms. Problems with air exchange in apartments of multi-storey buildings are caused by disadvantages of natural ventilation systems [19, 20, 21, 22].

Use of decentralized intake and exhaust ventilation systems with heat recovery could be a good solution for low-rise historic buildings of Saint-Petersburg (3-5 storey houses).

**Decentralized ventilation systems in residential buildings and apartments**

The first type of a decentralized ventilation system is an apartment one. In this case separate individual single-block intake and exhaust ventilation systems with cross-flow plate-based heat exchangers are installed in every apartment (Figure 3). An air ductwork is arranged throughout every apartment. Air intake into apartments is supposed to be arranged through air diffusers, and air recovery is supposed to be arranged in kitchens, toilets and bathrooms. Outer air is heated in a heat exchanger by the air recovered from an apartment.

![Figure 3. Decentralized air intake and exhaust mechanical ventilation systems with heat exchangers. [taken from 19]](image)

One of the measures to improve energy performance of buildings can be installation of decentralized air intake and exhaust mechanical ventilation systems with plate heat exchangers in apartments making it possible to «return» up to 85% of thermal energy (Figure 4). Fans have a possibility of 9-stage digital regulation [20].

![Figure 4. Scheme of a mechanical air intake and exhaust ventilation system in apartments.](image)
Residents may change air exchange levels from 0 to 9 (the value ‘0’ implies that the system is switched off; the values 1, 2, 3 are optimal for all the types of apartments and ensure the standard level of air exchange depending on the area of apartments, the values above 3 can level air exchange up but increase the level of noise).

It is necessary to meet all the regulatory requirements for air exchange before to put energy efficient building into operation. To achieve this aim the following intake and exhaust air consumption rates have been regulated: 110 m$^3$/h is for 1-2 room apartments, 130 m$^3$/h is for 3- room apartments and 180 m$^3$/h is for 4- room apartments. The balance of air consumption in intake and exhaust channels has been regulated with due account for standard exhaust air volumes in kitchens and toilets [20].

A controlled air exchange system makes it possible to save energy due to management of ventilation at different times of the day. Air exchange level can be limited up to 50% of the standard rate for those residents who work over 70 hours a week and are outside the building (at work, in a shop, or absent for a walk).

The major problem to be solved when operating ventilation systems of this type is to prevent a heat exchanger from icing in winter time. Operating modes of the system are presented in the Figure 5. It is possible to achieve maximum energy performance of the system only if the temperature level of outer air is equal or lower than minus 10 °C. When there is the lower temperature level additional measures to avoid acing should be taken. In this case energy efficiency decreases as well.

![Figure 5. Operating modes of an intake and exhaust ventilation system with plate heat exchangers.](taken from 19)

The second type of decentralized ventilation systems to be recommended is an apartment ventilation system with recovery and regenerative heat exchangers.

One of such systems with plate heat exchangers is presented in the Figure 6 [21]. The system is installed inside a building on an external wall, air intake is arranged through a horizontal slot in this wall, and the system components are mounted on the wall or inside an alcove of the wall which has already been prepared. Basic functions of such systems are as follows:
- air is taken in and exhausted from an apartment simultaneously with heat recovery and noise protection provided; in this case efficiency of a heat exchanger amounts up to 73%;
- intake air is been eliminated from dust;
- as soon as the system is switched off an air admittance valve closes automatically;
- a level of production of a 10-stage system is regulated with a remote control panel;
- it provides a possibility to program individual parameters of the system.
Ventilation systems with heat recovery and regenerative exchangers used in apartments normally consist of an air supply (intake) grille placed in a room, an axial fan, filters to clean air up, a ceramic thermal conductor and an external grille with fixed blinds.

A reverse axial fan alternately pumps exhaust air from rooms and intake air from streets through a regenerator. Exhaust air to be recovered transfers heat to a thermal conductor, and then intake air is heated through a regenerator. Both elements should work synchronically to make ventilation efficient. One element is in charge for air intake, and another one is in charge for air exhaust. A proper operation of both elements makes it feasible to ventilate straightway two rooms connected with air transfer grille in the area of doors or with the help of a duct placed beneath (Figure 7). Efficiency of such systems can amount to 97%.

There is another type of such a system consisting of two fans and heat exchangers (double-flow) set in one body which operate alternately to supply and exhaust air (Figure 8).
Figure 8. Scheme of a decentralized mechanical air intake and exhaust ventilation system with double-flow heat recovery and regenerative heat exchangers [taken from 22]

One of the reasons to use decentralized ventilation systems in apartments of historic buildings to be reconstructed is that there are available Z-shape channels in external walling of historic buildings which allow supplying outer air directly into dwelling apartments (Figure 9) [23, 24].

Figure 9. A slot in a wall of an apartment designed for ventilation, a façade fragment.

Summary

Decentralized intake and exhaust ventilation systems with heat recovery exchangers can be considered to be an efficient way to reduce thermal energy consumption required to heat and ventilate historic apartment buildings. It is often not allowed to make any changes and modifications to exterior walling of historic apartment buildings that makes it complicated to achieve energy upgrading in these buildings. Upgrading engineering systems of the buildings, and in particular installation of heat recovery ventilation systems, has no impacts on external appearance of historic buildings and ensures significant energy performance gain.

References


The Use of Decentralized Ventilation Systems with Heat Recovery in the Historical Buildings of St. Petersburg
10.4028/www.scientific.net/AMM.635-637.370