with the decreasing value of a β parameter. With very low β parameters, the influence of the type of brace member becomes virtually negligible and unimportant.

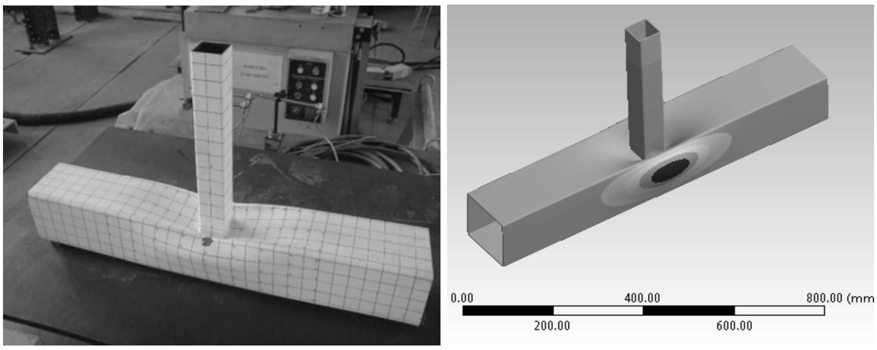

Figure 7. Comparison of the actual deformation of the specimen and the deformation modelled using the finite element method

Conclusion. The conclusions presented in this paper are only part of a number of results obtained in the experiments. The authors of the paper would like to continue in the analysis of such joints, while the main emphasis should be placed on the verification of the obtained results using an appropriate finite model for the joints in question.

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AIR QUALITY AND EFFECT OF VENTILATION IN BUILDINGS

Розкрито проблему якості повітря у деяких приміщеннях, зокрема у конференцзалі, офісних та класних кімнатах. Основною вимогою утворення здорового оточуючого середовища всередині приміщення і оптимальної інтенсивності праці людей є адекватна кількість свіжого повітря без фізичних чи хімічних забруднень. Фізичні та хімічні забруднення оточуючого середовища всередині приміщення часто продукуються працюючими там людьми. Діоксид вуглецю (CO_2) як хімічний забруднювач виділяється працюючими людьми через їх діяльність. Виділення CO_2 становить 4 % від усього повітря в приміщенні за температури від 34 до 36 °С.

Ключові слова: діоксид вуглецю, інфільтрація повітря, якість повітря, норми вентилювання.

The paper is concerned with air quality in selected ventilated rooms: conference room, office and classroom. The basic assumption for a healthy indoor environment and optimum occupant performance is adequate fresh air amount without the physical and chemical pollutants. The physical and chemical pollutants in indoor environment are also produced by occupants. The carbon dioxide (CO_2) as chemical pollutant is produced by occupants respecting human activities. The carbon dioxide production is 4 percents of the total air exhaled amount at the temperature of 34°C to 36°C.

Key words: carbon dioxide, air infiltration, air quality, ventilation rate.

Introduction. The experiments of Bucakova et al (2006) indicates that improving of classroom indoor air quality with higher ventilation levels 2, 4, 7 l/s.per substantially improve the school performance (1-3%). Increased ventilation rate usually increase the indoor air quality what definitely increase learning especially mathematic and problem tasks solving [1].

Indoor environment, carbon dioxide and ventilation The main indicator of human metabolic activity is carbon dioxide. The carbon dioxide is an atmospheric gas and it is composed of 2 oxygen atoms and one carbon atom. The carbon dioxide is also produced as by-product of biological processes (e.g. human breathing, fermentation processes, and carbon compounds combustion in the air). It is a colorless gas, non-flammable gas, little reactive and heavier than air. The human metabolic activity is characterized by metabolic unit "met". The human energy produced by surface body is represented by “met” and is a function of human physical activity (1 met-sitting =58.2 W/m2) [3].

The increasing of carbon dioxide concentration causes decreasing of human productivity and human concentrate ability. The high carbon dioxide concentration

The discomfort, perceived air quality and odors are also associated with higher carbon dioxide concentration. The carbon dioxide concentration in indoor environment depends on outdoor background concentration and occupants’ production. The outdoor background concentration values are of 350 to 450 ppm. The examples of CO2 background concentrations in outdoor environment according to European standard EN 13 779 are presented in Table 1 [4]. The outdoor background concentrations in Slovakia (Košice, city) were measured and correspond with values presented in Table 1.

Table 1

The examples of CO_2 background concentrations in outdoor environment according to European standard EN 13 779 [4]

Place type	Concentration					
	CO_2 ppm	CO mg m^{-3}	NO_2 µg m^{-3}	SO_2 µg m^{-3}	Total PM mg m^{-3}	PM_{10} µg m^{-3}
Non-city territory without important emission sources	350	< 1	od 5 do 35	< 5	< 0.1	< 20
Small cities	375	od 1 do 3	od 15 do 40	od 5 do 15	0.,1 – 0,3	od 10 do 30
Polluted city centre	400	od 2 do 6	od 30 do 80	od 10 do 50	0,2 – 1,0	od 20 do 50

The percentage of dissatisfied over the value 25% and discomfort in indoor environment are caused by CO2 concentration increase over the value 1000ppm. The relation between CO2 concentration and percentage of dissatisfied is presented in Figure 1. The increasing of CO2 concentration is caused by various types of human physical activity (Figure 2). The discomfort, headache and indisposition are also caused by production of various types of gases from human activity - breathing and perspiration. The discomfort, headache and indisposition are expressed at CO2 concentration over the value 2000ppm.

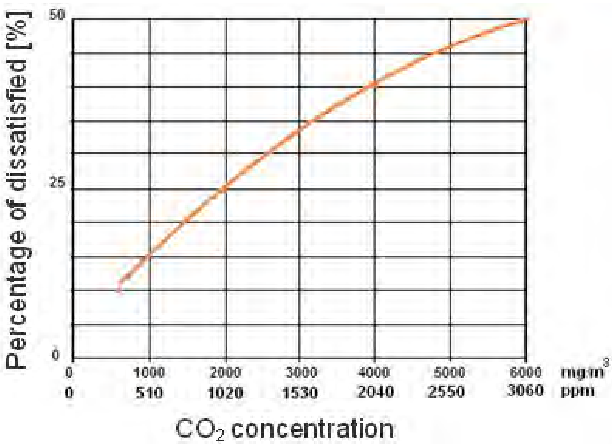

Figure 1. Relation between CO2 concentration and percentage of dissatisfied in indoor environment

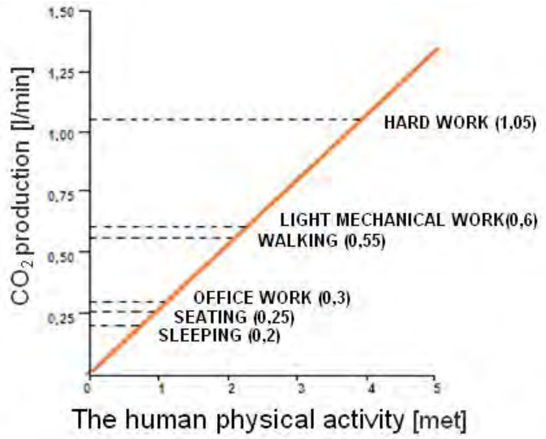

Figure 2. Relation between CO_2 production and human physical activity

The relation between CO_2 concentration and air ventilation rate are shown in Figure 3. In general, the CO_2 concentration under the value 1000 ppm is ensured by air ventilation rate at value 30m^3/h (8,3l/s).

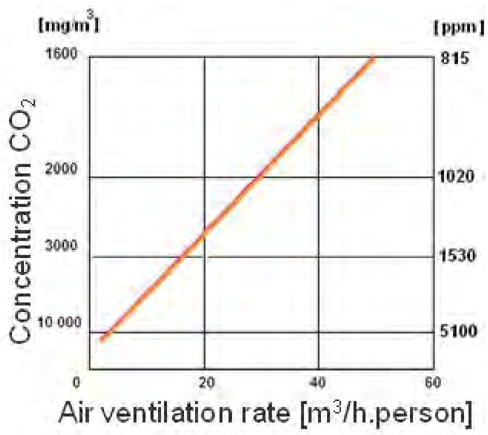

Figure 3. Relation between CO_2 concentration steady state and air ventilation rate

But the selection of ventilation system and air distribution system in relation to values of air ventilation rate presented in Figure 3 is not respecting. A lot of various investigations indicated that IAQ problems appear not only because of low ventilation rates, but also in cases when the location of exhausted and mainly supply jets (air distribution system) is not appropriate [5,6].

European standard STN EN 15251:2007

Three categories of indoor environment are specified for indoor ventilated spaces. Category A corresponds to a high level of expectation and leads to a highest percentage of satisfied occupants in respect of indoor environment, category B a medium level of expectation and category C to a moderate level of expectation. The designer may also select different levels using the same principles.

Recommended values of indoor CO_2 concentration for ventilated buildings are estimated as maximum CO_2 concentration above the outdoor concentration. Maximum CO_2 concentration is 350ppm (category A), 500ppm (category B) and 800ppm (category C) above background outdoor concentration for expected indoor air quality [7].

Ventilation and infiltration

The ventilation systems especially in the school buildings are important for providing a healthy and comfortable environment for their occupants. The impact of ventilation rates but mainly ventilation systems and air distributions schemes are the keys how to improve IAQ in breathing zone. The field measurement confirmed that the indoor air quality is generally unacceptable by lower ventilation rates because of not respecting the occupancy density of the spaces. The non-uniformity chemical pollution related to selected distribution system was investigated using the CO2 concentration in next presented study.

Recent studies deal with ventilation rates by infiltration confirmed, that in some cases the influence of air infiltration as addition to ventilation rate by mechanical ventilation can help to improve the indoor air quality conditions in school buildings [8]. The results of infiltration quantification are presented in Figure 4. Figure 5 presents ventilation rate that should be supplemented by mechanical ventilation to fulfil the requirements in according to European standard STN EN 15 251.

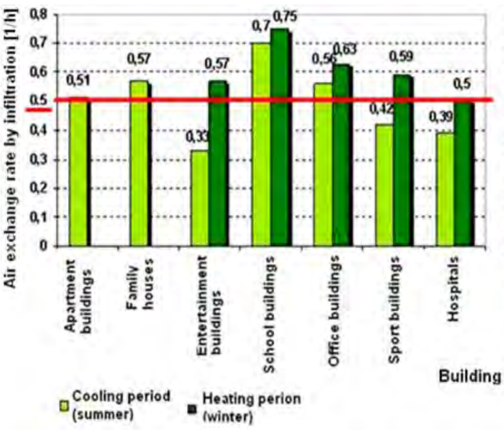

Figure 4. The quantification of air exchange rate (summer, winter)

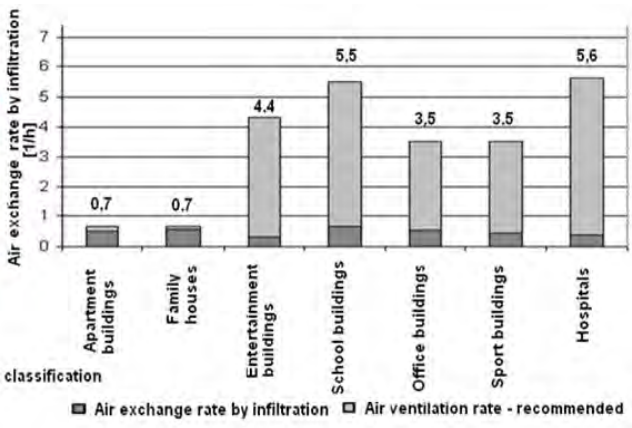

Figure 5. The share of infiltration and mechanical ventilation to total ventilation rate recommended according to STN EN 15 251

Natural ventilation in operation – experimental measurements

University workplace – meeting room (case study 1)

The research is focused to detection of air temperature and CO_2 concentration for standard human activities carried out in the workplace environment. The university environment for presented experimental measurements was used. The first measurement was realised in meeting room occupied by 14 persons during operation. The space volume is $98m^3$. Initial indoor air temperature was 25.6°C and initial indoor CO_2 concentration was 500ppm. The window was ajar and natural ventilation was ensured throughout all the time. The indoor air temperatures and CO_2 concentrations in time were measured, recorded and presented in Figure 6.

The university room occupation started in 4-th minute and continued to 11-th minute. Entrance door to corridor and window was opened during occupation. The fluctuation of CO_2 concentration during of 4-th to 11-th minute was caused by draft when door and window were opened. The active meeting starts after 11-th minute and continued until 30-th minute. The one person active lectured and others audiences were sitting at rest. The CO_2 concentration was stabilized and decreased during of 11-th to 30-th minute. The CO_2 concentration was increasing after 30-th minute when discussion was started. The air temperature was increasing and CO_2 concentration did not exceed value 1000ppm during all operation. It was not necessary mechanical ventilation during all operation. Consultation was completed after 45-th minutes.

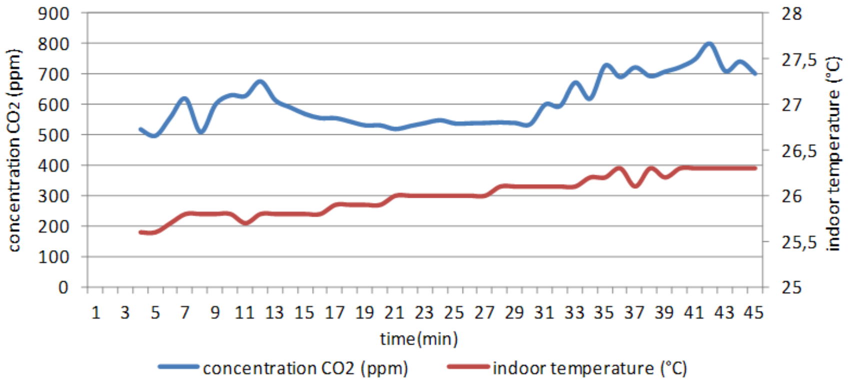

Figure 6. The CO_2 concentrations and indoor air temperature (University room) (time interval 45 minutes)

Single office room (case study 2)

The second experimental measurement was realised in single office room for one occupant. The space volume is 37m3. The subject of the investigation was to determine for how long time will CO2 concentrations over value 1000ppm when windows closed. The next subject of the investigation was to determine for how long time will CO2 concentrations back to background outdoor concentration when windows closed. The single office room is equipped by wooden window with a damaged weather-strip and window is not tight. The indoor air temperatures and CO2 concentrations in time were measured, recorded and presented in Figure 7. The window was closed on 16:00pm (hour), indoor air temperature was 25.1°C and the CO2 concentration was 492 ppm (measured values). From 16:00pm to 18:00pm one occupant was in the single office room and the windows were closed. The CO2 concentration value increased from 492ppm to 1050ppm and indoor air temperature increased from 25.1°C to 25.8°C for 2 hours.

The single office room was leaved by occupant after 18:00pm. The door and windows were still closed. The CO_2 concentration was decreased fastly from 18:00pm to 19:00pm and after 19:00pm was decreased only moderately. The CO_2 concentration value was reduced to background value for 13.5 hours when the window was closed.

The CO_2 concentration value was reduced to background value for 0.5 hours when the window was opened but the measurement is not presented in figure.

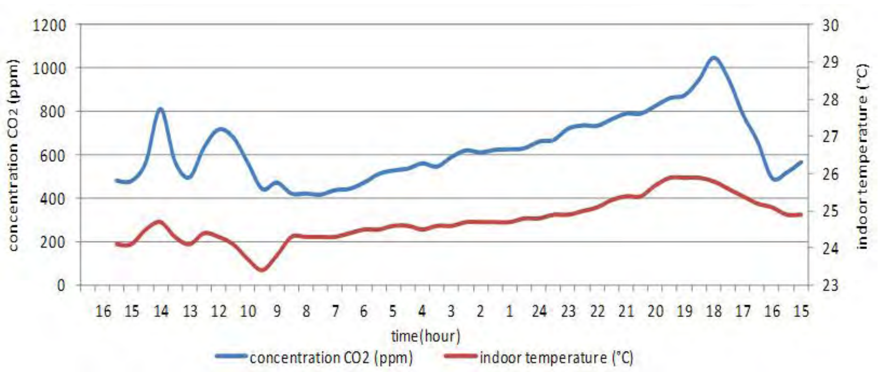

Figure 7. The CO_2 concentrations and indoor air temperatures (Single office room) (x - axis shows hour time from the right side to left side, from 15:00pm to 16:00pm another day)

University classroom (case study 3)

The third experimental measurement was realised in university classroom during the written exam. The space volume is 120m^3. The measurement device was installed in an empty classroom about 7:50am and the windows were opened. The windows orientation is to the west. The indoor air temperatures and CO_2 concentrations in time were measured, recorded and presented in Figure 8.

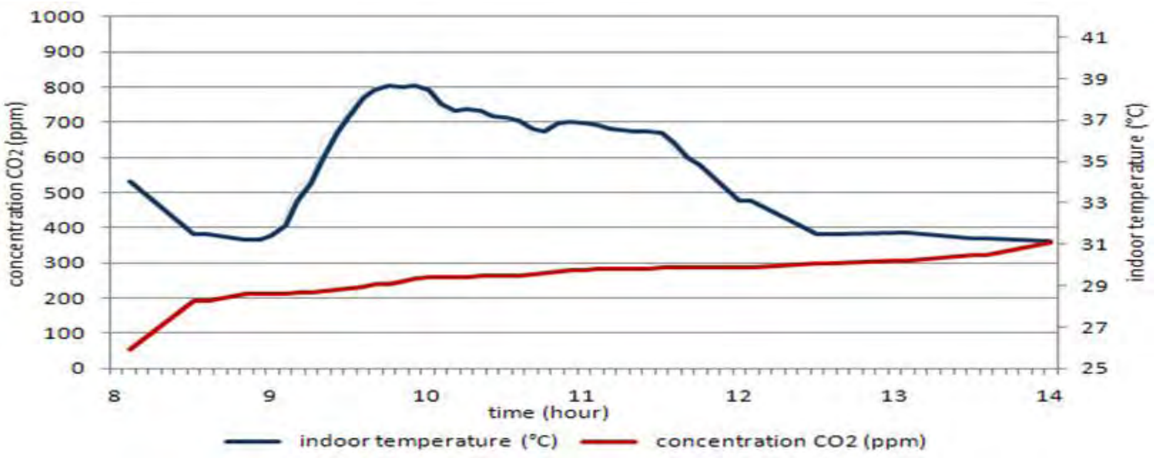

Figure 8. The CO_2 concentrations and indoor air temperatures (University classroom)

The classroom was empty to 9:00am. Indoor air temperature increased from 25.9°C to 28.3°C from 7:50am to 8:30am and CO_2 concentration value decreased from 531ppm to background outdoor concentration value 382ppm. The indoor air temperature and also CO_2 concentration were stabilised in initial measuring hour. The classroom was occupied by 15 occupants from 9:00am (start). The first half hour was an interview with the students about the exam process. The written exam started at 9:30am. The CO_2 concentration increased to maximum value in first half (at about 10:00am) and after 10:00am started to decrease. The initial stress of students increased CO2 concentration between 9:30am and 10:00am when the written exam was started. When the students worked quieter after 10:00am CO2 concentration was decreased. The students left the classroom at 11:35am. The classroom was empty and the windows remained open to14:00pm. The CO_2 concentration was sharp reduced for the first half hour.

Natural ventilation vs. mechanical ventilation – experimental measurement and simulation (high density occupation)

University classroom (case study 4)

At the first stage some introduction studies for general screening knowledge were realized towards to CO_2 pollution in the buildings with high density of occupation.

In the most of observed classrooms without mechanical ventilation average carbon dioxide concentration exceeded 2000 ppm. The problem represents also classrooms with mechanical ventilation, where designed ventilation systems and selected air distribution schemes have been insufficient response towards to CO_2 concentration increasing.

The average carbon dioxide concentrations during 1 hour in school buildings are presented in Figure 9. The results show carbon dioxide increasing in the both cases, with and without mechanical ventilation. The very similar results from experimental measurement and simulation in individual cases were obtained. The concentration growth is more evident in the case without mechanical ventilation because lower ventilation rate (only infiltration q_{TOT} = 17 [l/s]) than in case with mechanical ventilation with higher ventilation rate (q_{TOT} = 170 [l/s]).

Recommended concentration for all indoor air categories (A, B, C) was exceeded also in the case with mechanical ventilation even the exceeding was not so expressive than in case without mechanical ventilation.

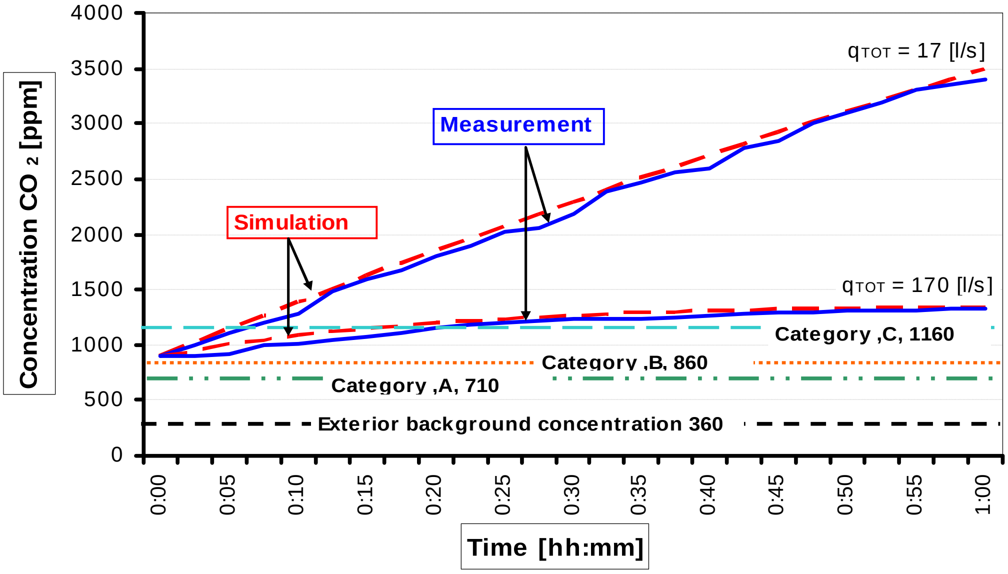

Figure 9. Carbon dioxide concentration, without mechanical ventilation (q_{TOT} = 17 [l/s]) and with mechanical ventilation (q_{TOT} = 170 [l/s])

Conclusion.

Results and discussion – natural ventilation in operation (case studies 1-3)

Presented experimental measurements referred that CO_2 concentration increase was not so massive to endanger human health. When the CO_2 concentration was increased over 1000ppm, odors were smelled as a result of human occupancy. All measurements were only with natural ventilation without mechanical and demand control ventilation (case studies 1-3).

The measurements of CO_2 concentration, indoor air temperature and humidity will be the subject to further research. The mutual relations, interactions and accompaniments of individual measured quantities will be investigated. The CO_2 concentration scale at different air temperatures and humidities will be created in the order to determine the necessary air ventilation rate. The hygiene and energy requirements must be respected.

Results and discussion – natural ventilation vs. mechanical ventilation (case study 4), (high density occupation)

Preliminary investigations for high density occupation have indicated that indoor air quality problems appear not only because of low ventilation rates using the natural ventilation, but also even when mechanical ventilation with higher ventilation rate is not proper designed. The location of supply and exhaust jets are usually not appropriate. Indoor air quality may be improved not only by increasing of ventilation, but also by favorable ventilation strategies.

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