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Overview and assessment of radiant systems in three administrative buildings

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Abstract. Administrative buildings should provide an acceptable environment for people's work where is no excess heat, draught, noise, or low internal air temperatures. It is necessary to provide thermal well-being in each administrative building, but especially in those where the facade is of the prevailing glazed window structures.
The aim is to eliminate thermal gains and to ensure the required conditions for residence and work in administrative buildings. It is necessary to propose appropriate systems of building environment techniques. Radiant systems, low-temperature heating and high-temperature cooling, can suitably ensure an optimal environment throughout the year.
In this contribution, three applications of radiant systems in three different administrative buildings are described. In the first administrative building is the dry application system - suspension radiant covers; in the second administrative building the capillary mats are applied. The concrete core activation system has been applied in the last administrative object. The parameters of the inner environment were examined: air temperature, operating temperature, relative humidity, and airflow rate. The CO2 concentration was measured for further measurement to assess the quality of the internal air. These objective measurements and subsequently subjective evaluations of people located in the measured space were compared with the requirements of international standards for the evaluation of the internal environment. From the measurement overview, we can say that in most measured offices, the parameters of the internal environment meet the normal values of the comfortable environment, suitable for work and residence in the workplace. During the summer season, objective evaluations corresponded to the requirements of the standard, in terms of subjective evaluation, the results were evaluated at the upper range of acceptability. For the winter period, the internal air temperature was slightly increased compared to the standards requirements, but in terms of subjective perception, the space was perceived as favorable.

Keywords. Radiant systems, low- temperature heating, high- temperature cooling, indoor environment, administrative builiding
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1. Introduction

A radiant system consists of low-temperature heating during winter and high-temperature cooling to ensure an acceptable environment throughout the year. By combining radiant systems and their placements, we can customize the required demands for any building. The combined system can also be used as one system placed in the same structures. Complying with the recommended values of the Ministry of Health, which describe the internal temperature, air flow rate, and moisture, we will provide the conditions required for the hygro- thermal microclimate. The surface temperatures of the structures are also important in order to avoid thermal discomfort.
The following chapters will describe three radiant systems in three different administrative buildings. The applied heating and cooling systems were subsequently assessed and evaluated in the following chapters. Based on previous measured from 2009 and 2011, a new assessment has been made for the indoor air quality.

2. Types of radiant heating/ cooling systems

Radiant systems that have water as a heat transfer substance transmit heat/cold into the room through the radiation prevailing over convection.

The group of radiant low-temperature heating includes: (2, 3)
- underfloor heating,
- wall heating,
- ceiling heating.

System types radiant heating/ cooling systems:
Insulated pipes from the main building structure: (2, 3)
- TYPE A,
- TYPE B,
- TYPE C,
- TYPE D,
- TYPE G,

Thermo - active building systems (TABS): (2, 3)
- TYPE E,
- TYPE F.

2.1 TYPE A System with pipes built into the plaster - wet system

This system, which has pipes built into in plaster, mortar, or concrete, is called a wet system. It is the most commonly used system in Europe and is applied to underfloor heating. (2, 3)

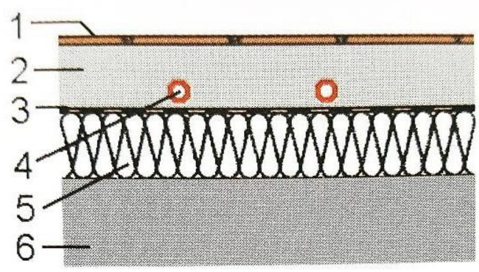


Fig. 1- TYPE A system with pipes built into the plaster: 1= floor covering, 2= carrier and heat distribution layer, 3= protective layer, 4= heating cooling pipes, 5= insulating layer, 6= floor construction (2, 3)

2.2 TYPE B system with pipes built into the thermal insulation layer, dry system

The pipes are stored in a system board, the function of which is as a thermal insulation layer. Temperature transfer from pipe to pipe is limited through the system boards. Well-conductive boards are used to streamline transmission. (2, 3)

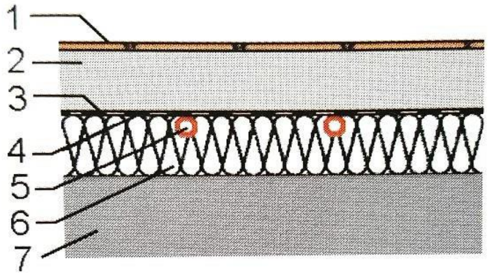


Fig. 2 TYPE B system with pipes built into the thermal insulation layer: 1= floor covering, 2= carrier and heat distribution layer, 3= protective layer, 4= Waterproof layer, 5 =heating/ cooling pipes, 6= insulating layer, 7 =floor construction (2, 3)

2.3 TYPE C system with pipes built into the bulkhead

The tubes in this system are placed in a leveling layer above which there is a second layer of screed, these layers being separated by layers of foil. (2, 3)

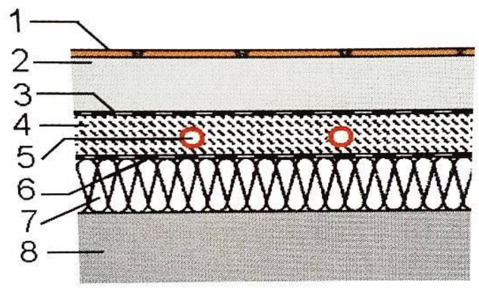


Fig. 3- TYPE C system with pipes built into the bulkhead: 1= floor covering, 2= supporting and heat distribution layer (screed), 3= double separating layer, 4= leveling screed, 5= heating / cooling pipes, 6= protective layer, 7= insulating layer, 8= building construction documents (2, 3)

2.4 TYPE D area system by sections

Instead of a number of single-pipe systems, this system uses extruded plastic panels with small capillary networks of channels in a planar section. This system is rarely used because it is more expensive and its installation is more complicated and depends on the quality of the installation. (2, 3)

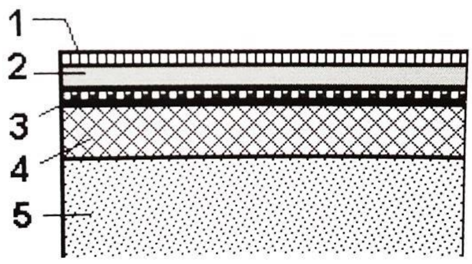


Fig. 4- TYPE D area system in sections: 1= floor covering, 2= load-bearing and heat-distributing layer (screed), 3= surface element, 4= insulating layer, 5= building construction of floors (2, 3)

2.5 TYPE G system with pipes built into a wooden structure

The pipes can also be applied to or under wooden structures, depending on the use of selected methods in construction. They can be fixed to the floor surface or they can be embedded in concrete. The pipes are in the range of 50 to 100 mm intervals. (2, 3)

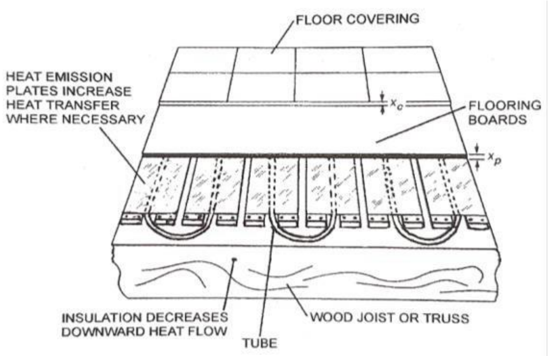


Fig. 5- TYPE G system with pipes built in wooden construction (2, 3)

2.6 TYPE E System with pipes built into the supporting structure

Active ingredients are walls, floors, and ceilings used in which pipes are applied to the neutral center of the concrete slab between the reinforcement, but the position may differ from the composition of the structure. The diameter of the pipes ranges from 17 to 20 mm with a pipe spacing of 150 to 200 mm. (2, 3)

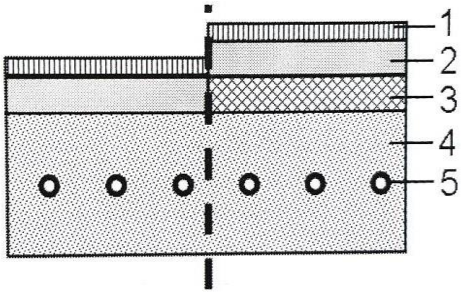


Fig. 6- TABS with and without acoustic insulation: 1 = floor surface covering, 2 = screed material, 3 = acoustic insulation, 4 = building structure, 5 = plastic pipes (2, 3)

This type E of application for radiant heating/ cooling was used in the measured Building C. In the next chapter 3 this system si more described.

2.7 TYPE F capillary mats built into the inner surface layer

Cooling grilles made of small plastic tubes with a diameter of 5 mm, which are placed close together, can be placed in plaster or plasterboard fixed to the ceiling, floor, or wall. (2, 3)

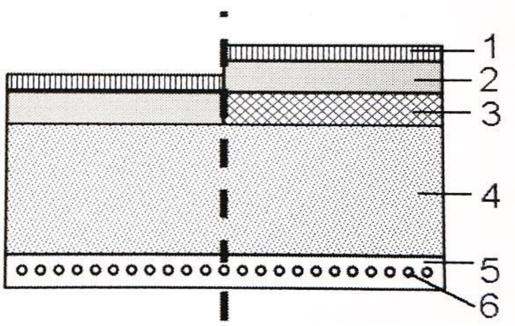


Fig. 7- TABS F with and without acoustic insulation: 1 = floor covering, 2 = screed material, 3 = acoustic insulation, 4 = building structure, 5 = plastic micro pipes, 6 = plaster or gypsum (2)

This type F was applied in Building B, where the measures were made. In the next chapter 3 is described this application.

3. Description of administrative buildings with radiant systems

3.1 Suspended ceiling system - Building A

The administrative building on Tomášikova in Bratislava was built in 2008. The building has two underground floors and eight floors. The facade contains double transparent glazing. The open-space offices and also the classical one local offices are located from the 2nd to the 8th floor. In the administrative part, fresh air is supplied to the office space by air distribution under the floor.

Fig. 8- View of office building A

Heating and cooling of an administrative building A use suspended radiant panels located on ceiling structures. Heating/cooling copper pipes have 8 and 12 mm diameters and are located in panels that are subsequently attached to ceiling structures. Cool panels cover most of the ceiling surface. The ceiling heating/cooling panels are suspended under a concrete plate. The radiant ceiling is composed of: insulation, hangers, pipes, wire net, plaster.

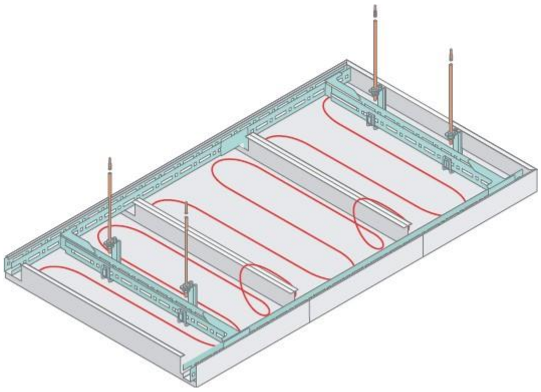


Fig. 9- Radiant heating/cooling system embedded in the ceiling panel (6)

3.2 Capillary pipe system - Building B

Administrative building B is located in Petržalka city district in Bratislava. It consists of two separate blocks: Block A, which has 5 floors, and block B, which has 8 floors. This administrative building B was built in 2009, has a full-glass facade. Fresh air is supplied to the office space by the mechanical ventilation system under the ceiling by slotted air diffusers.

Fig. 10- View of office building B

The capillary mats built into the inner surface layer of the ceiling structure heating or cooling this administrative building B throughout the year. The tubes in the mats have a diameter of 5 mm and are placed 30 mm below the surface plate of the support under the plaster of the ceiling structure. The cross section of construction can be seen in Fig. 7.

3.3 TABS system - Building C

Building C also has a radiant system. The administrative object is located in Bratislava, and has a full facade made of glass. The air supply is provided only by natural ventilation. Building C was built in 2008 and consists of two blocks: block A, which has 7 floors, and block B has 4 floors.

Fig. 11- View of office building C

In this administrative building, the thermal active building system (TABS) is used. Tubes are placed in carrier concrete structures. The diameter of the pipe is 20 mm. This is also called concrete core activation, where the tubes heat/cool the support structure. The cross section of construction can be seen in Fig. 6.

4. Methodology of thermal state assessment

4.1 Objective of the assessment

The surface temperatures of heating/cooling surfaces are due to their physical substance with a dominant parameter in creating thermal well-being in the internal environment.

- Subjective assessment is important for comprehensive assessment of the internal environment. According to this study, the temperature and users were subjectively evaluated by the temperature in the offices.

- One of the most favorable parameters in LTH/ HTC buildings is air flow rate. Mechanical ventilation is used to provide fresh air in the room and not to cool, so the speed and quantity of the supply air is relatively small compared to the conventional cooling methods of similar air buildings.

4.2 Assessed parameters

Experimental measurements were performed in three administrative buildings with glazed facades with various heating/cooling radiation systems. The parameters of the internal environment were measured and also performed in both summer and winter. (7, 8)

Subsequently, the measured values were assessed with the requirements of national and European standards (EN, ISO, CR), subjective assessment of space users.

Local (short-term) measurements were carried out

in each building, during the first week in the summer and during the first week in the winter:
- Inner air temperature (° C), operative temperature (° C), relative humidity φ (%), air flow rate (m/ s).

For local (short-term) heat condition measurements, Brüel & Kjaer 1213 (Indoor Climate Analyzer) was used with appropriate sensors. Measurements were made at individual locations in the office:

• on communication sites in the office - in the head area of a standing person 1.7 m, the center of the body area 1.1 m, and 0.1 m above the floor. Operating temperature was measured only at the height of the center of the body area 1.1 m above the floor.

• in a person's working area - in the head area of the seating man that was 1.1 m, the center of the body area 0.6 m and the ankle area of the seating man 0.1 m above the floor. Operational temperature was measured only in the center of the body area 0.6 m above the floor.

To ensure relevant data from the measurement of quantities, the values were readings: relative humidity and air flow rate up to 3 minutes from the start of measurement and the values for the operational temperature up to 20 minutes.

In Builing A was measured 2 floors 5.th and 8.th, in which there were 10 data loggers on each floor.

In building B, for measurements were done in single offices and also open-plan offices. In the summer 25 data loggers were used. In the winter there were 6 data loggers.

In Building C for measurements were done in single offices on the 3rd and the 5th floor, with 6 data loggers on each floor.

4.3 The results

Inner air temperature θ_a

In winter, the inner air temperatures in building A ranged from 22 to 25.0 ° C (Fig. 12). Building A meets the requirements of III. category from the STN EN 15 251 standards for acceptable heat ranges for heating. (4) The average exterior temperature was typically winter weather during exterior measurements of approximately -4 ° C.

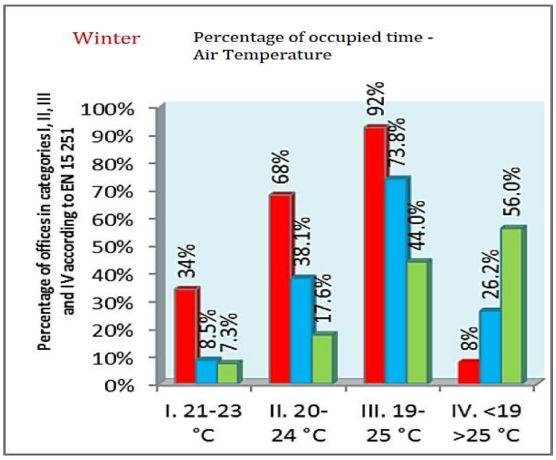
Building B was included in the category III**.** In winter the temperature in the winter ranged from 22.5 to 26 ° C (Fig. 12). It is possible to say that the administrative building is overheated.

In a building C with the built-in TABS system, the temperature during work hours in the winter ranged between 23 to 24 °C (Fig. 12). A great influence on air temperature has natural ventilation windows. Since the building has only a simple facade, the impact of exterior air was very significant. This can be seen in the indoor air temperature values during lunch, when employees were allowed to vent and the temperature decreased significantly. This was also reflected in the high percentage of working time during which the building has fallen into the IV. categories according to STN 15 251. (4)

Most of the internal air temperature, 85% measured in the summer in building A was in the range of 24 to 26.0 ° C and in building B it was 81,9% between 22 to 24.5 ° C (Fig. 12). Building A meets the requirements of II. category according to STN EN 15,251, for acceptable temperature ranges for cooling, while building B with the capillary mats is at the bottom boundary of the II. category up to III. category. (3)

The measurements were made under typical conditions in summer (average daily outdoor temperature 31 to 33 ° C).

Building C: The inner air temperature was about 25 to 26 ° C in the summer.



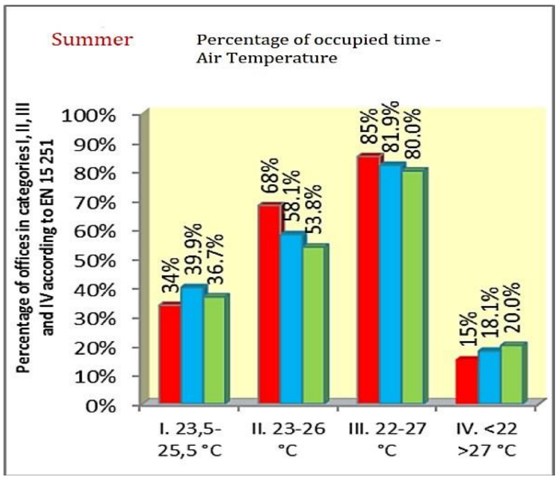


Fig. 12- indicates the percentage of working time during which the air temperature corresponded to individual categories according to STN EN 15 251. (1, 4) (red- building A, blue- building B, green- building C)

Operative temperature θo

In building A: The operating temperature in open-space offices ranged from 24 to 26.0 ° C in winter (Fig. 13). Due to the winter period, this temperature is slightly higher, but still at the acceptable level corresponding to the standard. Compared to subjective assessment (questionnaires), the employees were satisfied with a slightly warm indoor environment. In summer: the operating temperature was 25.8 to 27.0 ° C. In cell offices, the temperature ranged between 24.5 and 26.0 °C. In general, the operating temperature on the highest floors was 0.9 ° C higher than on a typical floor.

Building B: In winter, the operating temperature in building B with capillary mats was equal to the internal air temperature, therefore slightly lower than in building A with a suspended subheading of about 24 ° C.

In summer: the operational temperature was around 23.0 - 24.0 in the capillary mats.

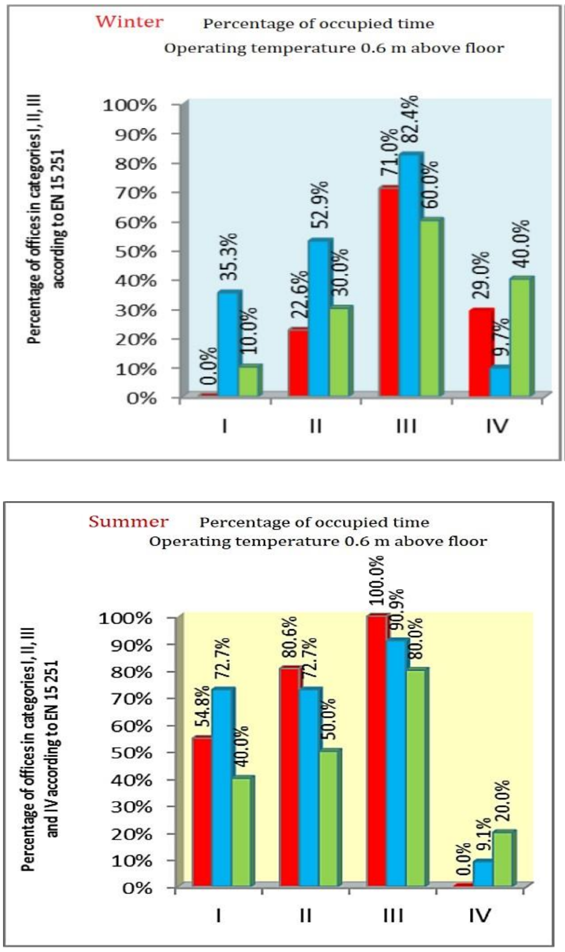


Fig. 13- indicates the percentage of working time during which the operative temperature corresponded to individual categories according to STN EN 15 251. (1, 4) (red- building A, blue- building B, green- building C)

Relative air humidity φ

Relative air humidity ranged from 30% to 40% in both buildings- A and C corresponding to the requirements of the standard STN EN 15 251 (Fig. 14). The values are in view of the winter heating period closer to the lower limit of the permissible standard, but there is still an effect too low humidity for employees.

In building C, there was relative humidity at the lower limit of the standards. However, this condition is caused by air drying due to heating, and the building has no mechanical ventilation, it would only be changed by local air humidifiers.

Relative air humidity in building B in the winter moves below the requirements of the standard (below 30%); therefore, it would be good to increase the moisture to avoid adverse impact.

Relative air humidity was around 50% in the summer, what it is the favorable value of relative humidity for the summer period.

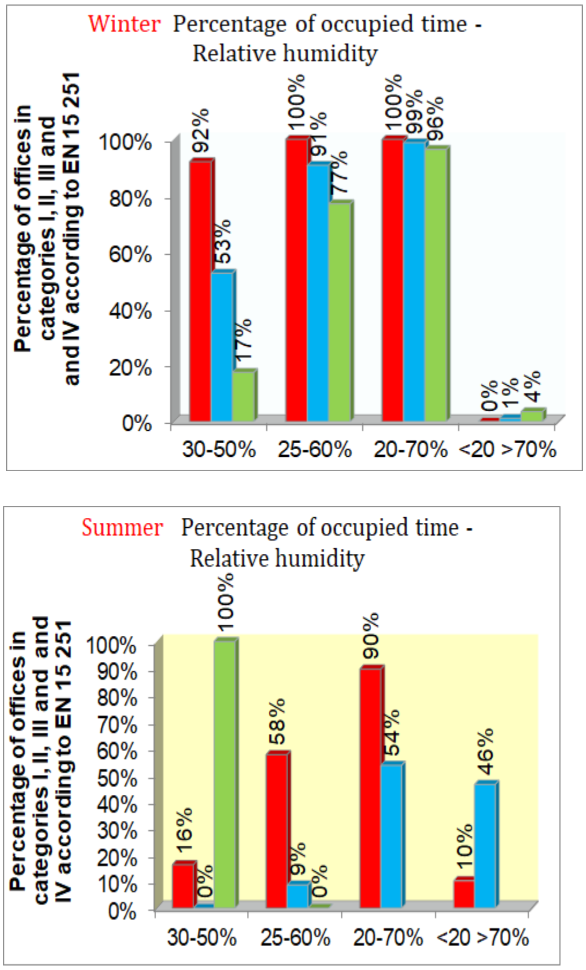


Fig. 14- indicates a percentage of working time during which the relative humidity corresponded to individual categories STN EN 15 251. (1, 4) (red- building A, blue- building B, green- building C)

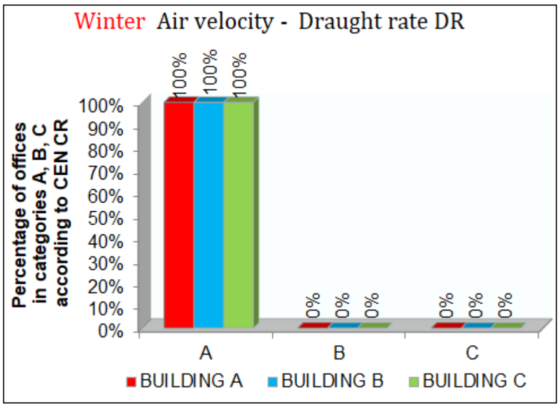
Air velocity v_a

Building A in the summer and also in winter was similar to air velocity. The average value was 0.09 m/s (Fig. 15). In large offices, the air flow rate was slightly increased in several places, but it still corresponds to the requirements CR 1752. (5)

Building B - the average air velocity was in both heights slightly lower than in building A - moved around 0.05 m/s to 0.1m/s. The difference between head height and ankle height was 0.02 m/s.

The airflow rate in building C was 0.1m/s, which was very low. The exception in the measurements was the office in which the window was opened. However, this condition is temporary and was removed after the window was closed.

All buildings are classified in A category which is defined in this category (<0,15 m/s) according to CR 1752. (5)



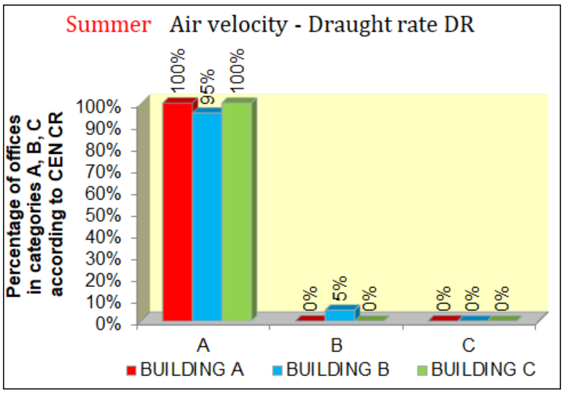


Fig. 15- indicates the percentage of working time in which the final value corresponded to the individual categories of the technical regulation CEN CR 1752. (1, 5) (red- building A, blue- building B, green- building C)

CO2 concentration measurements

Building A: Percentage of occupied time (occupied time), during which the indoor CO2 concentration above the outdoor concentration in the offices fell into the I. category according the standard EN 15 251 in winter (October - April) and in summer (May – September).

Building B and C were not measured for long-term and short-term measurements did not show the full value.

Subjective assessment

Subjective assessment is an important part of the comprehensive assessment of the internal environment. According to the results of the subjective assessment, the internal environment for most users is acceptable in all parameters covered by the questionnaire survey: the acceptability of the environment, the acceptability of the thermal environment, the acceptability of moisture, the flow rate and the quality of the internal air. The thermal sensation in all buildings evaluated users in the winter as slight heat, but the acceptability of the thermal state of the environment was rated as acceptable. It follows that they were happy with this slightly warm environment. However, the findings through objective measurements appeared to be a moderate precursor. In summer, the thermal feeling of users was rated as neutral. Likewise, users considered this condition acceptable.

In two of three building (buildings A and B) subjective evaluation was carried out due to the questionnaires in both summer and winter.

Building A: Percentage of the time the predicted mean vote in offices in categories according the standard ASHREA 55 [9] for winter season are in A category (35,3%), in B category (70,3%) and in last allowed category C (82,4%). For summer season it was 40,0% in A category, 76,5% in B category and in last allowed category C it was 83,6%.

Buiding B: Percentage of the time for winter season are in following categories: in A category (4,6%), in B category (62,7%) in last allowed category C (100%). According to the standard ASHREA 55 [9] for summer season are in following categories: A category (76,8%), in B category (100%) and there was no data outside the allowed categories.

Building C: Percentage of the time the predicted mean vote in offices in categories according the standard ASHREA 55 [9] in the winter season are in A category (8%), in B category (46%) and in last allowed category C (88%). For summer season it was 33% in A category, 80% in B category and in last allowed category C it was 99%.

According to Ashrae [9] the categories were category A (-0,2 < PMV < +0,2), category B (-0,5 < PMV < +0,5) and category C (-0,7 < PMV < +0,7).

5. Acknowledgement

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6. Conclusion

The internal air temperature in all three buildings moved to the upper limit of standards in winter. Given the user's preference (employees) to a higher temperature led to moderate precursor. But in view of the nature of sitting administrative work, it does not disturb significantly. In the summer, there was very favorable thermal conduct in all buildings. It is clear from year-round measurements that the thermal condition is very stable throughout the year, with little differences thet are not audible or different oriented offices.

The relative air humidity in the building A moved at an acceptable level. In building B and C there was less moisture in winter, it moved closer to the lower limit of standards requirements, but still not at the level at which it could come to the difficulties caused by dry air. The reduction in moisture is due to a higher degree of heating, which naturally occurs in air drying in winter. In summer, relative humidity ranged between 50 to 60%, which is a favorable value in terms of residence.

The air flow rate in all three buildings corresponds to the highest categories of international standards requirements. In the internal space, there is no increased air flow or draft.

In the end, it can be stated that all three types of heating/cooling - with a suspended ceiling system, with capillary mats, and with a concrete core activation system - have a favorable impact on the internal environment and thermal well-being of users without unnecessary risk of creation and beneficial effects on the employees that move in the space.

It is very important to choose the correct type of low-temperature heating system (type E/ type F/ ceiling radiant panels) for different types of buildings (massive construction, light construction, etc.)

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The datasets generated during and/or analysed during the current study are not publicly available because building operators did not allow us to provide gathered data from measurement but will be available after individual communication and disclosure of data available after authorization.