

Analysis of Various Ventilation Systems Due to the Quality of Indoor Air in Educational Buildings [†]

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Abstract: The quality of internal air is one of the factors that affect the pace and quality of knowledge acquisition. Therefore, it is important that the classrooms have high air quality. Using computer simulation, the effect of various building ventilation variants on air quality in classrooms was analyzed. As an indicator of air quality, the concentration of carbon dioxide in school halls was assumed.

Keywords: indoor air quality; ventilation systems; indoor microclimate; air stream; concentration of carbon dioxide

1. Introduction

The quality of internal air is one of the factors that affect the pace and quality of knowledge acquisition. Therefore, it is important that the classrooms have high air quality [1].

In Poland, the indoor environmental quality requirements specified educational buildings stored in the Polish standard PN-EN 13779:2008 [2]. According to the standards, the following climate comforts have the most important impact: air temperature, air humidity, physical and biological quality of air, and CO₂ concentration.

Educational buildings are characterized by a significant density of people staying in a single room. This situation makes it particularly important to provide learners with appropriate conditions [3–5]. Most thermo-modernization works have aimed to reduce the costs of educational buildings. Increasing the tightness of rooms worsens the operation of the ventilation system, which reduces heat loss through ventilation and reduces the heating costs of the building. This ultimately results in a significant deterioration of air quality in the teaching rooms [6–8].

The aim of the article is to analyze various ventilation systems due to the quality of indoor air in educational buildings. Taking into account the above recommendations, tests were carried out to determine the ventilation parameters of the teaching rooms, which guarantee the comfort in these rooms.

2. Materials and Methods

Using computer simulation, the effect of various building ventilation variants on air quality in classrooms was analyzed. The analyses were carried out using the CONTAMW. The calculations were carried out on the school model (see Figure 1). It is a compact three-story building. As an indicator of air quality, the concentration of carbon dioxide in school halls was assumed. It was assumed that people do a light job sitting, which results in about 13 dm³/h of carbon dioxide emission. We adopted two criteria [9]:

1. the concentration of carbon dioxide during the lesson (net) on average in classrooms throughout the heating season for a distribution of 50% should not exceed 1000 ppm;
2. the concentration of carbon dioxide during the lesson (net) on average in classrooms throughout the heating season for a distribution of 90% should not be higher than 1200 ppm.

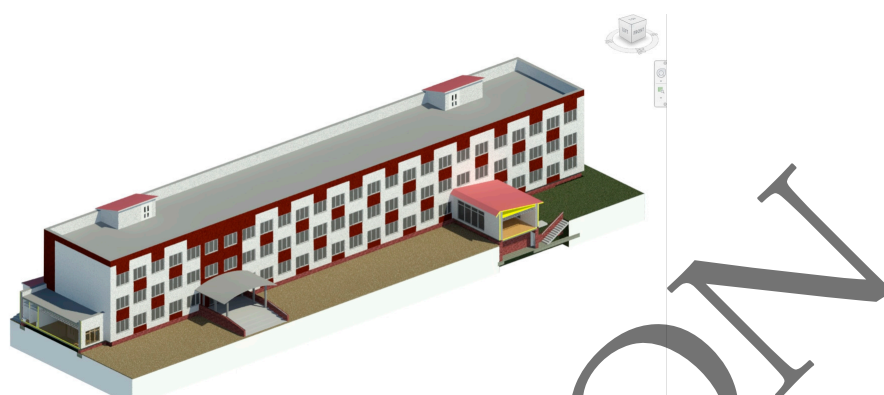


Figure 1. Analyzed school building. Arrangement of rooms by level.

Six variants of building ventilation were analyzed:

- A. gravity ventilation system; building before replacing windows;
- B. gravity ventilation system; building after replacing windows;
- C. gravity ventilation system, building after replacing windows as in option B, classrooms are additionally ventilated during breaks by opening;
- D. gravity ventilation system, building after replacing windows as in option B, windows of all rooms are equipped with air ventilators;
- E. mechanical exhaust ventilation system;
- F. mechanical ventilation system for supply and exhaust.

The calculations were carried out for the entire heating season, which takes into account the breaks in learning and the daily variation of the room loads.

3. Results

As a result of the calculations carried out, the results of the values of ventilation air streams in each zone and the distribution of carbon dioxide concentration in classrooms were obtained. The air flow caused by wind force and heat displacement depends on the location of rooms, which also depends on the world side and levels [10].

Such varied air exchange is reflected in the concentration of pollutants in the rooms. The course of variation in carbon dioxide concentration and its cumulative distribution in the heating season for a selected room are shown in Figure 2.

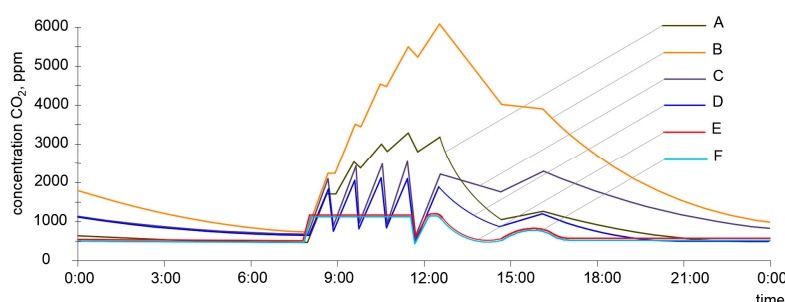


Figure 2. The course of variation in the concentration of carbon dioxide in the classroom (room located on the last level on the west side of the building) on one January day for the six variants considered.

4. Discussion

The rooms on the third floor with a western exposure are characterized by the largest air exchange. In turn, the smallest airflow occurs in the rooms on the last floor with eastern exposure.

Case A shows the status of the school before upgrading windows, which did not utilize any work related to the modernization of the ventilation system. Air exchange at the level of 1.0 h⁻¹ results in poor air quality, at which the concentration of carbon dioxide exceeds 3000 ppm (at the average value of 1640 ppm) as shown in the literature [11,12].

On the one hand, the replacement of window frames improves the energy consumption of a building (variant B). However, the other five reduce the coefficient of tightness of windows, which resulted in a significant deterioration of air quality in the classrooms. The CO₂ concentration on average reaches 2800 ppm, reaching up to 6000 ppm at the top (see Figure 2).

The cheapest method in terms of the cost of investment outlays is the use of window pressure air intakes [13,14].

Installation of roof fans at the outlet of gravity ventilation ducts (option E) is the easiest (least invasive) way to introduce mechanical ventilation in an existing building [15,16].

The utilized mechanical ventilation system was allowed to obtain the required internal air quality [17].

The solution offering the greatest control over the environment is the use of mechanical supply and exhaust ventilation. The introduction of a system that takes into account variable room loads is a source of additional energy savings [18–20].

5. Conclusions

The analyses and literature [9,12,16] show that natural ventilation is not able to provide proper air exchange.

Only the use of exhaust fans with the simultaneous use of window ventilators allows us to keep the concentration of carbon dioxide at an average level of 1000 ppm [2]. The best control over the internal environment can be obtained by using a supply-exhaust ventilation system with heat recovery.

Achieving effective ventilation in educational buildings is not easy. Taking into consideration the potential health effects and deterioration of mental work caused by bad ventilation, educational buildings should be invested.

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