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ANALYSIS OF VENTILATION RATE AND CONCENTRATIONS OF CARBON DIOXIDE IN THE OFFICE

The aim of the article is to establish the necessary air exchange rate in the room at the principal production carbon dioxide calculation and experiment. In order to determine the necessary volume the air flow was made more experimental measurements in selected rooms. From the measured data of concentration CO_2 by combination of graphic method and mathematical formulas we can determinate the required air flow which meets the hygiene requirements. The entire computation we can see on the example.

Key words: concentration of carbon dioxide, ventilation, flow.

Метою статті є встановлення необхідного рівня кратності повітрообміну в приміщенні на основі розрахунків концентрації вуглекислого газу та експериментально. Для встановлення необхідного об'єму потоку повітря були зроблені експериментальні заміри у обраних приміщеннях. З виміряних даних щодо концентрації CO_2 у комбінації з графічною методикою та математичними формулами можна визначити необхідну кратність повітрообміну, що задовольняє гігієнічні вимоги. Розрахунок супроводжується прикладом.

Ключові слова: концентрація вуглекислого газу, вентиляція, потік.

Introduction

According to EuroACE [1] are 57 % energy used in building heating, 25 % for heating hot water, 11 % for lighting and electrical appliances a 7 % for cooking. Improving the thermal properties of building and Improving air tightness of building, there is a change of air quality in buildings – without mechanical ventilation to a deterioration of air quality. People living in the room can not guess the momentary air quality. Ventilation is provided by subjective feelings. The low-energy and passive houses is about 80 % of the total heat consumed to heat the fresh air needed for living persons.

Measure the concentration of carbon dioxide

In the course of the research has been detected in the selected room (office for one people) measuring indoor environment parameters: temperature, relative humidity and carbon dioxide concentration.

Considered room: Office in the five floors building on the second floor. The Office has the dimensions: length 5,63 m, width 3,4 m and height 2,72 m.

In the room is one window with dimensions: height 1,75 m and width 1,1 m. the internal volume of the room is 52,07 m^3 and the floor area of the room is 19,14 m^2. In outdoor environments was the concentration of CO_2 C_{SUP}=380 ppm. During the measurement were in the room one adult person.

Measurement of the parameters of internal air: temperature of air, relative humidity and concentration of CO_2 was realized in winter from 1.2.2013 to 2.2.2013. For measurement of concentration of carbon dioxide was used sensor concentration of CO_2: C-AQ-0001R working by NDIR method. For measurement the temperature and relative humidity was used thermo-humidity meter S3541.

For mathematic definition of process concentration CO_2 from measured data was very important provide ideal conditions during the measurement. In addition to the measured internal parameters of air was clock data of parameters of outdoor air like temperature outdoor air and wind speed too. The data are manipulating on intensity ventilation by infiltration.

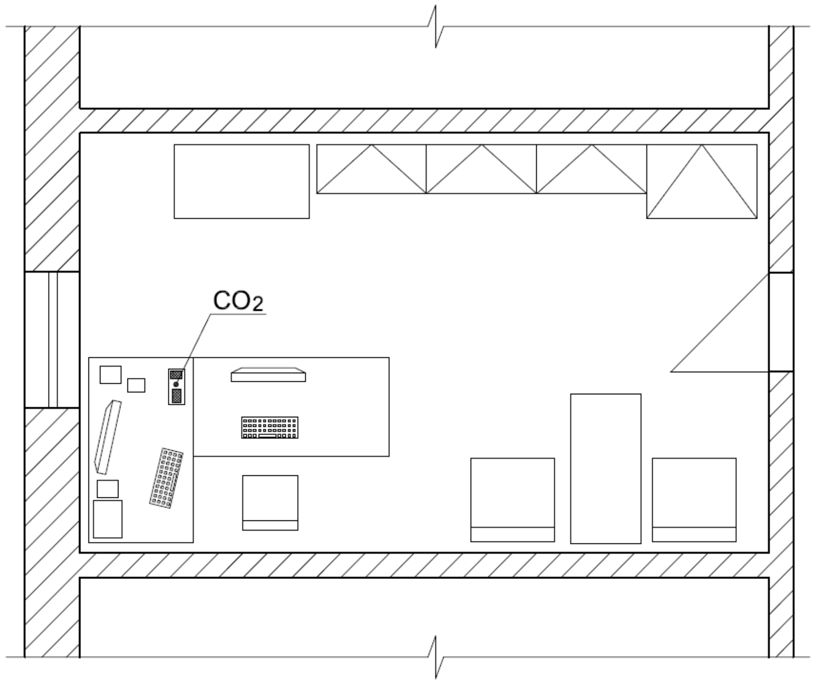

Fig. 1. Plan of the office with an indication of sensor concentration CO2

Analysis the concentration of carbon dioxide

Measured data of internal air are documented on the next picture. Form measured parameters is possible watch how the same with growing concentration CO_2 rising relative humidity too. If we want mathematically describe all process on the picture is necessary deal the chart for two main independents sectors and that are:

– Rising concentration CO_2, the time when is in the room resource of the pollutants – sector A-B,

– Ventilation of room by infiltration, when is not resource of the pollutants in the room – sector B-C.

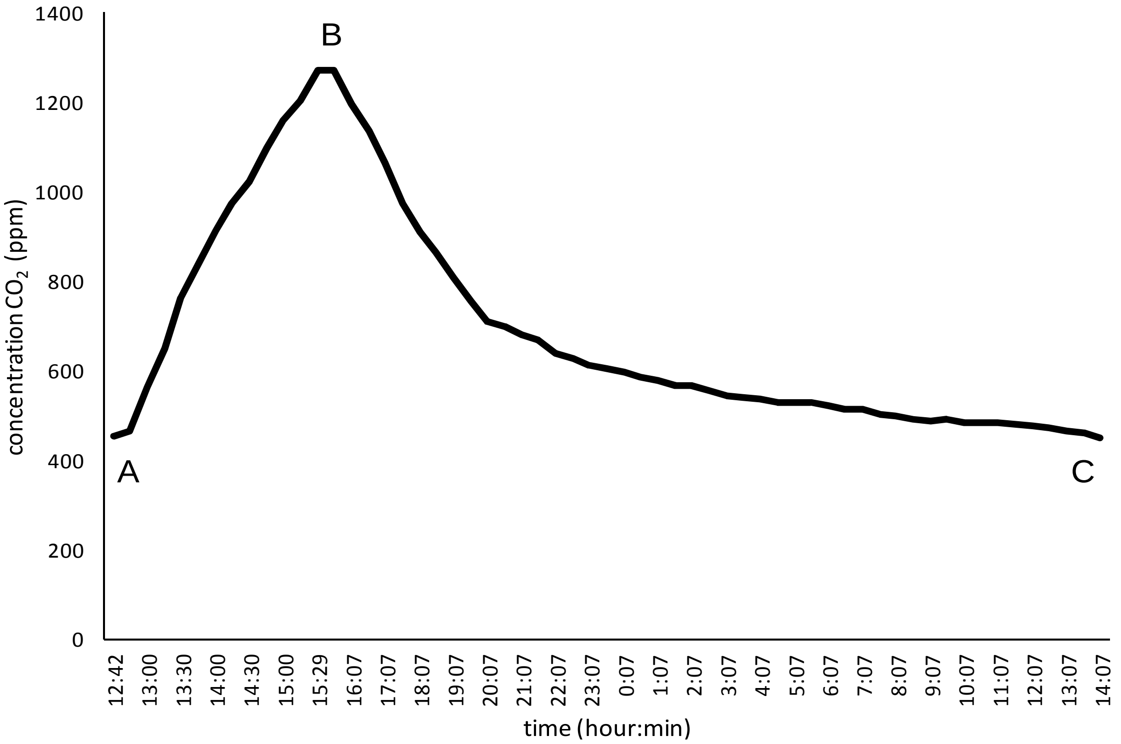

Fig. 2. Process of concentration CO_2 – separation on sectors

In sector A-B come into being to raising concentration CO_2, where the main resource is human. Rising of concentration CO_2 can be expressed by the formula [2]:

$$C_{IDA} = C_{SUP} + \frac{q_{ms}}{q_V} \cdot \left(1 - \exp\left(\frac{-q_V}{V_M}\right) \cdot t\right), \qquad [\text{mg/m}^3] \qquad (1)$$

Where: C_{IDA} – concentration CO_2 in air in the room in the time t [mg/m^3]; C_{SUP} – concentration CO_2 in supply air in the time t [mg/m^3]; $q_{mš}$ – weight flow CO_2 in the room form resource the pollutants [mg/s] q_V – volume flow of air necessary by ventilation of room [m^3/s]; V_M – volume of room [m^3]; t – time [s].

From listed parameters we know volume of the room, time of concentration CO_2, time of concentration CO_2, concentration CO_2 in units ppm, which we need to recount to units mg/m^3. Unknows parameters are for us volume flow of the pollutants and volume flow fresh air, which permeate into the room by infiltration.

The determination of intensity ventilation by infiltration from measured drop of concentration CO_2

In sector B-C in room isn´t any person so we can consider with zero production CO_2. Enhanced concentration CO_2, which was caused by presence of a person (sector A-B) in sector B-C gradually reduces by influence uncontrolled ventilation by infiltration. Whereas during the reduction of concentration CO_2 limited condition was changing (temperature outdoor air and wind speed) which were impacting on process of infiltration is necessary determinate intensity of ventilation form measured values concentration CO_2.

Intensity of air by infiltration in considered room we determinate from function drop of concentration CO_2 in independence of time.

$$\frac{C_{IDA,B} - C_{SUP}}{C_{IDA,C} - C_{SUP}} = e^{-nt} . \qquad (2)$$

By edit of equation we expressed intensity of ventilation by infiltration:

$$n = \frac{1}{t} \cdot \ln \frac{C_{IDA,B} - C_{SUP}}{C_{IDA,C} - C_{SUP}}, \qquad [1/s] \qquad (3)$$

Where: n – intensity of ventilation by infiltration [1/s]; $C_{IDA,B}$ – concentration CO_2 in room on the start reduction concentration [mg/m^3]; $C_{IDA,C}$ – concentration CO_2 in room at the end of reduction concentration [mg/m^3]; C_{SUP} – concentration CO_2 supply air in the time [mg/m^3]; t – time reduction concentration CO_2 [s]

Substitution parameters the air: $C_{IDA,B}$ = 2 288 mg/m^3; $C_{IDA,C}$ = 1752 mg/m^3; C_{SUP} = 683 mg/m^3; t = 7200s

$$n = \frac{1}{t} \cdot \ln \frac{C_{IDA,B} - C_{SUP}}{C_{IDA,C} - C_{SUP}} = \frac{1}{8100} \cdot \ln \frac{2288 - 683}{1752 - 683} = 0{,}00006\, 1/s . \qquad (4)$$

Volume flow the air calculating volume flow of air we calculate from detected intensity ventilation by infiltration and volume of the room:

$$q_V = n \cdot V_M = 0{,}00006 \cdot 52{,}07 = 0{,}0029 \text{ m}^3/\text{s} \qquad (5)$$

From measured concentration CO_2 was calculated intensity ventilation by infiltration n= 0,00006 1/s. next was calculated volume flow of air q_V = 0,0029 m^3/s, by whom was into the room uncontrolled supply fresh air by infiltration.

Determination mass flow of CO2

In the office was exercised work by one person in a sitting position, which produced CO_2 by breathing. For the expected average 0,5 liter volume of breath / exhale and for intensity of breathing from 12 to 20 breath per minute was calculated mass flow carbon dioxide.

Actual production carbon dioxide by breathing of person in the office we find graphically form the picture 3, where is for all the intensity of the breathing according to formula 1calculed process of concentration CO_2. On the picture with calculated process of concentration CO_2 je plotted course the actual measured value CO_2.

From the submitted curves is possible to observe, that actually production of the pollutants is corresponding to the intensity of breathing 15,5 breath per a minute, with which is corresponding produced mass flow of carbon dioxide 10,15 mg/s.

From graphic subject is possible to observe the course of concentration of CO_2 by different mass flow carbon dioxide. A person working in the office produces 10,15 mg/s.

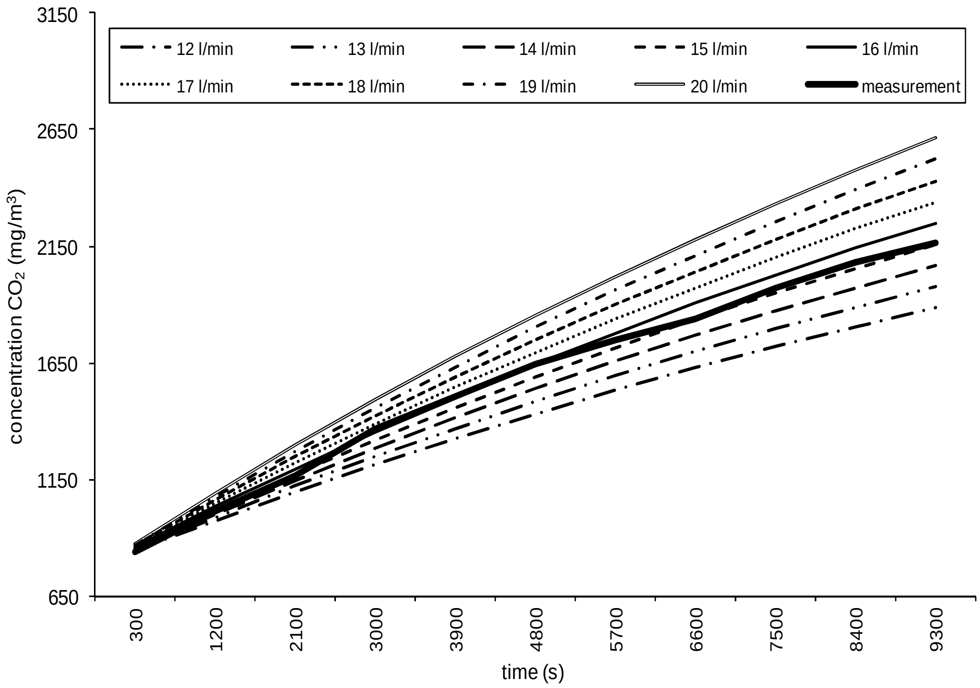

Fig. 3. The course of concentration CO_2 – according to intensity breathing

Determination volume flow of fresh air

Volume flow of fresh air we determinate similar graphically from course concentration $CO_{2.}$ By making course concentration CO_2 we use a formula 1, to which we substitute determinate mass flow CO_2, volume of the room and calculated started concentration CO_2. The calculation we perform for all hour and for different intensity of ventilation. The result is necessary adjusted so that the resulting value of concentration CO_2 was determinate in units' ppm. For our case are all results shown on next picture.

If we have required level of CO_2 together 1 000 ppm, next form the picture we are looking for course of concentration CO_2, which do not exceed the limit of the 1 000 ppm. In our case is it course of concentration with an indication of intensity ventilation 0, 7 1/h.

This method is enough exact but on finding necessary intensity ventilation is very hard and long. The resulting value of intensity ventilation we compare with values intensity ventilation obtained from other sources: legislation and applicable standards on the Slovakia.

Conclusion

According to the measured data of concentration CO_2 and calculated value of intensity ventilation in considered room is possible allege, that the result is the closest to actually necessary intensity of ventilation according to STN EN 13 779, where standard for all category of air IDA 2 determinate volume flow outsides air per person 45 m^3/hour – after calculated 0,86 – multiple exchange of air in the room.

Needed value ventilation rate detected by measurement is 0, 7 – multiple air exchange per hour in room. Calculated value meets from listed methods only calculation according to standard STN EN 13 779.

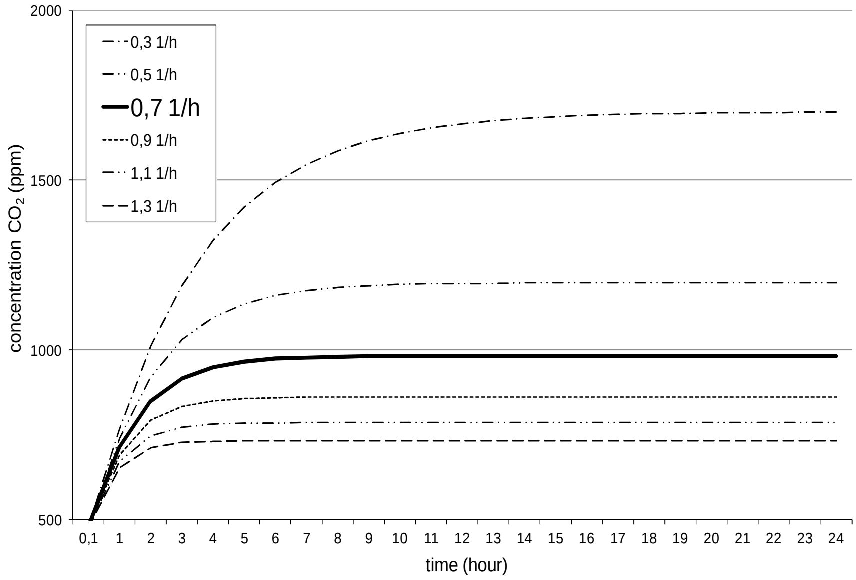

Fig. 4. The course of concentration CO_2 – for different ventilation rate

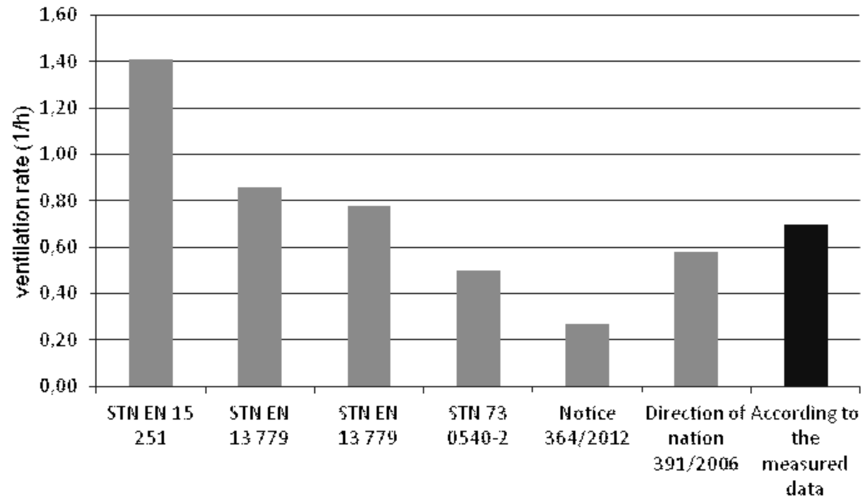

Fig. 5. Compare of ventilation rate

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1. EuroACE, Towards Energy Efficient Buildings in Europe, final report June, 2004. 2.STN EN 13 779:2007 Ventilation in non-residential buildings. General requirements for ventilation and air conditioning equipments. 3. STN EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. 4. S. S. Žukovskij, O. T. Voznjak, O. M. Dovbuš, Z. S. Ljuľčak: Ventilljuvannia primiščeň, Lviv, Vidavnictvo Nacionalnovo zniversiteta „Lvivska politechnika" 2007, ISBN 978-966-553-645-1, str. 45-47. 5. STN 730540: 2002, Thermal performance of buildings and constructions. 6. Direction 391/2006 Z.z. Nariadenie vlády Slovenskej republiky z 24. mája 2006 o minimálnych bezpečnostných a zdravotných požiadavkách na pracovisko. 7.D.Košičanová, P.Fedorčák: Progressive indoor technologies in buildings – reduce energy consumtion In: SGEM 2011 : 11th International Multidisciplinary Scientific GeoConference : Conference Proceedings : Volume 3 : 20-25 June, 2011, Bulgaria. – Sofia : STEF92 Technology, 2011 P. 77-84. – ISSN 1314-2704. 8. D.Košičanová, R.Nagy, I.Šenitková: Prenos a distribúcia škodlivín vo väzbe na sústavy techniky prostredia In: Košice : TU, SvF – 2011. ISBN 978-80-553-0829-6. 9. D.Košičanová, A.Sedláková:Energy precautions in buidings in dependence on energy consumption of buildings In: Budownictvo o zoptymalizowanym potencjale energetycznym. – Czestochowa : Wydawnictwo Politechniki Czestochowskiej, 2010 P. 146-150. – ISBN 978-837193-486-5.