The microclimate parameters change in the occupied zone inside some large-volume buildings with significant influence of the heat emission from people staying inside

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Abstract. The paper shows selected aspects of the microclimate change in the occupied zone of the large-volume buildings. The air temperature and some other microclimate parameters change because of heat emission from people staying inside there. There are shown exemplary methods and results of research conducted in sacral buildings and residential apartment buildings. It is based on author's research. The novelty is the research of the human heat emission in case of a big number of people staying inside sacral buildings. It can be useful for a large-volume buildings design (especially for the sacral buildings) and for microclimate shaping in many types of buildings and residential buildings also. In some buildings with a big number of people staying inside at the same time (such as the sacral buildings) heat emitted from people significantly influences on microclimate. Another situation is observed in residential apartment buildings, where heat and moisture gain are distributed in separate rooms. Human heat streams can be useful as a part of the heat balance of the room especially in case the big number of people staying in the room.

1 Introduction

The heat emitted by people can be often considered as an additional heat streams in buildings, which are useful and considerable part of the room heat balance. In sacral buildings, there are specific conditions. Volume of the room is often large, and so large is a floor area (giving the possibility of staying big number of people). Very often those buildings (especially their main nave) are tall. People are staying all time in the same place and their physical activity is not changing significantly during Mass. So, calculating the heat emitted by people in such circumstances is possible and those heat streams seem to be an important part of room heat balance and can be predicted in the design phase. So, here are shown exemplary results of research conducted in the sacral buildings and in the residential apartment buildings. It is based on author's research conducted in sacral buildings and residential apartment buildings. The main aim was to test the influence of the human heat emission on the microclimate of those types of buildings. Also, the aim was to check whether there is such an increase in internal temperature due to the human heat emission of people, which does not deteriorate the selected microclimatic parameters and is important from the point of view of energy efficiency.

The regulation of a blood supply to the skin is the basis of heat exchange between the environment and the man. Enlargement of the blood vessels results in better blood supply and increases skin surface temperature. It can also take place in the other direction, caused by artificial external heat. The blood can be transferred from the skin to the inside of the body then. Resting man emits sensible heat (79%, by convection and radiation) and latent heat (21%, by evaporation and respiration). Human emission of heat depends on physical activity, gender, clothing, and other factors. Resting metabolism occurs in the body when the person is lying down, in complete physical and mental calm, more than a 12 hours after the last meal, in neutral ambient temperature (for a man: 16÷20 °C) and it is about 1,163 W/kg (mass of the human body) [1]. At the temperature of 8 ºC (possible for unheated churches) the calculated heat stream is about 370 W/m^2 (area of a body surface), with the use of the P.O. Fanger's method [1] and 193 W/m^2 with the use of the J.A. Pogorzelski's method [2] (at the air temperature of 16 ºC, just for comparison, it is less value: 243 W/m^2 [1] and 150 W/m^2 [2]). In case of resting in a laying position – average internal heat stream from man it is about 70-93 W, in sitting position – 81-105 and in staying position about 93-128 W [3]. Another question is the ventilation of the room and the feedback influence of room microclimate on human heat streams emission. In case of air quality deterioration, thermoregulation metabolic processes of the human body will adapt to the ambient air temperature and humidity (also human body will react to the surfaces temperatures). In case when the big number of people is staying in the room, those processes are multiplied and they cause an increase in the temperature. So, the main

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question is if it is possible to treat human heat emission as a useful heat gain in such buildings when a big number of people is staying inside and microclimate parameters is changing.

2 Materials and Methods

The sacral buildings research has started in the years 2000 at the Warsaw University of Technology (under the scientific supervision of Prof. Leszek Wolski). All tested buildings were located in the Masovian Voivodeship in Poland. The research at the residential apartment buildings has started in 2014 at the Faculty of Biology and Environmental Sciences of the Cardinal Stefan Wyszyński University of Warsaw in the Department of Environmental Engineering. The tested buildings were the residential apartment buildings and single-family residential buildings. Researches on all types of large-volume buildings mentioned above are still ongoing.

During research, there were used TROTEC's diagnostic equipment, including the EC060V thermal imaging camera and also the Infratec / Jenoptik VarioCAM HD Inspect 675 (with NETD even less than 30 mK) camera. Temperature and humidity measurements were also performed with the use of the thermohygrometers and other microclimate measurement equipment.

In the aspect of air temperature and relative humidity measurements, thermohygrometers were placed at different heights in the building at fixed measuring points or on portable tripods staying on the floor. In the case of measurements made at the points located at the significant height, there were used the author's method of using balloons with helium to hang the ropes on construction elements in the room such as tie rods on which the measuring devices later were mounted. In addition, to carry out the research surface thermometers, pyrometers and other microclimate and external climate testing equipment were also used to conduct surface temperature tests.

2.1 Objects location

The measurements in the occupied zone of buildings were performed with thermohygrometers and thermal imaging cameras. Tested buildings were located in the town of Płock and the Masovian Voivodeship in Poland. The tested buildings were 18 large-volume buildings with at least one large-volume room, and about 10 residential buildings (with separate apartments). During the research there were achieved about 300,000 data, 1,200 photos registering people staying inside buildings. Several thousand individual thermal images have been made in the last years for many different buildings, including buildings affected by the sick building syndrome in which mold occurs. Special software MAPKALK were written for data analysis also.

2.2 Tested objects characteristics

Three distinct types of sacral buildings have been identified and there have been selected 9 from group of 18 tested objects.

Below the selected sacral buildings are shown:

Object 1: Chappel „Kaplica Rzymskokatolickiej Parafii pw. Ducha Świętego", Płock, contemporary construction.

Obiekt 2 : Church „Kościół pw. św. Józefa", Płock, contemporary construction.

Object 3 : Church „Kościół pw. św. Krzyża", Płock, contemporary construction.

Object 4 : Church „Kościół pw. św. Stanisława Kostki" (lower), Płock, contemporary construction.

Object 5 : Church „Kościół farny pw. św. Bartłomieja", Płock, contemporary construction.

Object 6 : Church „Kościół pw. św. Jana Chrzciciela", Płock, 18th century construction.

Object 7: Church „Kościół rzymsko-katolicki pw. św. Stanisława Kostki" (upper), Płock, contemporary construction.

Object 8: Cathedral Basilica: „Bazylika Katedralna pw. Wniebowzięcia Najświętszej Maryi Panny", Płock, 11th century construction.

Object 9: Church „Kościół Matki Boskiej Częstochowskiej", Płock, contemporary construction.

Types of objects classified by their volumes:

Type I (small): Volume range: 1,413 – 2,760 m^3, height range in the middle part of the room: 3.7 - 8.5 m (objects 1,2,3).

Type II (medium): medium-volume objects and average height: Volume range: 3,451 - 6,000 m^3, height range in the middle part of the room: 5.8-12 m (objects 4, 5, 6).

Type III (large): large-volume and significant height objects. Volume range: 17,218-34,058 m^3, height range in the middle part of the room: 12-26.5 m (objects 7, 8, 9).

2.3 Measuring points location

Measuring points were located in different parts of the area of the church nave. It depended on its layout and the possibility of measurement equipment location. So, at objects 1, 2, 3, 5, 8 and 6 it was located along the walls and the benches (Fig. 1 a). In the objects 4, 9 and 7, because of a round shape, measuring points are located in more "dispersed" places in the space of the room (Fig. 1 b). In those points there were fixed a mounted or portable thermohygrometers - on tripods, portable poles or suspended on ropes attached to the tension rod or other existing rod. It is shown on Fig. 2 (mounting rods for the chandelier were used there to attach the ropes).

Objects, number of points and location of the measuring points over the level of the floor:

- Object 1, Points: 1-9, Heights: 0; 1; 1,8; 2,6; 5,2;
- Object 2, Points: 1-9, Heights: 0,7; 2; 4;
- Object 3, Points: 1-8, Heights: 1,2,3,4;

- Object 4, Points: 1-7, Heights: 1,2,3,4,5;
- Object 5, Points: 1-9, Heights: 0,1; 1; 2; 3; 4;
- Object 6, Points: 1-10, Heights: 0,1,2,3,4,6,9,12;
- Object 7, Points: 1-9, Heights: 0,1,2,3,4,5,6,7,8;
- Object 8, Points: 1-9, Heights: 0,1; 1,2,3,4,6,8,11;
- Object 9, Points: 1-8, Heights: 0,1,2,3,4.

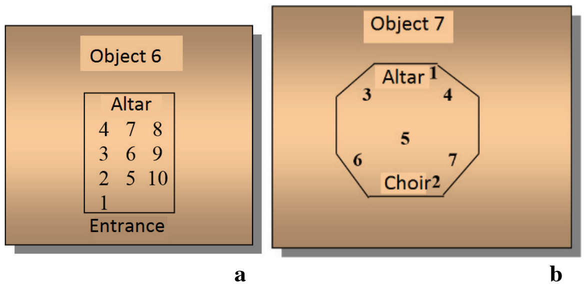

Fig. 1. Typical measuring points location basic on examples of object 6 (a) and 7 (b).

At the residential buildings, measurements were performed in the occupied zone in the different points of the rooms or there have been made thermograms using thermal imaging cameras.

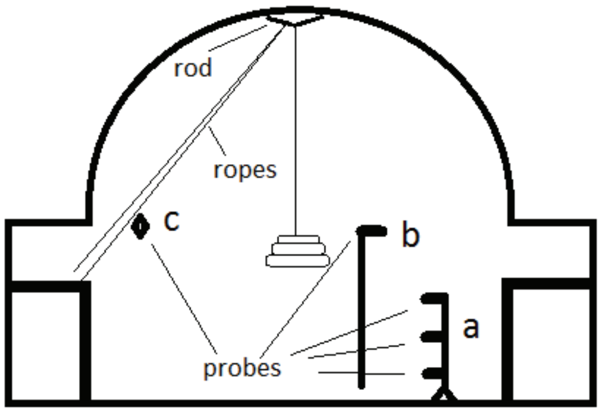

Fig. 2. The types of the measurements with the use of the thermohygrometers: probes were mounted on tripods (a), portable poles (b) or suspended on ropes fitted to the existing rods (c).

2.4 Methods of people's stay characteristics in the churches

In the churches, especially those of modern design and architectural form, there is many different constructional solutions and therefore there are different heights and volume. So, there are small churches (300 to 600 of Mass attendees) and even very large (even 3-6 thousands of Mass attendees). The differences in the impact of the human heat emission on the microclimate depend on the volume of a room, its height and also they are proportional to the area occupied by persons to the rest of the room's space and other parameters.
Regarding the specific features of the sacral buildings, there are also different proportions of seats to standing places. Because of the people standing in the churches, it is possible to obtain a relatively high density of settlement, in the order of 2.8-3.0 persons/m^2. The objects of tested types show differentiation considering such defined coefficient of the settlement. The lowest values are observed on weekdays in the morning and in the afternoon. The highest values and full use of the object space are observed at high Mass on Sundays. The settlement coefficient does not change during the Mass, which was important for assessing dependency and temperature rise. People enter the building about 15-20 minutes before the Mass and leave it about 5 minutes after the Mass. The settlement coefficient assumes the highest values in the area closest to the altar. First are occupying seating places at the benches, then standing places. The high values of settlement in Type III (large) object are the least obvious and repeatable, due to the large space available for staying as well as the different architectural features. Small objects generally have the principle of making the best use of the space of the church, and therefore the size of the human space is as large as possible in relation to the space of the room [4].

2.5 Specific formal aspects of the research methodology

During the thermography research, there were used the requirements of the polish standard PN-EN 13187 [5]. It is Polish version of the European standard EN 13187:1999 "Thermal performance of buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method".

Including for example: the difference between indoor temperature and outside temperature - at least 15 K, indoor air temperature as stable as possible, outdoor maximum test conditions, for instead before sunrise or late evening. Wind speed of not more than 1 m/s, no dampness of barriers, no measurements can be processed during bad weather, e.g. rainfall, snowfall or fog. The angle to the partitions surfaces during the measurement cannot exceed 45°. Research met the requirements of Polish civil engineering law for buildings and their location [6] and requirements of many European Standards such as PN-EN ISO 6946:1999 [7] for example.

3 Results and discussion

Below the results of the research inside sacral buildings of three types are presented. Additionally, those buildings are compared in the aspects of the specific features of the residential apartment buildings treated as the opposite cases.

3.1 Air temperature and relative humidity distribution in the large-volume rooms

Within the scope of the research, measurements have been made in the objects of the three types, described earlier in the subsection 2.3. (Type I, Type II and Type III). The space of the tested rooms was divided into zones. These zones (shown on the Fig. 3 and Fig. 4) are: "mean" - those are mean results from the whole space of the room (on the selected height over the floor), "center"

- means strictly the central part of the room, "edges" - denotes the area along the walls, "extended center" - denotes the middle part of the room, and "ext. mid. with. cent." - which means the middle part of the room, excluding its strictly central part. Then, the space of the room is divided into planes of fixed height over the level of the floor. Fig. 3 and Fig. 4 [8] concern the human occupation zone and room space just above it. Those graphs illustrate the results obtained from hundreds of measurements in many objects grouped into the three discussed types of buildings.

Buildings precise location: All selected sacral buildings were located in the city of Płock. The tested residential buildings were located in the Płock, Ciechanów, and Płońsk districts. The results show that there are a significant increases in temperature in the occupied zone in sacral buildings where many people are staying during the Masses.

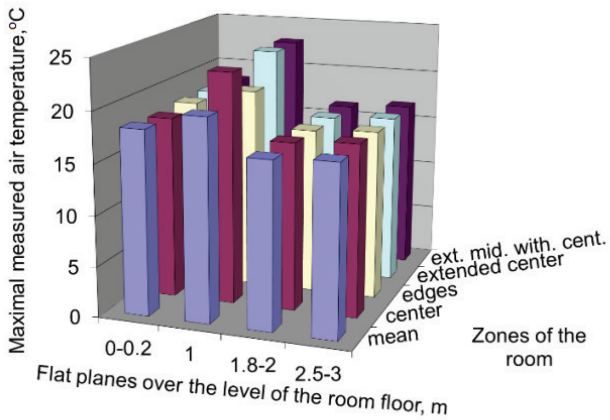

Fig. 3. The maximal air temperature after Mass inside object of Type I (small).

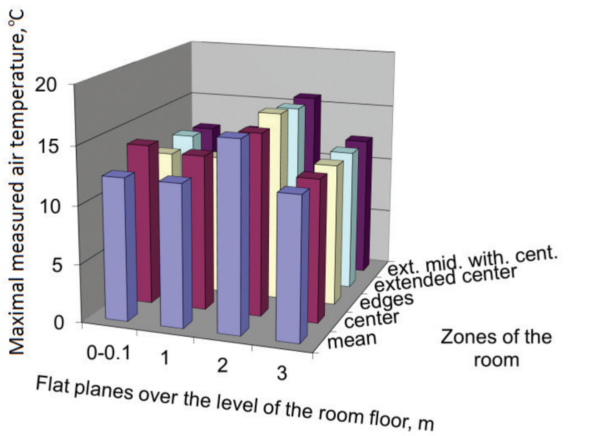

Fig. 4. The maximal air temperature after Mass inside object of Type II (medium).

It is profitable from the point of view of a thermal comfort. In addition, the highest air temperature after Mass is observed in Type I objects, which results from the smaller volume and height of objects with a relatively large number of occupants and a relatively high settlement coefficient (as a number of people referring to the area they are staying in). The tested sacral buildings of a large volume were generally unheated or poorly heated. The analyzed cases are those for which the temperature rise during people's stay is significant (not less than 0.5 ^{o}C) and the impact of external climatic conditions can be assessed as negligible. This allowed to analyze those cases which deserve attention. In those cases the heat from humans is a major cause of the increase in indoor air temperature.

In the height range of more than 3 meters (as included in Fig. 5 and 6 [8]), a convective heat transfer is observed. Fig. 5 and Fig. 6 show the situation in objects of type III (large objects).

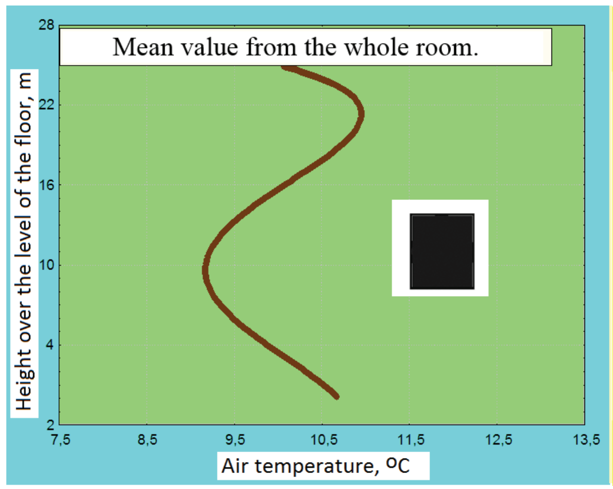

Fig. 5. The air temperature profiles after Mass inside the large objects (above the occupied zone - from 2 m to the highest level of the measurements). Black square marks area of the measuring points location.

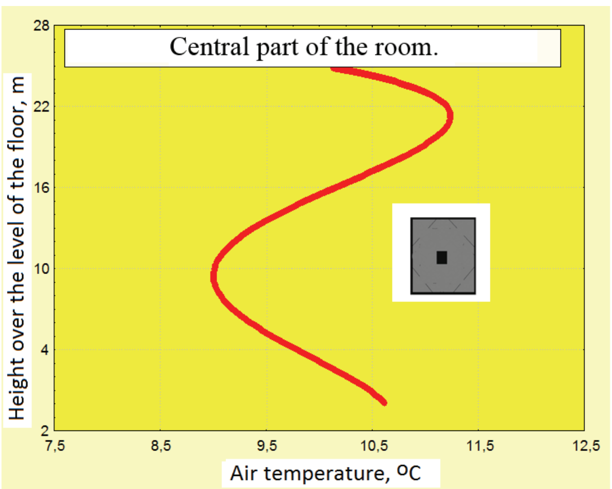

Fig. 6. The air temperature profiles after Mass inside the large objects (above the occupied zone - from 2 m to the highest level of the measurements). Small black square marks the location of the measuring points.

These objects are characterized by considerable height (the charts scales reach to 28 m, but in some cases rooms even reached the height of more than 30 m). For convective heat transfer, the curvature of the graph and the higher temperature at a certain height (from about 15 to 25 m) are observed, followed by a slight reduction in the air temperature near the ceiling (as a result of heat transfer to the outside through the partition). There is a significant increase in air temperature in the human occupation zone up to an average of about 10.5 ^{o}C in rooms where the initial temperature is around 6-8 ^{o}C.

The Table 1 shows the brief conclusions concerning changes in air temperature and relative humidity in the studied objects of the three selected types. It is interesting that the Type I objects, due to the smaller volume and height of the objects, achieve a more uniform temperature distribution in the vertical section of the room, whereas in the large objects (Type III) the most characteristic vertical profile temperature is observed. Evident convective upward flow is observed especially in this type of buildings.

Table 2 shows the mean differences between air temperature after Mass and the normative air temperature of thermal comfort.

Table 1. The horizontal and vertical heat zones.

Considered specific value	Range of the occurence inside rooms of tested types
Mean air temperature increases:	
Small objects	Inside whole room, in occupied zone, there are the highest air temperature increases.
Medium objects	Above occupied zone, there occurs gradual air temperature lowering.
Large objects	In the occupied zone, to the height of 6 m above the level of the floor, there occur the highest air temperature increases.
Mean air temperatures after Mass:	
Small objects	The higher air temperatures after Mass at the height of: from 4 m to the half of the object height.
Medium objects	Lower mean air temperaturę at the height of: lower part even to the half of the object height.
Large objects	Above the occupied zone – there occurs gradual air temperature lowering. Convectional raise of the heat stream and its flow to the top of the room.
Mean air relative humidity increases:	
Small objects	At the range of occupied zone the highest air relative humidity increases occur. Lower air relative humidity increases occur at the rest part of the room.
Medium objects	The values of the air relative humidity increase in parallel to the change of the room height.
Large objects	In the occupied zone up to the height of the half of the room there occurs similar distribution of the air relative humidity increases.

Table 2. The difference between air temperature after Mass and normative temperature of thermal comfort (mean values calculated from data achieved in the all measuring points fixed in the area of the room), ^{o}C.

Objects	Mean	Median	Minimum	Maximum
Small	3.27	2.91	-2.81	11.2
Medium	6.76	7.08	0.08	8.79
Large	5.07	5.07	2.72	7.31

Objects during tests did not always achieve the normative air temperature of thermal comfort, because of the low number of people staying in the sacral building during the test. It causes relatively low human heat gain. It doesn’t affect significantly to the microclimate. Another obvious reason that the thermal comfort is often not achieved, is the very low initial air temperature in the church.

As the opposite situation, in some cases (mainly in Type I and Type II objects), there occur very high differences between the normative thermal comfort air temperature and indoor air temperature (which is higher). This is due to a large number of people and relatively huge human heat emission. Additionally, Type I and Type II objects are relatively not too high so air in room is warmed quite quickly. Also, the cumulative effect of successively air temperature increase occurs because of low intervals between the Masses (in Type I and Type II more often than in Type III objects).

Table 3 and Table 4 shows the combination of air temperature increments and air relative humidity increments in the different room zones (mean results from zones). The "mean" in the columns is the mean value for the whole room, while the "mean" in the rows is the mean value for all measurements. In addition, the maximum and minimum values are included in the tables. Particular attention could be paid to small objects, where the increase in the air relative humidity due to the presence of people in the object reaches up to about a dozen percent (in the case of long people’s stay in successive Masses).

In aspect of objects comparison, there is a different situation than in the another category of objects - apartment residential buildings. There is a large number of people staying at the residential building a long time also, but the heat gains are divided into individual dwellings and distributed in the many rooms.

Table 3 also shows temperature increases in each type of objects, and the highest observed temperature increases are observed in small objects and in tall buildings where even up to several thousand people can be present inside one room at the same time. Increases in air temperature reach even 6-7 ° C.

The heat gains shown in Table 3 are important for microclimate and thermal comfort, especially if the room is unheated. In practice, this allows for self-heating of many sacral buildings. For small objects, there is often a risk of excessive air humidity, which requires adequate ventilation. Sacral objects are intensively ventilated between the Masses when the faithful leave the church.

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Table 3. The mean air temperature increases, °C.

Small objects (Type I)

Type of value	**Mean**	**Cent-ral part**	**Edges**	**Ext. mid-dle**	**Ext. mid. without center**
Minimum	1.593	1.525	1.571	1.365	1.325
Mean	2.144	1.908	2.146	1.958	1.946
Maximum	2.967	2.308	3.150	2.439	2.433

Medium objects (Type II)

Type of value	**Mean**	**Cent-ral part**	**Edges**	**Ext. mid-dle**	**Ext. mid. without center**
Minimum	0.839	0.850	0.920	0.870	0.909
Mean	1.190	1.102	1.204	1.155	1.176
Maximum	1.519	1.450	1.458	1.470	1.700

Large objects (Type III)

Type of value	**Mean**	**Cent-ral part**	**Edges**	**Ext. mid-dle**	**Ext. mid. without center**
Minimum	-0.056	0.000	-0.075	-0.033	-0.060
Mean	1.716	1.755	1.831	1.886	1.711
Maximum	6.340	5.820	6.337	7.511	6.393

Table 4. The increases in the air relative humidity during the Mass (mean values calculated for the all measuring points), %.

Small objects (Type I)

Type of value	**Mean**	**Central part**	**Edges**
Minimum	5.429	5.393	5.423
Mean	10.418	9.582	10.444
Maximum	15.881	15.227	15.876

Medium objects (Type II)

Type of value	**Mean**	**Central part**	**Edges**
Minimum	2.228	3.042	2.590
Mean	3.808	4.213	3.861
Maximum	5.059	5.569	5.073

Large objects (Type III)

Type of value	**Mean**	**Central part**	**Edges**
Minimum	1.280	0.665	3.352
Mean	3.702	3.003	4.397
Maximum	5.794	4.343	6.500

In the case of relatively high objects (especially in Type II and Type III), the heated air also rises upward, so it minimizes the effect of air temperature rise due to the presence of people in the room. Heat gains from humans in the considered cases (at least 0.5 ° C increase in indoor air temperature) are important for the heat balance of the buildings, especially in objects of Type I.

In the case of tested apartment residential buildings, heat gains from people were often a reason for significant humidity increases and adequate infiltration of fresh air and proper ventilation were necessary there. In some tested cases, ventilation was insufficient and led to serious troubles with inner air quality. Thus, cases of residential apartment buildings constitute partially in the opposite to the cases of sacral buildings larger in volume (Type II and III). In all mentioned buildings there is a large number of people staying inside but in sacral buildings, they stay generally in one large-volume room. However, there is also a need for adequate ventilation to prevent excessive air humidity problems. Nevertheless, the large volume of sacral objects (especially Type II and Type III) in a certain way causes that adequate air quality is provided. The ventilation needs are much smaller there than in residential apartment buildings and sacral buildings of Type I.

Nevertheless, the human-derived moisture gains are important for the microclimate of the residential buildings, often contributing (in conjunction with other factors) even to the sick building syndrome and mold (Fig. 7).

Fig. 7. Detected troubles in the tested residential apartment buildings: mold in the room corner, on the internal surface of the external wall, caused by limited infiltration of external air, poor natural ventilation, thermal bridges and significant moisture gains from people.

3.2 Specific differences in microclimate shaping between selected types of buildings

The division of tested sacral buildings into small, medium and large displays the following differences in the microclimate change between objects:

• Air temperature rises (in cases of the same occupation of people) decrease when the volume of the considered object enlarges. The greatest increase in temperature is achieved in small objects. In larger buildings, heat rises upward due to convection. Because of that, in tall buildings the effect of the air temperature increase is limited and the greatest increase is in the occupied zone.

The rise in temperature of the tested objects changes with the height above the floor level.
• The highest temperature rise is achieved in the human occupation zone (all types of tested buildings)
• In smaller sacral objects there is greater ability to design the microclimate by predicting temperature rise in case of people's presence.
• The rate of decrease in temperature depends on the use of the room after leaving it by people - whether windows and doors are opened and at how long it lasts. The sacral buildings are often ventilated between the Masses.
• The effect of raising the temperature during use of objects depends on the number of persons staying, as well as on the duration of use of the object and the density of people in the space.
• The shape of the temperature distribution caused by people staying depends on the volume of the building. In the case of smaller sacral objects, there are often several Celsius degrees of temperature increase.
• In Type I objects there is the greatest increase in air temperature and humidity in the middle zone and the lowest temperature variation between zones. In large buildings, the highest temperature rise in the middle zone and the highest temperature and humidity differences between the zones are observed.
• The distribution of the temperature that is shaping during people staying is varied in both the horizontal plane of the room and at the different heights. The presence of heat sources, the unevenness of the density of the people's occupation in the space of the room, the air movement near the windows - all those parameters influence on the formation of temperature distribution.
• It has been observed that in the lowest and smallest objects (Type I objects) buildings microclimate deterioration is most common. It depends on a large extent on the time of people's stay and their number.
• On the basis of the achieved results, it was found that in the smallest objects there are heat gains which allow to reach the thermal comfort (in winter and during whole heating season). Especially in large objects - studies do not confirm the previous views on the air temperature distribution because there is also a cooler zone in the middle part of the room. Some results suggest that further research should be carried out.

3.3 Influence of people staying in room parameters

It has been found that the considerable air temperature rise depends on some minimal number of people staying inside the room. It is possible to indicate the number of about 25 people. - Then, about 50% of cases in objects of small volume cause a noticeable increase in temperature.
• The effect of a significant temperature increase with a minimal amount of persons causing a noticeable rise in temperature occurs within about 10 minutes after entry to the object and is maintained for about 30 minutes after leaving it by Mass attendants.
• Accumulation of air temperature increase caused by the presence of people can be seen in the Sunday successive Masses. In 90% of the cases, it results in a gradual increase in temperature. It is even up to 300% higher than in the case of a single Mass.
• The effect of daytime on the temperature raise while maintaining the presence of the people is not significant and amounts 0.2 ºC.
• The increase in room volume results in a reduction in possibility of the use of human heat for heating purposes. It is stated with limit of 2000 m^3. For these value there was a noticeable increase in temperature.
• Shaping a microclimate with particular attention to the effects of heat emissions from people for microclimate and energy efficiency is possible under the following conditions:
- Keeping the minimum number of occupants for the type of objects;
- Providing adequate residence time;
- Providing adequate ventilation, especially small objects, so that there is no deterioration in air quality. In larger buildings, the amount of air available may be sufficient to ensure adequate air quality in room during the people's presence.

3.4 Achieved results summary

• Considering the influence of the heat emission from people on room's microclimate, some improvement of methods of its assessment have been developed;
• In tested objects, the most considerable air temperature increases (caused by heat emission from people) are observed in the occupied zone of sacral buildings. Influence is often reduced by convectional raise but, in general, this emission is important as a useful heat gain in aspect of achieve thermal comfort and in aspect of the building heat balance;
• The influence of the human heat emission on microclimate depends on ventilation intensity. It is not so important in buildings of larger volume (especially in Type III objects).
• As an opposite case to the sacral buildings, in residential apartment buildings poor ventilation often causes significant humidity growth and sick building syndrome risk (troubles with partitions and thermal insulation, as an effect of poor ventilation, badly performed thermo-modernization, thermal bridges, etc.). The same situation can occur in sacral buildings because of the same technical problems and also because of low air temperature and high air relative humidity. It was observed in some cases in sacral buildings also and it led to the sick building syndrome, serious partitions damages and mold there.

4 Conclusions

The results of the research helped to improve some methods of assessment of the influence of the heat emission from people on the room microclimate. The preliminary assessment and conclusions are:
- There is direct dependence between number of people staying inside the sacral building and the air temperature growth.

- The human heat emission is the considerable part of the heat balance especially in Type I objects. However, the useful heat emission should be reduced by the ventilation heat loss, but even after this reduction, there is still even a few dozens watts per person as an effective heat gain (these research results now are processed). So, almost all sacral buildings (considering Polish climatic conditions) can be designed as unheated, passive buildings.

- In the case of the largest volume buildings (Type III objects), there are less possibilities to achieve a thermal comfort conditions (especially right air temperature) only as the result of the human heat emission. But there are still significant possibilities of achieving it in the case when there are a bigger number of people is staying inside (about hundred and more).

- Higher height of some buildings causes convectional raise of the warmer air so the effect for the same number of people staying inside three tested types of buildings is different.

- Another situation is observed in the residential apartment buildings, where the heat and moisture gain from people are distributed in the separate rooms. It seems that all room has its separate microclimate, but heat emission from whole building causes microclimate changes especially in the rooms laying on the highest floor causing significant air quality deterioration.

- Inside the Type I objects, in the occupied zone, the air temperature increase was 7.76 ºC, 3.77 ºC in Type II objects, and in Type III objects it was 5.95 ºC (as a mean value for the entire research period, considering cases when air temperature increase was at least 0,5 ºC).

The achieved results indicate that thermal impact of a big number of people staying inside large-volume buildings (especially sacral buildings) can be useful as a part of heat balance of those buildings.

Research on the large-volume buildings is still ongoing and newer results will be published next year with the precise assessment of the heat gain.

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