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HEAT RECOVERY OF VENTILATED AIR IN AN EXISTING EDUCATIONAL BUILDING IN THE CITY OF DOBOJ

Veselin Blagojević[1], Nebojša Lukić[2], Novak Nikolić[3], Aleksandar Nešović[4]

Summary: *This research is related to the ventilated air heat recovery. The analysis includes the heat recovery of air in case when ventilation is defined according to the air changes per hour and according to the current presence of people in the ventilated zones. The research was conducted for an existing nonresidential (educational) building in the city of Doboj. The large heat losses through the ventilation system can be reduced by installing an energy recovery ventilator. Analysis of the presence of people in the zones can have a major impact on the operation of the ventilation system and electricity consumption. It is assumed that the dependence of these two factors is very important and that the study could be a starting point for solving this problem in a given area. The analysis was conducted in the software EnergyPlus.*

Key words: Heat recovery, ventilation, EnergyPlus, nonresidential building.

1. INTRODUCTION

Requirements for room ventilation and maintaining of hygienic conditions are big problem in the modern construction of buildings. The solution of this problem is installation of heat recovery ventilation system. In order to reduce energy consumption of a ventilation system, utilization of heat from the exhaust air is almost mandatory. However, the problem may represent leakage of heat, which can drastically reduce the efficiency of ventilation and heat recovery. In addition, these systems use electricity, and their improper handling can lead to the increase of electricity consumption [1].

This work represents the first steps for implementation of the methodology for calibration of simulation models through definition of parameters that have the most impact on the energy consumption of buildings and the end-use of buildings. Sensitivity analysis was applied over the estimated load for the heating and cooling of the building in order to determine more accurate values for the input parameters representing a major impact on the heat load.

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The global crisis and greenhouse gases put additional pressure on the energy consumption in buildings. Particular emphasis is on high energy consumption in nonresidential buildings. Urban planning is a set of measures, guidelines and suggestions for improvement and unification of economic, social and sustainable development of certain areas. Planning in the modern era, accompanied by a number of bad consequences, has led to a steady rise in consumption of natural resources used to build traffic and utility infrastructure and expansion of settlements. Insufficient care of human race for the environment and ecosystems caused the emergence of large-scale climate change and global warming [2].

2. CALIBRATION AND SIMULATION OF BUILDING MODEL

The investigation was conducted for an existing nonresidential building (educational building), The Faculty of Transport and Traffic Engineering in the city of Doboj (B&H).

To simulate thermal behavior of this building and obtain accurate calculation results, the software EnergyPlus (version 7.1) was used. This program is very useful tool for modeling of energy and environmental behavior of buildings [3]. In the software, it is possible to input how people use building during the space heating and cooling. Following this direction, the complex schedules of heating and cooling can be defined simultaneously with schedules for the use of lighting, interior equipment and occupancy in the building. The influence of the solar radiation, shadowing and infiltration can be also taken into consideration. The first step in the study was the collection of project documentation and definition of the object geometry in the software Google SketchUp (version 8).

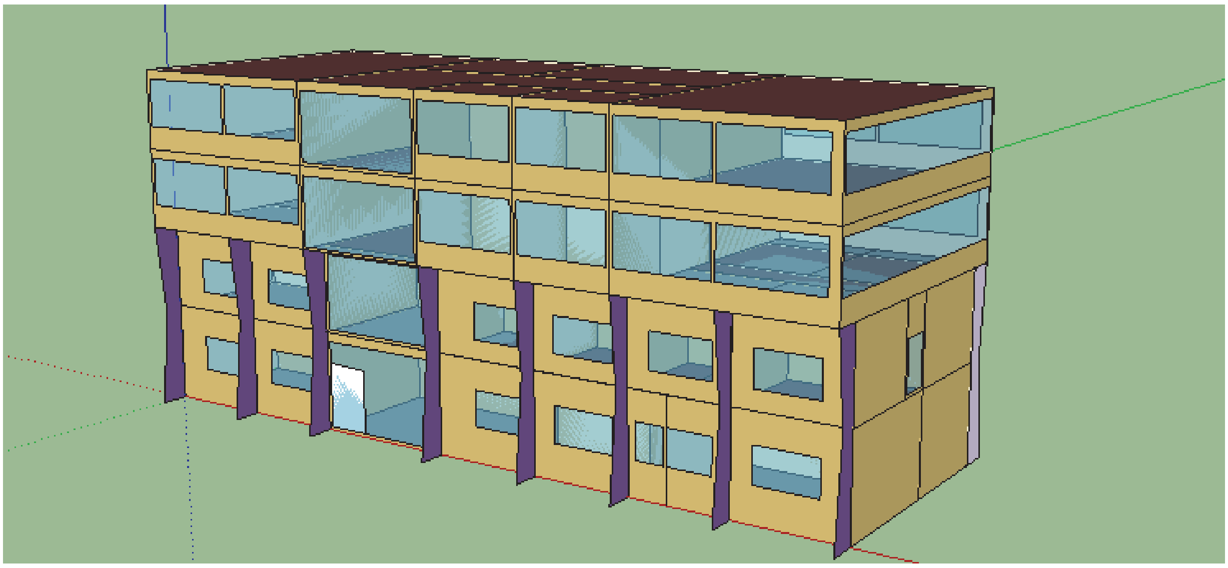

Fig. 1 *The geometry of the investigated building*

2.1 CHARACTERISTICS OF THE BUILDING AND PARAMETERS

The investigated building has 34 zones distributed on 4 levels and total floor (heating) area of 1562.70m^2 (Fig. 1). Since it is a new building, the attention was paid for the biggest part of the building to be oriented toward south in order to maximize solar gains. The percentage of the window area relative to the area of the entire surface of the walls of the building is 32.62%. The value of the parameter SHGC is 0.765. It was assumed that building is not surrounded by any other building. Large windows provide sufficient daylight in the rooms and for this reason the use of lighting in most rooms is only required in the morning and evening. The characteristics of the building constructions are given in Table 1.

Table 1 *The characteristics of the building constructions*

Construction	Layer	U[W/m^{2}K]
Window	Glass (0.4cm), Air (1.3cm), Glass (0.4cm);	2.770
Exterior wall	Brick (12cm), Expanded polystyrene foam (15cm), Air (2cm), Clay block (25cm), Lime mortar (2.5cm)	0.225
Interior wall	Lime mortar (2.5cm), Brick (12cm), Lime mortar (2.5cm)	0.17
Roof	Gravel (5cm), Waterproofing (0.2cm), Vapor barrier (0.2cm), Cotton (5cm), Vapor barrier (0.2cm), Lightweight concrete (5cm), Cement screed (4cm), Clay block (16cm), Lime mortar (2.5cm);	0.566
Floor with tiles	Stone (25cm), Gravel (5cm), Lightweight concrete (4cm), Waterproofing (0.2cm), Lightweight concrete (4cm), Ceramic tile (1.5cm)	2.831
Interior ceiling (with tiles)	Ceramic tile (1.5cm), Cement screed (4cm), Clay block (16cm), Lime mortar (2.5cm);	1.21

Data about lighting and interior equipment were entered in the software on the basis of the current situation. In the whole building the neon lighting is installed. The power of lights is in range of 72W to 504W depending on the surface area.

The lights in the hallways and toilets operate from 8 AM to 4 PM, in the offices and classrooms from 8 AM to 11 PM. The power of interior equipment in the hallways ranges from 20W to 1500W. In classrooms it amounts 200W. The maximum power of this equipment in the toilet is 500W. Equipment operation follows user activity in the building. The number of people (users) is defined based on the capacity of the rooms and their purpose, while the occupancy of the rooms is defined based on the teaching schedule in the winter semester of 2016/17.

The activity level of people is defined as walking and sitting. The activity level, age, body weight and clothing of people are the factors that present heat gains. Since the majority of users in the building is between the ages of 18 to 30, the average heat gain per person for walking (210 W) and seating (105 W) was adopted [4].

The number of people and their occupancy within the building are very important in this investigation. Therefore, Table 2 gives the data about zone floor area, number of people and their occupancy.

Table 2 *Floor area of the zones, number of people and their occupancy*

Zone	Area	People	
	[m^2]	Num.	Fractions of people occupancy
P1	69.20	50	8:45-9:00=1; 9:00-10:00=0.1; 10:00-11:45=1; 11:45-12:00 =0.1; 12:00-13:00=0.1; 13:00-14:50=1; 14:50-17:00=1;
P4	43.44	21	8:00-9:00=0.8; 9:00-13:00=1; 13:00-14:00=0.8;
P4a	43.19	49	8:00-9:00=0.8; 9:00-13:00=1; 13:00-14:00=0.8;
P5	71.30	2	8:00-9:00=0.5; 13:00-14:00=0.5; 14:00-15:00=1;
P6	19.55	2	8:00-17:00=0.5;
P7	42.12	43	8:00-13:00=0.5;
P8	51.98	48	8:00-13:00=0.5;
P9	9.31	2	8:00-11:00=0.5; 11:00-15:00=1; 15:00-18:00=0.5;
PS1	64.19	50	8:00-16:00=0.1;
PS3	51.98	48	9:00-15:00=0.5;
PS4	42.12	29	9:00-13:00=0.8; 13:00-14:00=0.5;
PS5	20.18	2	8:00-16:00=1;
PS6	18.51	2	8:00-16:00=1;
PS7	18.77	2	8:00-16:00=1;
PS8	20.40	2	8:00-9:00=1; 9:00-19:00=0.5;
PS9	28.86	2	8:00-17:00=0.5;
PS10	22.56	2	8:00-19:00=1;
PS11	20.63	2	8:00-12:00=0.5; 12:00-13:00=1; 13:00-15:00=0.5;
PS12	20.35	2	8:00-19:00=0.5;
PS13	22.18	2	8:00-11:00=1; 11:00-15:00=0.5;
DS1	76.08	50	8:00-9:00=0.2; 9:00-15:00=0.1; 15:00-16:00=0.1;
DS3	53.39	43	8:00-9:00=0.3; 9:00-12:00=0.5; 12:00-13:00=0.3;
DS4	118.78	78	8:00-12:00=0.3; 12:00-14:00=0.2;
DS5	14.66	2	8:00-11:00=1, 11:00-16:00=0.5;
DS6	15.98	2	8:00-15:00=1; 15:00-16:00=0.5;
DS7	115.83	78	8:00-9:00=0.2; 9:00-11:00=0.3; 11:00-14:00=0.2;
DS8	36.23	2	8:00-15:00=0.5;
TS1	76.08	80	8:00-13:00=0.1; 13:00-14:00=0.5; 14:00-16:00=0.01;
TS3	53.39	43	8:00-10:00=0.3; 10:00-11:00=0.5; 11:00-14:00=0.3;
TS4	118.78	78	9:00-15:00=0.2,
TS5	14.66	2	8:00-15:00=1;
TS6	15.98	2	8:00-15:00=1;
TS7	115.83	78	8:00-12:00=0.3;
TS8	36.23	2	8:00-16:00=0.5;
Total	**1562.70 (Sum)**	**902 (Sum)**	

2.2 HEATING SYSTEM

The heating system consists of a natural gas boiler, convective baseboard heaters, variable flow pump and heat recovery ventilators. The water convective baseboard heaters and ventilators are put in each of the heated zone. The heating system operates each day of the heating season from the 15th of October to the 15th of April. During the day, they operate from 7 AM to 10 PM, if the room temperature is below 20˚C, from 10 PM to 7 AM if the room temperature is below 15˚C. The heat exchanger of the energy recovery ventilator is activated when the outdoor temperature is below 18˚C.

2.3 SIMULATION SCENARIOS

This investigation is related to the ventilated air heat recovery of an existing nonresidential building in the city of Doboj. The analysis includes three simulation scenarios: 1 - heating without ventilated air heat recovery; 2 - heating with ventilated air heat recovery for the case when ventilation is defined according to the air changes per hour; 3 - heating with ventilated air heat recovery for the case when ventilation is defined according to the current presence of people in the ventilated zones. In order to simulate the operation of the existing heating system, its size is determined by assuming that the ventilation rate is 0.5 1/h. For the scenario 2 the adopted ventilation rates are: 1.5 1/h for offices and toilets and 2 1/h for classrooms [5]. On the other hand, for the scenario 3 the ventilation rate is determined according to the people occupancy. The adopted value for the supply (outdoor) air is 7m^3/h per person [6]. It has to be noted that for all three scenarios it was assumed that air tightness of the thermal building envelope is minimal. In other words, there is no infiltration of outdoor air. The opening of doors and windows is not taken into consideration.

3. RESULTS

This investigation includes analysis of energy consumption for heating of an existing educational building for three proposed scenarios of the heating system operation. The values for energy consumption, energy savings percentage and specific energy consumption for all three scenarios are given in the Table 3. The energy savings percentage for the scenario 2 and 3, compared to the scenario 1 are 65.91% and 81.72%, respectively. The obtained values can be explained by the fact that the ventilation heat losses are significantly higher than transmission heat losses. The reason is very low value for the U coefficient of the exterior wall as well as the high values of the air changes per hour for the investigated educational nonresidential building defined according to [5]. The energy consumption for the scenario 3 is the lowest as the ventilation is defined according to the current people presence in the zone.

Table 3 *The simulation results for three analyzed scenarios*

RESULTS OF THE RESEARCH			
	Scenario 1	Scenario 2	Scenario 3
Natural Gas [kWh]	196430.46	64753.09	35545.41
Electricity:Heating (Fans, Pumps) [kWh]	3510.41	3410.71	1010.44
Total energy consumption [kWh]	**199940.87**	**68163.8**	**36555.85**
Specific energy consumption [kWh/m^2]	**127.95**	**43.62**	**23.39**
Percentage of energy savings [%]	-	**65.91**	**81.72**

4. CONCLUSION

In order to provide energy efficiency in buildings, the ventilated heat recovery system air is often installed. The efficiency of this system depends on many factors as the duration of the heating season or climatic conditions. In this paper the heating consumption for an existing nonresidential (educational) building for three proposed scenarios of heating system operation was analyzed. The proposed simulation scenarios are: 1 - heating without ventilated air heat recovery; 2 - heating with ventilated air heat recovery for case when ventilation is defined according to the air changes per hour and 3 - heating with ventilated air heat recovery for the case when ventilation is defined according to the current presence of people in the ventilated zones. The obtained percentage energy savings for the scenario 2 and 3, in relation to the scenario 1 are 65.91% and 81.72%, respectively. The reason is the fact that the ventilation heat losses are significantly higher than transmission heat losses. The heating consumption for the scenario 3 is the lowest because the ventilation is defined according to the current occupancy of people.

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