Impact of Fire Ventilation on General Ventilation in the Building

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Abstract. The fire of building is a threat to its users. The biggest threat is generation, during lifetime of fire, hot gases and smoke. The purpose of quick and efficient evacuation from the area covered by the fire, at first step the escape routes have to be secured from smokiness. The smoke ventilation systems are used for this purpose. The proper design and execution of smoke ventilation is important not only because of the safety, but also of the maintenance of comfort in the building at a time when there is no fire. The manuscript presents the effect of incorrectly realized smoke ventilation in the stairwell of the medium building. The analysis shows that the flaps of smoke ventilation located in the stairwell may have a significant impact on the proper functioning of mechanical ventilation in the period when there is no fire. The improperly installed or incorrect insulated components cause perturbation of air flow and they change pressure distribution in the building. The conclusion of the analysis is the need to include the entire technical equipment of the building during the design and realization of its individual elements. The impact of various installations at each other is very important, and the omission of any of them can cause disturbances in the proper work of another.

1. Introduction

Due to the high risk posed by fire of buildings the applicable laws introduce the need for using the smoke ventilation. [1]. However, the improper operation of this installation can lead to disturbances in the operation of the other systems. The analysis covered two medium-high buildings located in the city in the temperate climate in the third climatic zone. The study was conducted over the months of autumn and winter in the year 2016/2017, i.e. September - January.

The both buildings were equipped with supply and extract mechanical ventilation systems and the smoke ventilation to protect the stairwells before smokiness. The analyzed buildings belong to ZL III category according to [1]. Theirs fire resistance is B-class.

The users complained about the lack of thermal comfort in one of the buildings. This prompted the authors to carry out research. The first building was equipped with a correctly functioning smoke ventilation system. The analysis of system in the second building showed the leaks of smoke flaps in the stairwell.
The smoke ventilation system of the stairwell consisted of two air supply systems. One of the fans was located in the lower part of the building and it was supplying the air through the flaps in the wall between the ground floor and first floor. The second fan was located on the building roof. The duct attached to this fan was equipped with smoke flaps positioned on the wall on the level between floors: the second and third, fifth and sixth, and seventh and eighth. The smoke ventilation system was similar in both public buildings and in accordance with [2] was designed to create a pressure differential. It was to protect the escape route against smokiness.

The supply and extract ventilation system was equipped with air handler unit. Supply air was realized in the offices and exhaust air was realized in the hallway.

The literature describes the analysis of the flow of smoke during a fire [3]. The researchers also analyzed the flow of ventilation air, for example [4]. However, the impact of the smoke ventilation system on the work of the mechanical ventilation, at a time when there is no fire, has not been determined.

2. The subject of the analysis
The rooms in the public building equipped with supply and extract mechanical ventilation system were analyzed. The task of ventilation system was supplying to the premises the air; whose parameters ensure thermal comfort. The building was also equipped with the installation protecting the stairwell from smokiness. The fire flaps were not correctly installed and insulated what resulted in the air supply into the stairwells. The inflow in the stairwells was disrupting the pressure distribution in the building, what in turn adversely affected the conditions in the offices.

The study covered the measurement of the airflow through the fire flaps, the carbon dioxide concentration, the pressure and the temperature in the rooms.

3. Results and discussions
In the public buildings the man is the main source of pollution. This also for men the conditions inside the building should be properly configured. As a criterion for assessing the interior microclimate the concentration of carbon dioxide was used. For the measurement of the carbon dioxide concentration (CO2) double beam sensor was used taking the dependence of damping a specific band of infrared radiation. The measurement ranged 0 ÷ 5000ppm. The temperature was the second parameter for assessing the quality of the internal air. This was measured by a miniature solid-state sensor with a measurement range 10÷45°C.

3.1. The analysis of the carbon dioxide concentration in the internal air
The carbon dioxide concentration level over time are shown in the graphs (figure 1). The conditions in rooms on two floors in buildings with correctly and incorrectly functioning smoke ventilation were presented.

In all cases the analysis showed that the CO2 concentrations did not exceed the limit value, i.e. 700ppm above the concentrations in outdoor air [5]. On the fourth floor, the CO2 concentration in the building equipped with a correctly functioning smoke ventilation system was higher by an average of 480ppm. On the sixth floor the values of the CO2 concentration were higher in a building equipped with the correctly operating smoke ventilation system and simultaneously it was nearly constant during the entire measurement period. Whereas the values reached in the building equipped with the incorrectly operating smoke ventilation system fluctuated in a considerable range: from 196ppm to 1034ppm.

3.2. The analysis of the internal temperature
To analyze the impact of smoke ventilation system on the air temperature in rooms the graphs were created and they are presented in figure 2 and 3.
Figure 1. The concentration of carbon dioxide in the building equipped with the smoke ventilation functioning correctly and incorrectly a) – storey IV (p. III); b) – storey VI (p. V)
Figure 2. The temperature of indoor air in building equipped with the smoke ventilation functioning correctly and incorrectly a) – storey IV (p. III); b) – storey VI (p. V)

The analysis of the internal temperature showed that in the building equipped with correctly functioning smoke ventilation systems the value of parameter was stable throughout the measurement period and fluctuated in a range 22.6 – 23.2°C. On the fourth storey in the building equipped with incorrect functioning smoke ventilation system, the temperature fluctuated in the range of 21.8 – 22°C. And on the sixth storey of this building the parameter ranged in 26.1 – 27.6°C. This means that the value from the last range exceeded the limit value, specified in the standard [6], ie. 19 – 21°C.

Figure 3. The temperature of the supply air through the leaky smoke dampers located in the stairwell
Figure 4. The stream of the supply air through the leaky smoke dampers located in the stairwell

Correctly installed smoke flaps should be tight and should not supply air or exhaust air during the term when installation is in normal circumstances. The measurements have shown the air flow through all smoke flaps installed in one of buildings. The temperature of air supplied through the smoke flaps in the lower part of the building fluctuated in a range 9,8 – 11,6°C. At the same time, in the upper part of the building the air was flowing out. The average amount of air inflowing through the smoke flap between the first and second floor equaled 115 m³/h, through the smoke flap between the third and fourth floor equaled 236 m³/h. The average amount of air outflowing through the smoke flap between the sixth and seventh floor equaled 138 m³/h, through the smoke flap between the eighth floor and roof equaled 8 m³/h.

In addition, the supply air which was the most, had the lowest temperature. This was due to the location of the air intake of smoke ventilation system on the ground floor of the building (the handler unit had attached only the lowest mounted flap). The second handler unit with air intake of smoke ventilation system was located on the roof of the building. The highest value of buoyancy force in this duct, resulting from the height from midpoint of lower opening to midpoint of upper opening, appeared at the height of the smoke ventilation flap located between the third floor and fourth floor. Hence the high amount of air flow in time when the handler unit of smoke ventilation system was turn off.

The mechanical ventilation working in the building was equipped with a control system of supply air temperature. This was due to mounting the temperature sensors inside building. The air heater was turned on because of low recorded values of temperature. The supply air temperature was raised after starting the heater. As a result, at the third floor the desired value was achieved figure 2A, whereas at the sixth floor the desired temperature was exceeded figure 2B.

4. Conclusions

The building both during the design stage, performing and modernizing should be treated as a whole, i.e. design, along with the technical equipment. This is particularly evident in the analysis of the effects of thermo-modernization works in buildings of what was written in the [7].

Not only the building structure affects installations it is located in it, but also installations interact each other. It is extremely important for the technical equipment which transports the same medium, but for different purposes. In case of the smoke ventilation system, it should be designed and constructed in such a way as not to affect the global ventilation system located in the building. However, mistakes in design or execution of installation have significant effect on the conditions in the room. Uncontrolled airflow through the smoke flaps results reaction of automatic control system of...
the supply and extract ventilation system, and this in turn does not allow to keep thermal comfort in
the building

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