Optimal air exchange rate in order to avoid CO_2 and moisture problems

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Summary

This paper is devoted to the analysis of indoor air quality in Latvian dwelling buildings after renovation. It presents the calculation method for evaluation of the indoor air quality in airtight buildings which can be easy implemented by designers and end-users.
Over the past years due to the governmental energy performance requirements for buildings and drop in the prices of PVC windows have led to better thermal insulation and air tightness of building envelopes. Also the European Union's issued directive no. 2010/31/ES on the energy performance of buildings dictates that starting from year 2015 all new buildings will need to consume less energy for heating. This will cause for the necessity to implement mechanical ventilation to provide healthy indoor environment because natural ventilation through cracks in building envelope be impossible.
In the scope of this paper the main problems of indoor air quality in airtight buildings were identified and calculation methods of predicting dynamically changing indoor air contaminant levels as well as relative humidity is provided.
The proposed calculation method takes into account parameters of outdoor air, internal CO_2 and moisture production, buildings volume and air exchange rate.
The paper also presents the results of monitoring of indoor air quality specifics of apartments and offices in Latvia and compares the obtained results with the calculated ones.
The results have shown that proposed method is accurate in predicting CO_2 level and could be used for evaluation of CO_2 level.

Keywords: Ventilation, indoor air quality, CO_2 concentration, humidity, prediction

1. Introduction

As the issued directive no. 2010/31/ES on the energy performance of buildings is binding for Latvia as a member state of the European Union there needs to be paid increasingly more attention to energy effectiveness of buildings. This regulation states that starting from year 2015 all new buildings will need to comply with reduced energy consumption requirements and use less than 35 kWh/m^2/year for heating but staring from the year 2021 all new buildings will need to be zero energy. This means that the buildings will need to comply to today's standards of low energy houses. As seen from the experience of these buildings the needed low level of energy consumption can only be achieved by complex solutions including - increased building envelopes thermal conductivity by applying thicker insulation, usage of low-e coated passive windows, passive solar energy use as well as higher air tightness to reduce air infiltration. The last means that there will be necessity for mechanical ventilation as no longer air will be able to penetrate through building envelope and by only using controlled ventilation we obtain possibility to regain energy from the exhaust air to supply air through heat exchanger.

As the existing data of built low energy and passive houses shows the energy consumption for ventilation is making up relatively large part of total energy consumption and is in rage of 15-25%. This can provide good opportunity for energy savings but if the mechanical ventilation is undersized to save money also can lead to insufficient ventilation air exchange rate and inappropriate indoor air quality. To prevent this it is necessary to incorporate into existing national building codes requirements for ventilation to ensure appropriate IAQ not specific air exchange rates.

As of now the local regulations in Latvia require a minimum of 5 l/s of fresh air per person if it is the only pollutant in the room or determine the necessary air exchange according to occupied spaces type and area. However it would be more accurate to assess the necessary volume of fresh air to provide appropriate IAQ, as this is the main purpose of ventilation. The main characteristics that define IAQ are CO_2 level and relative humidity. Both of these indicators are mainly related to human beings while the air pollution can also be caused by ozone from printers/copy machines, cooking fumes and emissions from building materials and described using total volatile organic compound value. All these characteristics describing IAQ are affected by air exchange rate, indoor pollutants, parameters of outdoor air and room specifications.

2. Method of determining optimal air exchange rate

To theoretically predict the dynamically changing indoor air quality parameter levels based on air ventilation rate, pollution rate and outdoor air parameters a theoretical calculation method was developed which is based on mass and energy balance and allows to calculate concentration of pollutant at any given time moment and for CO_2 concentration can be expressed as follows:

$$c_{in}(t) = c_{out} + (c_0 - c_{out}) * e^{-n*t} + (1 - e^{-n*t}) * + \frac{n_{pers.} * q}{n * V} \quad (1)$$

Where V – room volume, m^3; n – air exchange rate, c_{out} – outdoor air CO_2 concentration, kg/m^3, $n_{pers.}$ – number of persons in room; q – CO_2 production by one person, kg/h, c_{in} – indoor air CO_2 concentration, kg CO_2/m^3.

For the purpose of practical evaluation of IAQ and to verify the precision of the developed theoretical model, an apartment and office building where analyzed and measurements were done twice in each of these buildings for higher validity. The obtained results were analyzed using mean square error method and presented as absolute mean error as well as in percents.

The results showed that the proposed method gives accurate results for predicting indoor air quality parameters. The average precision for CO_2 concentration prediction is 94.5% while for relative humidity 87.2%. Precision for predicting relative humidity can be improved if absorption and desorption processes are taken into account and averaged moisture gains are used.

An example of practical application of developed method for low-energy one story high residential building is given as well as prediction results for CO_2 and relative humidity levels at different ventilation air volumes.

3. Discussion

The analysis of the results showed that given method can be used to determine the optimum air exchange rate in new low-energy buildings to provide the necessary indoor air quality by using the minimal volume of fresh air to reduce total energy consumption.

Some drawbacks of provided method might include the necessity to predict exact occupancy profile what in most cases might be difficult and therefore a fixed design value of people must be used. Also in cases when the ventilation system is equipped with high efficiency heat recovery you do not save much energy by small decrease of air flow. Therefore you can afford higher ventilation rates without a big energy penalty.