UDC 697.9

M. Kovac, K. Kovacova
Technical University of Kosice, Slovakia
Institute of Architectural Engineering, Department of Building Services

ENERGY POTENTIAL OF ATRIUM SPACE IN VENTILATION SYSTEM

Метою роботи є енергетичний аналіз системи вентиляції з використанням енергетичного потенціалу простору атріуму. Метою дослідження є аналіз енергетичного потенціалу підігріву повітря в атріумі для його використання в механічній системі вентиляції. Для визначення кількості енергії для нагрівання повітря було розраховано необхідний повітрообмін системи механічної вентиляції. Проаналізовано стару будівлю школи, яка є об'єктом реконструкції. Реконструкція будівлі орієнтована на скорочення споживання енергії та покращення параметрів внутрішнього повітря. Одним із запропонованих заходів є встановлення механічної системи вентиляції з рекуперацією тепла (ККД теплообмінника 65 %). У зв'язку зі складністю енергетичних потоків у будівлі для розв'язання задачі моделювання енергетичних потоків було використано інструмент Design Builder. Створено геометричну модель будівлі школи з атріумом, розташованої в місті Кошице. Результати енергетичного аналізу показали позитивний вплив системи рекуперації тепла на споживання тепла для опалення приміщень – воно було знижене на 69 % від початкового значення (у системі без рекуперації тепла). У запропонованому атріумі можна досягти підвищення температури свіжого повітря в середньому на 4,0–7,0 К протягом дня. Використання підігрітого повітря в атріумі для механічної системи вентиляції з рекуперацією тепла може призвести до зниження потреби у тепловій енергії для опалення приміщень на 49 % від початкового значення (у системі без рекуперації тепла).

Ключові слова: атріум, механічна вентиляція, система рекуперації тепла, простір надходження теплової енергії.

The content of paper is energy analysis of ventilation system with using energy potential of atrium space. The aim of case study is to analyze energy potential of air preheating in atrium space and its utilisation in mechanical ventilation system. In order to energy analyse the heat demand for space heating was calculated in relation to required air exchange by mechanical ventilation. The analysis was done for old school building that is the object of renovation. The building renovation is oriented on reducing of energy consumption and improving the internal environment. The one of designed measurements is the installation of mechanical ventilation system with heat recovery (heat exchanger efficiency 65 %). With regard to complexity of energy flows in building it was used for problem solution the energy simulation tool Design Builder. There was created geometric model of school building with atrium space located in Kosice. The results of energy analyse have shown the positive impact of heat recovery system on final heat demand for space heating that was reduced on 69 % from starting value (without heat recovery system). In the proposed atrium is possible to achieve the increase of supply fresh air temperature at average about 4.0 – 7.0 K during day. The utilisation of preheated air in atrium space for mechanical ventilation system with heat recovery can bring the reduction of heat demand for space heating on 49 % from starting value (without heat recovery system).

Key words: atrium, mechanical ventilation, heat recovery system, space heating energy demand.

Introduction. The building sector has been identified as one of the key sectors to achieve the 20/20/20 targets of the EU. The 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive are the EU's main legislation when it comes to reducing the energy consumption of buildings. Under the Energy Performance of Buildings Directive all new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018). Under the Energy Efficiency Directive all EU countries make energy efficient renovations to at least 3 % of buildings owned and occupied by central government [1].

The increasing requirements on energy performance of building lead to an improvement of the thermal properties of external building constructions what leads to the air tightness increase and to reducing of air infiltration. The required air exchange must provide the effective mechanical ventilation system. In terms of EPBD legislation the buildings with required air tightness and very low energy demand (nearly zero energy buildings) must use the heat recovery system with energy efficiency at least 60 % [2].

Utilisation of atrium space in buildings. Atrium spaces are very often used in newly-built public buildings or for the refurbishment of existing buildings. Atria are large enclosed spaces attached to a building with at least one transparent façade which typically has significant height [3]. This space can fulfil various kinds of function, bring daylight, enable more surfaces to be open to nature, circulation of people etc.

The four main reasons for including atriums in buildings were defined by Tofigh Tabesh and Begum Sertyesilisik (2015) following:

- architectural function,
- connection to outdoor environment,
- economic function, and
- energy conservation.

The most advantage of atrium space is its energy potential as “buffer zone” and “solar collector” offering some positive benefits [4]. A lot of present studies are oriented on atrium space in term of its utilisation for natural ventilation of buildings. The main advantage of utilization of natural ventilation in building design is not only reducing energy consumption and cost but also providing acceptable, comfortable, healthy and productive conditions. The difference in the pressures in the inside and outside environments, resulting from factors such as wind and buoyancy driven forces, causes air movement throughout the building [5].

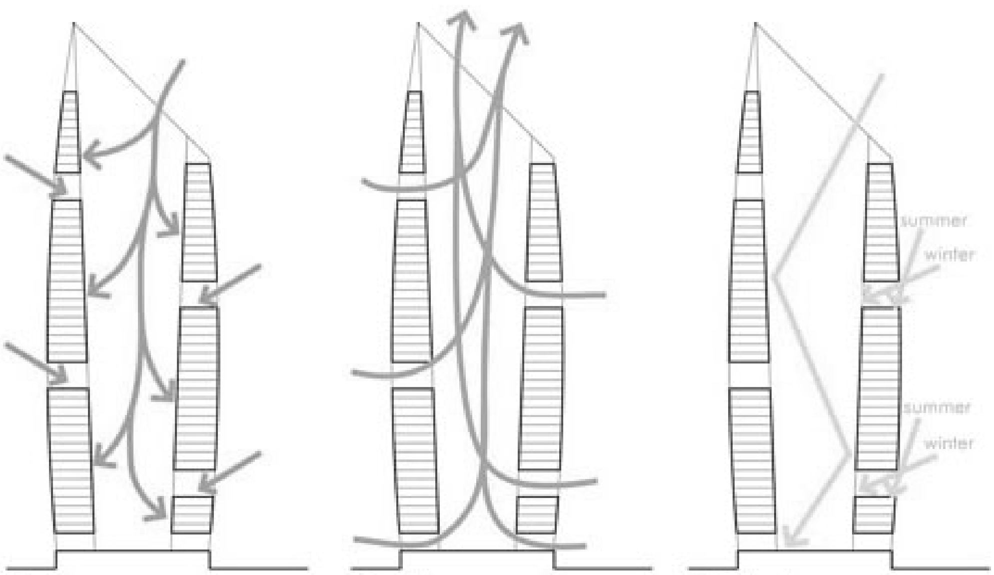

Fig. 1. The utilization of atrium space – passive heating and cooling, day lighting

In case of buildings with mechanical ventilation system there is effort to reduce energy need for heating of supply air by heat recovery system. Mechanical ventilation with heat recovery system provide required air exchange in interior and use energy from exhaust air to preheat the fresh supply air.

The aim of case study is to analyze energy potential of air preheating in atrium space and its utilisation in mechanical ventilation system. In order to energy analyse the heat demand for space heating was calculated in relation to required air exchange by mechanical ventilation.

Case study. There was selected school building in order to energy analyse. In case of building renovation there is thinking with improvement of thermal properties of external walls, roof, replacement of external windows and increasing the air tightness of building. Therefore it is designed mechanical ventilation system to achieve the required air exchange by standard STN EN 15251.

With regard to complexity of energy flows in building it was used for problem solution the energy simulation tool Design Builder. There was created geometric model of school building with atrium space located in Kosice. Dimensions and thermal properties of all building construction were defined. The boundary conditions of internal environment as occupancy, required illumination, and minimum fresh air per person or minimal ventilation intensity in rooms were defined for individual zones of analysed building. The heating system is operated in two modes with different requests in order to assure operative temperature in internal spaces. In classrooms there was considered the operative temperature in value 20 °C during teaching in time from 6:00 till 17:00, the operative temperature in value 17 °C was considered in the rest time, during weekends and holidays. The others rooms (corridors and toilets) are heated at operative temperature 15 °C. In such a way we gained start state of analysed school building.

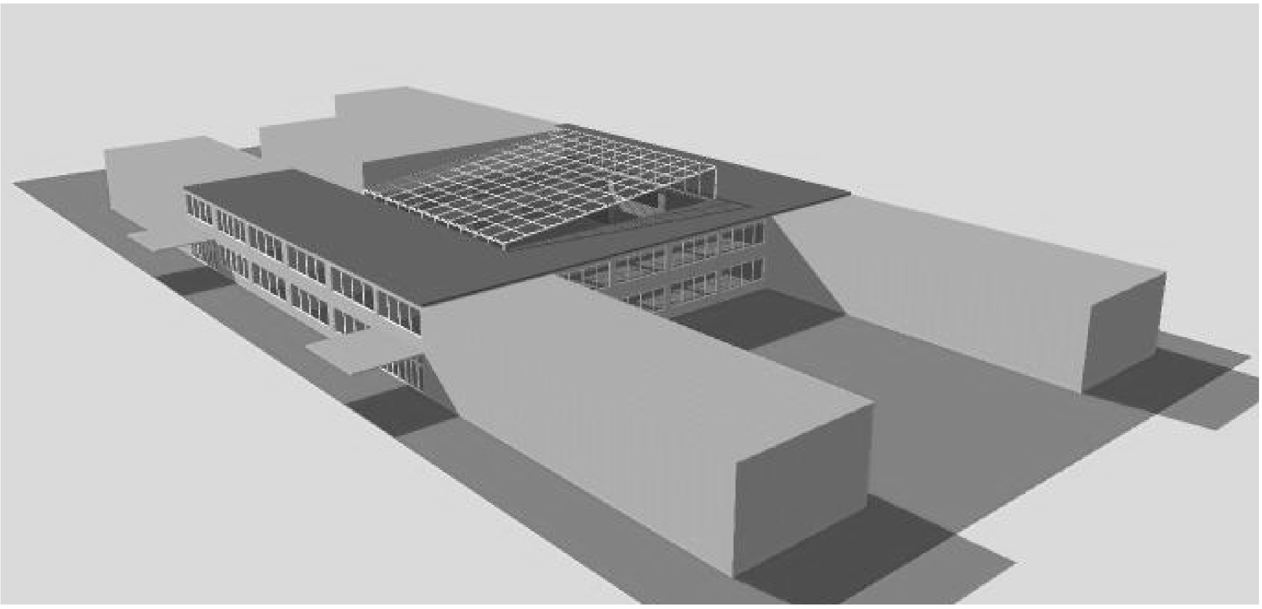

Fig. 2. The visualisation of proposed glass atrium in school building

In order to assure the required air exchange in individual classrooms the mechanical ventilation system was proposed that is in operation during work days in time from 6:00 till 17:00 with total fresh air flow circa 12,000 m^3/h (fresh air rate 7.0 l/(s.person) [6]). In the rest time there was considered with ventilation intensity 0.5 l/h. The heat demand for space heating was calculated for three different states:

– 1^{st} – mechanical ventilation system without heat recovery,
– 2^{nd} – mechanical ventilation system with heat recovery (heat exchanger efficiency 65 %),

– 3rd – mechanical ventilation system with heat recovery (heat exchanger efficiency 65 %), completed about using of supply fresh air preheating in space of glass atrium (glass system U = 1.4 W/(m^2.K), g = 0.72), see Fig. 3.

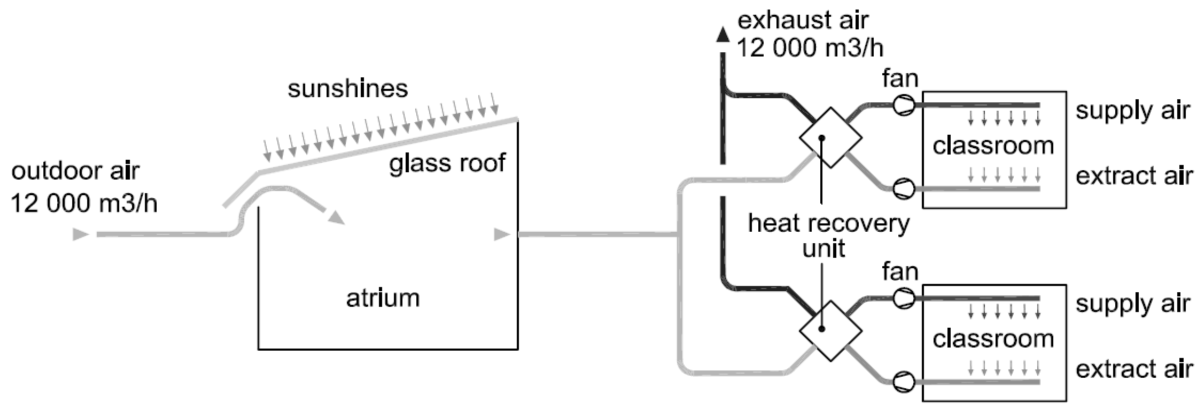

Fig. 3. Mechanical ventilation with heat recovery system and preheating of supply air in atrium

Results of energy analyse. Following utilisation of energy simulation tool there were gained results about possible energy savings for variants under consideration. The gained results are shown on the following graphs (Fig. 4 and Fig. 5). The results have shown the positive impact of heat recovery system on final heat demand for space heating that was reduced on 69 % from starting value (without heat recovery system).

The proposed glass atrium represents active exploited energy space in that it is possible to achieve the increase of supply fresh air temperature at average about 4.0–7.0 K during day in dependence on solar radiation and outside air temperature. During operation of mechanical ventilation system the fresh air with required airflow (12,000 m^3/h) is supplied into atrium. Out of ventilation system operation the atrium is closed in order to avoid space cooling. The utilisation of preheated air in atrium space for mechanical ventilation system with heat recovery can bring the reduction of heat demand for space heating on 49 % from starting value (without heat recovery system).

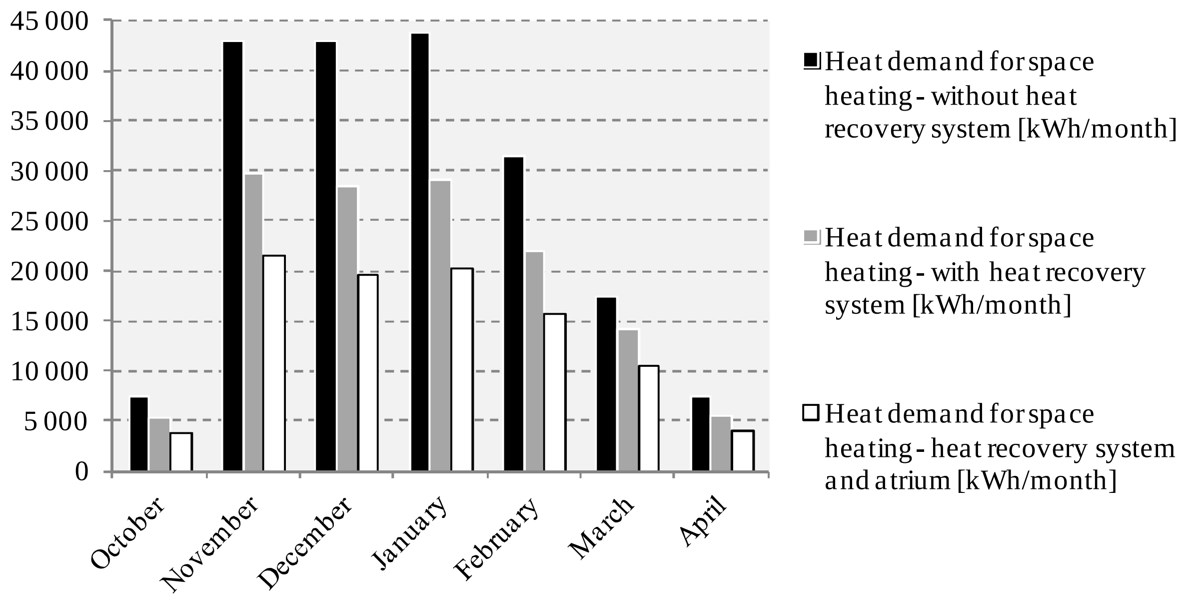

Fig. 4. The heat demand for space heating – monthly balance

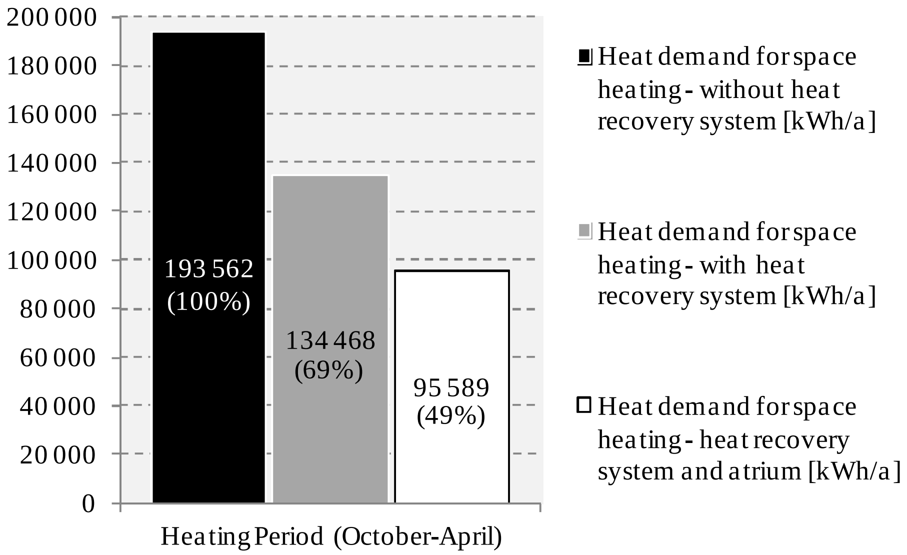

Fig. 5. The heat demand for space heating – heating period from October till April

Conclusion. The aim of case study was to analyze energy potential of air preheating in atrium space and its utilisation in mechanical ventilation system. In order to energy analyse the heat demand for space heating was calculated in relation to required air exchange by mechanical ventilation. From results is clear energy gained from heat recovery system that is required in new and renovated energy efficiency buildings nowadays. Energy efficiency of heat recovery system is depending on temperature gradient between extract and outdoor air and on total airflow through system. Primary the atrium space is used as buffer zone between external and internal environment what leads to energy savings. Energy analyse confirmed the possibility to use the atrium space for preheating of supply air into mechanical ventilation system.

Acknowledgements. This paper is the result of the Projects implementation: KEGA 052 TUKE-4/2013 – The implementation of a virtual laboratory for designing energy-efficient buildings, and University Science Park TECHNICOM for Innovation Applications Supported by Knowledge Technology, ITMS: 26220220182, supported by the Research & Development Operational Programme funded by the ERDF.

1. ECOFYS GmbH, Towards nearly zero-energy buildings. Definition of common principles under the EPBD, final report February 2013. 2. Regulation No. 282/2012 (in Slovak language). 3. Tabesh T., Sertyesilisik B. Focus on Atrium Spaces Aspects on the Energy Performance. International Conference on Chemical, Civil and Environmental Engineering, Istanbul, 6.2015. 4. Li R., Pitts A. Thermal Comfort and Environmental Modelling in Atrium Buildings. PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture, Geneva, 9.2006. 5. Moosavi L. et al. Thermal performance of atria: An overview of natural ventilation effective designs. Renewable and Sustainable Energy Reviews 34 (2014), 654–670. 6. STN EN 15251:2008. Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.