The reversible ventilation for administrative buildings

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Abstract. The article describes the method of ventilation of administrative buildings premises with the use of reverse flow of supply and exhaust air on the same flues. A scheme of a reversible ventilation system and methods of designing this systems are presented, the conditions of its work are described.

1. Introduction
According to numerous surveys of administrative buildings with mechanical ventilation systems, the microclimate in their premises does not conform to standard. This situation occurs due to errors in the design, installation and operation of such systems. The number of office buildings is growing steadily in megapolises, hence the quantity of employees faced with the problems of poor air quality in the workplace is consistently increased. This very common issue compels the engineers to develop ventilation systems that use most of the natural forces. The efficiency of these systems is already confirmed by some researches in [1]. The reversible ventilation system belongs to such systems [2].

2. General information
The reversible ventilation is hybrid system (half mechanical and half natural) which combined the advantages of mechanical and natural systems. It has two operation modes:
1. Natural
2. Reverse
The change of operation modes is carried out by the valve group switching and activation of air supply device.

Figure 1a comprises the scheme of natural operation mode. In this mode outdoor air goes to premises via supply and exhaust devices. Further, it assimilates excess heat and moisture and is removed by air flues. In this case air movement is provided by natural forces only therefore the air supply device is inactivated and disconnected from the air flues. The natural mode may exist during the cold season of the year when the pressure difference is sufficient to provide the air exchange.

Figure 1b comprises the scheme of reverse operation mode. In this mode the air supply device takes the outdoor air and performs its pre-processing, subsequently moving it to the premises. Exhaust air is removed by supply and exhaust devices under the effect of excess pressure in rooms. The reverse mode may exist during the warm season of the year due to low natural pressure difference during this period. Hence the proposed ventilation system makes the most of the natural forces to provide the air exchange.
The application of reversal of air flows is not absolutely new idea. The investigations of this conception performed before in [3], however all of them discuss providing air exchange in a single or few number of premises and did not offer to use this principle centrally. The idea of air-permeability constructions was considered earlier [4] but not solved until the end.

The change of operating modes occurs due to the following circumstance: in natural operation mode the inlet air needs to be heated, therefore the supply and exhaust device is located directly behind the heating surface. When the outdoor temperature drops below +8 °C (in Russia), in the case when the heating system is switched off, the supply air begins to flow into the rooms with too low temperature. This situation violates the sanitary standards, therefore the operating mode of ventilation system is necessary to be changed to reverse. In this mode the inlet air is heated in air supply device and moves to premises with an acceptable temperature.

3. Supply exhaust devices
As part of the research, the author proposes a design of supply and exhaust device which corresponds to all necessary requirements. The proposed design of this device is presented on figure 2.
Due to the relatively large area of the device, the air velocity in the supply jet is low. The low velocity of the supply jet does not cause overcooling of the water in the heating device and allows heating the air sufficiently. In order to fill the breathable element, the author proposes to apply large-porous media. These include backfilling of bloating clay or expanded polymers. In accordance to preliminary calculations, these materials provide the necessary hydraulic behavior during filtration. This can also be investigated from the papers [5].

Filtering through porous media is not a fully studied section of hydraulics. Because of low amount of information describing hydraulic mode filtering in large-pore filling, the author has assembled an experimental appliance for studying these modes. The equation of the exponential type and binomial type and experimental expressions for the filtration coefficients are known.

As part of the research, a simulation of filtration by equation 1 was performed.

\[
\frac{dP}{dx} = C_{R1} \times w_{f,x} + C_{R2} \times w_{f,x}^2
\]  

(1)

The coefficients \( C_{R1} \) and \( C_{R2} \) were determined experimentally. Comparison of experimental and simulation results is shown in the figure 3. The deviation of results was less than 5%. This suggests that it is possible to apply filtration equations to simulate the flow in large-porous backfills. However, filtration coefficients should be determined experimentally.

![Figure 3. The experimental results (points) and simulation (lines) of air filtration in claydite filling. On the vertical axis, the pressure drop at the ends of the sample is marked. On the horizontal axis, the velocity of air flow in pores is marked. Labels indicate the thickness of simple, mm](image)

For comparison, the author has performed modeling using the coefficients by expressions mentioned in other papers. In this case the convergence of simulation and experimental results was not found. It is known that the presence of any inhomogeneity in external walls violates thermal protection of a building, therefore it is necessary to consider the supply and exhaust device as a thermal conductivity insertion and apply the requirements of thermal protection norms to it.

4. The requirements of thermal protection

Russian standards describe two requirements to thermal protection. They includes hygienic and energy saving criterions [6]. The hygienic requirement limits the temperature on internal surface of external wall and the energy saving requirement limits the heat flux through external wall. The modern Russian method of accounting for thermal heterogeneity is developed by Gagarin and Kozlov [7]. In accordance with this method, in order to describe the specific heat fluxes through elements of external wall it is necessary to calculate temperature behavior of wall contour. The temperature of internal surface of a wall can be defined by the same simulation as well.
As part of the study the simulation of thermal behavior of external wall with supply and exhaust device was performed. In this simulation the filtration of cold air through porous filling was taking into account. The simulation was performed with varying values of the insertion height (from 100 to 600 mm) and the air velocity in the pores. The example of computation result is presented on figure 4. This simulation is allowed to calculate the specific heat fluxes through porous filling and apply the requirements of thermal protection norms to it. The dependence of specified heat flux on the air velocity in pores is presented on figure 5.

Figure 4. The results of thermal behavior simulation in external wall with breathable opening

Figure 5. Depending specific heat flux with air velocity in pores
Here the dimension of specific heat flux is correct that proved in paper [7]. All calculations were performed in ANSYS CFX и Matlab computation systems. Summarizing the above, it is possible to propose an engineering technique that allows using breathable openings in external walls without violating the requirements of thermal protection. It can be formulated in the form of the following paragraphs:

1. The area of the supply and exhaust device is determined by the known flow rate and the velocity (from 3 to 30 mm/s) of the supply jet (the problem of non-isothermal filtration in filling at different velocities is considered in the article [8]). The height of device is determined by structural features of walls and should be as large as possible. The length of device is calculated by area and height values.

2. Such parameters as reduced thermal resistance of external wall and thickness of thermal insulation coat can be calculated using the method, described at [7] if height and length are known. This makes possible to execute energy saving criterion.

3. In order to take into account the hygienic criterion the temperature of internal surface of a wall should be calculated at known height and length. The air velocity in pores can be corrected providing that this temperature would not be too low.

5. **Benefit cost analysis**

As a part of the study the benefit cost analysis is performed. The reversible ventilation system was compared with usual supply and exhaust system. For example, the central-corridor administrative building with 6 floors was considered. In case of the usual supply and exhaust ventilation consists of 1 supply 2 exhaust systems. Total value of supply air rate is equal to 17700 m³/h. The results of comparing are presented on diagram 1.

![Figure 6. The results of benefit cost analysis](image)

For calculating the value of capital and exploitation allocations in addition to the cost of equipment, the assembling, heat and electrical energy, repair activity and pay allocations was also considered. The results of cost analysis show the benefits in the effectiveness of reversible ventilation in
comparison with usual ventilation was 25%. The budget keeping arises from minor cost of equipment and also by inactivation of supply devices during cold season of the year.

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