

The influence of building and installation conditions on shaping the optimal conditions of room microclimate

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Abstract. We expect comfortable conditions when staying in a room for a long period of time. Architectural and constructional conditions (including, in particular, thermal parameters, or radiation transmittance - for transparent elements), and installations in confrontation with external conditions shape the microclimate of rooms. The standards and trends in the development of construction technologies, especially in terms of energy efficiency, equipment and installation systems, the role and the parameters of comfort in the rooms of contemporary solutions have been presented. The classic technologies of boilers (including solid fuel) and natural ventilation are presented. Technologies regarding modern boilers are discussed, both on conventional fuels and biomass, heat pumps, ventilation units, as well as installation systems in terms of energy, ecology and economy. The microclimate parameters were analysed, which shape the comfort and possibilities of influencing them with a construction and installation technique. The paper presents partial results from the conducted research on the impact of weather conditions, thermal protection and building installation solutions on shaping the parameters of the internal environment.

1 Microclimate

The development of energy-saving construction, heating and ventilation technologies allows more and more adjustment to the needs of use - material and design and implementation solutions.

1.1 Microclimate of rooms

The microclimate of a room is a set of physical and chemical factors affecting the body.

A close relationship was found between environmental factors and the health status of the population. An appropriate thermal environment in one's place of residence is one of the most important factors determining in a direct or indirect way the function of many systems of the human body.

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The basic parameters describing the microclimate of rooms include:

- internal air temperature,
- relative humidity of the air,
- speed of air movement in the human area,
- temperature of thermal radiation (building partitions),
- air quality (purity and smell),
- the influence of the sun through transparent partitions,
- influence of external temperature and wind on external barriers,
- the degree and type of air ionization,
- noise and vibrations.

In practical considerations, the microclimate of rooms is considered in terms of thermal and humidity parameters, as well as quality and air cleanliness. The humidity and heat parameters (air and radiation temperature, air speed, humidity) affect the feeling of thermal comfort.

Thermal comfort is assured when there are conditions of well-being (thermal balance of the human body is maintained), and the feeling of comfort is an individual matter. Sometimes, comfort is called "state of mind" [1]. In thermal comfort conditions, the human heat balance equation takes on a zero value. It defines the relationship between human heat accumulation and its metabolic production, mobility efficiency, heat losses and its exchange with the environment [2].

People have adaptation skills. They allow you to adapt to the conditions prevailing, among others, in rooms. They constitute the thermal balance of the body with various physical influences of the environment [3].

Thermal comfort and indoor air quality are issues in close correlation. Temperature and humidity significantly affect the human quality of air, for example an increase in enthalpy causes this air to feel as a lower quality air, and dry and cool air is perceived by the room occupants as fresh.

1.1.1 Microclimate of rooms and health

Due to the fact that the human body is warm-blooded, mechanisms protecting against overheating or hypothermia are used. The thermal regulation system maintains a constant body temperature affecting the amount of heat given up (by radiation, convection, conduction, evaporation of moisture). The body can adapt to certain (small) limits to changes in the environment. The acceptable temperature of human surface tissues varies depending on the ambient conditions in the range of 20-44.5°C. However, crossing the boundaries leads to imbalances which affect health or even life [4]. Examples of health problems associated with exceeding the scope of thermal comfort: disease of the upper respiratory tract (caused by dry excessively heated air). Above 40°C, tissue damage occurs (e.g. protein denaturation). In turn, high humidity and temperature affect the development of mold, which directly results in the development of, among others, asthma.

The optimal temperature depends on a number of factors, including the type of work and clothing. The most frequent relative humidity in a room in the range of 30-60% is most often not distinguished by people. The various speed of up to 0.2 m/s does not affect the feeling of comfort. In turn, the increase in humidity at temperatures over 23°C is felt like an increase in temperature, while the increase in speed for temperatures up to approximately 30°C is felt as a decrease in temperature [5].

Deviations of physical and optimal parameters depend on the types of parameters. They are as follows:

Too warm:

- feeling of exhaustion, drowsiness,

- longer reaction time,

Too cold:

- feeling of anxiety, nervousness,

- loss of vigilance, concentration.

The effect of humidity on the body:

- less than 30% - drying of the mucous membranes - weakening of the protective barrier of the body,

Too fast air movement:

- headaches,

- increased nervous excitability.

The temperature distribution in the room has a significant impact (in combination with selected physiological and health characteristic) on the feeling of comfort. The room temperature distribution is influenced by many geometrical, architectural factors, air parameters and installation solutions used. This distribution can be easily disturbed.

The ideal vertical temperature distribution (with an average air temperature of 20°C) is assumed: the floor should have approx. 24°C, and 19°C around the shoulders. This profile guarantees the best possible exchange of air into the environment, while protecting the face area from high temperatures. The profile can be provided by underfloor heating.

A higher ground temperature, lower humidity and partial heat transfer by convection cause dirt particles to float in the air. The problem is especially in the floor zone up to a height of 40 cm, and when the user suffers from an allergy [6].

In heating with radiators installed under the windows, the temperature of the substrate is approximately 20°C, while in higher parts it gradually increases to 21°C at a height of 1.7 m. The air above can reach a temperature of 21-22°C. The solution is especially recommended for children's rooms.

1.2 Examination of the microclimate of rooms

Microclimate measurement methods are presented in the following standards:

- PN-EN ISO 7730:2006 Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using the calculation of the PMV and PPD indices and local thermal comfort criteria,

- PN-EN ISO 7726:2002 Ergonomics of the thermal environment. Instruments for measuring physical quantities.

The norms are aimed at assessing the heat exchange between a person and their environment, and consequently checking the risk of discomfort.

The method of measurements, stages:

1. Preparation for tests using local vision, determination of measurement points, etc.,
2. Measurement of parameters of the thermal environment,
3. Determining and comparing the value of the indicator appropriate for a given type of thermal environment.

1.2.1 Measuring apparatus used

The research was conducted in a small house located near Lodz with a usable area of 90 m². The house was put into use in 2016, one - storey with attic, furnished with experimental heating and ventilation installations.

Microclimate tests were conducted with continuous and occasional registration.

During the tests, the following were used:

- portable - handheld set, consisting of: universal meter 9565 with 986 VOC probe (air quality measurements: T, w, CO₂, CO, VOC) with their current registration; AeroTrak 9306-V2 particle meter,
- portable - suitcase set - made to order, consisting of a central unit with a wireless communication module and 10 sensors (measure T, w, CO₂). The set enables measurement, visualization and analysis of many sensors at the same time.
- portable - suitcase set - made to order, consisting of a central unit with a wired communication module and sensors: thermohygrometers, thermo-resistance flow velocity sensors, thermal radiation sensors of envelopes, contact sensors. The set enables measurement, visualization and analysis of many sensors at the same time,
- meteorological station - portable - Delta OHM, consisting of a piranometer, anemometer with wind direction measurement, thermo hygrometer.

2 Building and installation features

2.1 Building aspects

The construction aspects are basic from the point of view of: the functionality of the facility, the comfort of staying, visual or energy efficiency. It is an important foundation on a parcel (large space on the south side - it allows opening for winter solar yields), they must be limited (e.g. by vegetation) during the summer season. From the north side, it can be enclosed with auxiliary rooms.

Another aspect is the shape of the building (compact, straight, without unnecessary bends), preferably a building without a basement, rather a double-decker than a wide-rise one-storey building. The shape of the building largely determines the energy consumption of the building. It should be deprived of unreasonable breaks, bay windows, performances due to potential thermal bridges. The use of: arcades, descending roofs, vestibules or porches can be beneficial from the point of view of energy efficiency.

Single-family houses, compared to semi-detached or terraced buildings, have higher heat losses due to greater exposure to external conditions. With limited thermal insulation, this deteriorates the comfort of using the rooms caused by "cold wall".

An important issue is the method of making external envelopes of the building (quality and correctness of execution). The use of modern technologies when ignorant of them can contribute to the making of mistakes. Particular attention should be paid to the materials used, combining them or finishing. Errors can contribute to operational and thermal problems.

The key point from the point of view of thermal protection is to maintain low values of heat transfer coefficients, to ensure the stability of parameters (regardless of place and time), i.e. avoid thermal bridges, and dampen partitions. Meteorological station - portable - Delta OHM, consisting of a piranometer, anemometer with wind direction measurement, thermo hygrometer.

2.2 Heating installation

The type of heating system used enhances thermal comfort and energy consumption. Water heating can provide more comfort, however it takes place at the expense of more energy consumption for auxiliary equipment. At the same time, water installations (especially surface heating) will consume less heat - this is associated with greater efficiency of use (providing heat where it is currently needed) [7]. Air heating will provide less comfort, but

also lower energy consumption for auxiliary equipment; the air distribution is practically constant [8].

The type of water heating system has little effect on the relative humidity of the air, which cannot be said about air systems.

Summing up, the modern heating system has a determining influence on shaping comfort through:

- ensuring constant temperature, possibly with night-time reduction,
- no air drying,
- providing small differences in heating surface and air temperatures.

2.3 Ventilation system

There are three types of ventilation systems: gravitational ventilation (depending on external conditions), hybrid ventilation (in cold weather it operates based on natural forces, in a hot one due to forced flow through the fan), mechanical ventilation with heat recovery (flow of supplied and exhaust air stream) it is controlled, and heat is transferred from the air removed to the supply air).

In the case of gravitational ventilation, it can be assumed that the drop in outdoor temperature contributes to the increase of ventilation intensity (the relationship is linear). The increase in the intensity of the air mass movement (wind) increases the air exchange in the room (in the square) [9]. These dependencies cause gravitational ventilation, which rarely meets the tasks located in it.

With mechanical ventilation, there is no influence of external conditions (at least in theory). In turn, ensuring adequate humidity conditions in the cold season is difficult to achieve in not very extensive mechanical installations. Incorrectly operating a ventilation system may contribute to health problems and reduce the feeling of thermal comfort. Diseases include asthma, allergies, breathing problems and even cancer. The installation of ventilation as a result of fresh ventilation and the exhaust of used air causes fresh and used air to be mixed inside the building (the amount of harmful compounds is getting thinner), and as a result its humidity and temperature change. The majority of currently installed air handling units (especially not the smallest ones) are equipped with the necessary solutions. They guarantee high energy recovery, wide air flow regulation and the possibility of air transport to the rooms without replacing the exchanger (e.g. during the summer season).

Summarizing, the modern ventilation system has a decisive impact on shaping comfort through:

- providing a minimum amount of fresh air,
- effective removal of contaminants including moisture,
- fresh air supply does not cause discomfort.

3 Practical aspects of shaping the proper microclimate of rooms

In practical solutions, the effect of three types of the heating installations on the formation of microclimate conditions (taking into account temperature and humidity parameters) was analyzed. In the case of ventilation, an atypical solution with "on demand" ventilation was considered.

3.1 Air conditioner heating

Heating with an air conditioner (air-air heat pump) can be an interesting solution for facilities with low heat demand, with positive outside temperature and the use of a cheaper

night tariff. It is particularly suitable for so-called reheating when outside temperatures oscillate around 10°C. The use of the air conditioner also has disadvantages:

- noise generated by the internal and external unit is disruptive to dense buildings,
- increased costs in the daily tariff,
- fast cooling down after turning off.

3.2 Heating by fireplace

Heating in the fireplace is considered in Poland as heating that provides comfort, and at the same time is inexpensive. "Low heating costs" can be illusory when low efficiency is taken into account (operationally slightly exceeds 50-60%, it is low compared to, e.g. a gas boiler). Additional reduction efficiency is caused by: high losses on its "start-up" and the costs of involvement in "support for the smoking process".

In terms of comfort, it is difficult to support its fulfillment with facts. The heating is periodic, which generates high temperature fluctuations (exceeding 3K), large amounts of pollutants are lifted up together with the hot air from the fireplace (as a consequence of the dirt prevailing in the building), as well as it causes a drying of the air. The fireplace is being used mostly in the afternoon after returning from work - they are not comfortable in the daytime and night time, as a result of overheating in the period of intense burning in the fireplace. The temperature changes in the room heated by the fireplace during the evening, during the daytime period (1:00pm-3:00pm) of the air conditioner – are presented below:

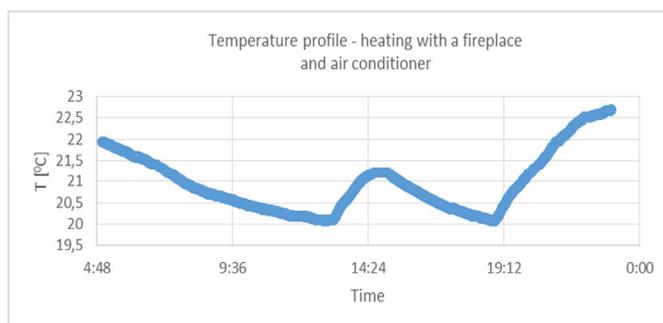


Fig. 1. Temperature changes during heating with a fireplace and air conditioner.

At this point, it is worth taking a look at the problem of air pollution during and after burning in the fireplace. The problem especially concerns solid particles getting into the room when cleaning and loading new fuel. There is a significant increase in the number of particles in a room that is particularly significant for particles of 1-3 µm and 3-10 µm. The increase in their number is even doubled or tripled. The issue must be seen in the context of the harmfulness of these particles to our respiratory system.

Disadvantages of heating by the fireplace:

- temperature fluctuations,
- contamination in the living room,
- dirty walls,
- noise of the flowing air.

3.3 Floor heating

It seems to be a very good solution. Both: temperature distribution, low temperature of the radiator (energy saving), as well as the high freedom of arrangement of the room are significant advantages of surface heating.

Unfortunately, heating also has its disadvantages. The most serious is the cold floor surface (finished with the best material for heat transfer - terracotta) - for a warm building during the transition period, which is not available in the literature. The building is well insulated, with outdoor temperatures - a few degrees in the plus - it does not require frequent start of the heating system. In the case of traditional radiator installations, this is undoubtedly an advantage - less running installation - saving costs. In the case of surface heating, there is also the less frequent start of heating, but it does not involve much less gas consumption. This is due to the fact that the accumulation mass of the screed cools down too much and it is necessary to reheat the screed. At the same time, the floor is simply cold for most of the time. Keeping the floor temperature constant at the desired level would result in the overheating of the rooms.

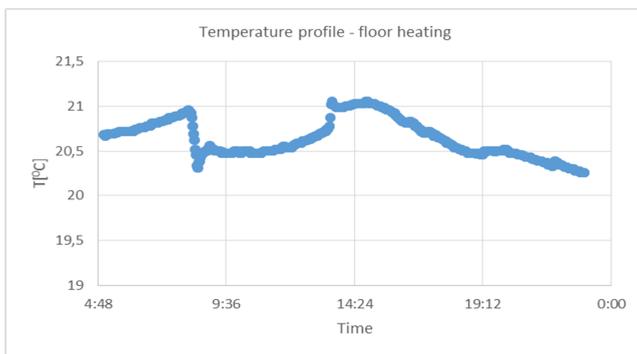


Fig. 2. Temperature changes during floor heating.

When comparing the two profiles, much lower temperature fluctuations can be observed, which in the case of floor heating is 0.7K when it is used for periodical heating exceeding 2K.

3.4 Perhaps periodic ventilation?

The function of ventilation is to exchange used air for fresh air. An alternative to continuous ventilation could be periodic ventilation. Although national requirements do not allow such a possibility, it is not so strictly observed in private construction.

Advantages and disadvantages:

- keeping the relative humidity at an optimum level, which is difficult to achieve for mechanical ventilation permanently activated in winter; it may cause air to dry out,
- reduced energy costs,
- reduced noise,
- there may be insufficient air exchange when the ventilation is switched on too rarely.

The frequency of switching is an issue to be further developed in order to ensure sufficient air exchange, i.e. that the concentration of contaminants remains at an acceptable level while at the same time ensuring the low frequency of start-up. In analyzing the data on the CO₂ concentration and relative humidity, it can be seen that the increase of the former leads to an increase in humidity (this is understandable when we consider that the increase of both compounds is related to insufficient mechanical ventilation) [10].

4 Summary

The adequate microclimate of rooms requires a multifaceted action, which should lead to:

- Achievements of high temperature-compatible air - temperature of external partitions;

- Ensure thermal and air-tightness of the partitions;
- Use of natural shading elements from the southern side in summer, opening to solar radiation in winter;
- Ensuring a constant temperature regardless of temperature changes outside;
- Correct temperature distribution in the room in a vertical and horizontal perspective;
- Quality assurance - clean indoor air;
- Providing the right level of humidity (removing excess in the warm season, limiting the removal of moisture in the cold season);
- Draught limitation;
- Low sound pressure level in the room;
- Energy efficiency - high efficiency of heating devices, high heat recovery in the ventilation unit.

Focusing on installation issues, it can be stated that achieving optimal conditions from the point of view of comfort in rooms is not as obvious as it may seem. Modern technologies (surface heating, ventilation with heat recovery) are not always able to provide comfortable living conditions. In particular, air heating is characterized by a high temperature spread caused by the periodic operation and significantly lower heat capacity of the air. Optimization activities in this area are necessary.

The article mainly deals with the temperature aspects most relevant from the point of view of space heating. The relative humidity and carbon dioxide content were recorded during the tests, which will also be analyzed in a separate study.

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