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EXPERIMENTAL RESEARCH ON THERMAL CONDITIONS IN INTERMITTENTLY HEATED BASEMENT

Summary

The article presents the results of air temperature measurements inside a basement, outside it and in the ground adjacent to the building. The results and their analysis reveal that indoor thermal conditions develop differently in rooms with earth-contact structures. Intermittent heating exerts an important influence on the shaping of temperature conditions in a basement and its vicinity.

Key words: basement, ground, experimental studies, intermittent heating

INTRODUCTION

Basements are currently often adapted as storage rooms, offices, commercial premises or even apartments. Altering their utilization purpose results in changes in their thermal and humidity conditions. The major part of partition walls are in contact with the ground. The ground adjacent to the building is characterized by high thermal accumulation, which significantly alters thermal performance of the partitions adjacent to the ground when compared to other partitions [Nawalany et al., 2005].

Basements can be heated on a continuous basis. In such a situation, indoor thermal conditions are similar to rooms situated above the ground level. If the basement is not heated continuously, indoor thermal conditions are changeable. Temperature fluctuations result in temporary thermal accumulation in partitions (walls, ceiling, floor) and the ground; the heat is then returned from the ground with a delay [Gryc and Radoń, 2011].

Identification of phenomena occurring inside a intermittently heated basement was possible thanks to the experimental research conducted in the Department of Rural Buildings at the University of Agriculture in Kraków. The measurements were carried out in the basement used as laboratory and classrooms. Inner and outer air temperature as well as temperature of the surface of partitions and in the ground was measured. The long-term comprehensive results of experimental studies constitute a set of data that makes it possible to describe the distribution of temperature and heat transfer in the ground and partitions surrounding the basement in real life conditions. The article presents selected results of experimental studies and analyses the way the thermal conditions develop in intermittently heated basements.

EXPERIMENTAL STUDIES

The building where experimental studies were conducted was constructed in 1960s. The basement walls are made of brick, covered with the layer of plaster. Total wall thickness is 0.55 m. The concrete floor 10-cm thick is covered with PVC tiles. The floor and basement walls are not thermally insulated. One wall-mounted radiator powered by central water heating system heats the basement room. Electric heater was applied additionally during colder periods.

Table 1 presents dimensions of the researched basement, whilst Fig. 1 contains a projection view and a cross section. The structure of partitions is shown in Fig. 2.

Table 1. Geometrical data for the basement

Specification	Unit	Value
Length, width, height	m	6.30 × 5.80 × 2.45
Inside cubic capacity	m^3	89.52
Floor square area	m^2	36.54
External wall area	m^2	11.59
Internal wall area (adjoining the library)	m^2	15.44
Internal wall area (adjoining the classroom)	m^2	12.50
Internal wall area (adjoining the corridor)	m^2	14.21
Entrance door area	m^2	2.94
Ceiling area	m^2	36.54
Window area	m^2	2.62

Source: own research

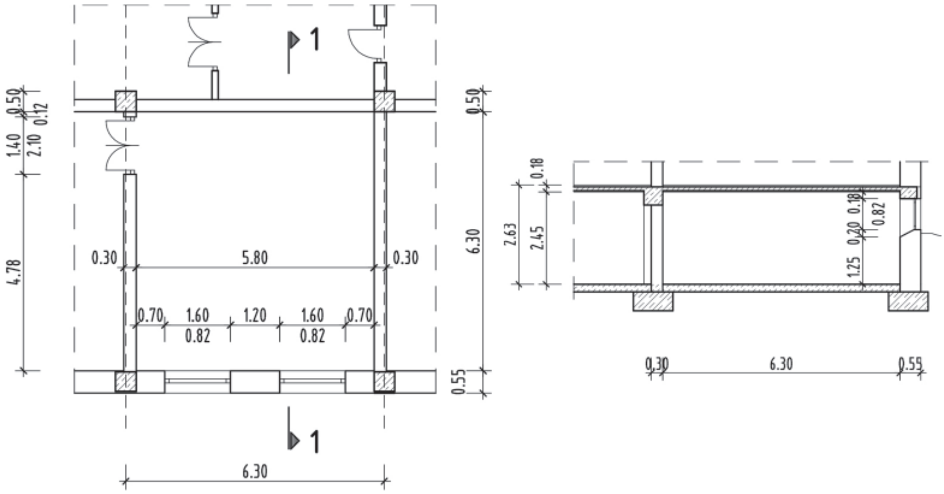

Figure 1. Researched basement, used as an office room: vertical and horizontal cross-section

The basement, the subject of the research, is situated approx. 1.5 m below the ground level. The building is surrounded by flat ground at the stretch of 1.2 m; further on, the ground rises up to create a mild slope of 25°. After approx. 2 m, the ground becomes flat again. The measurements in the ground outside the building were conducted at the distance of 0.4 and 1.1 m from the external wall in 8 measurement points. Inside the building, the following measurements were made: floor temperature (3 measurement points), temperature of walls in contact with the ground (3 measurement points), surface temperature of three internal walls and the ceiling (1 measurement point for each). Moreover, temperature and relative air temperature of inside and outside air was measured.

Basement geometry and the distribution of measurement points are presented in Fig. 3.

Experimental studies were conducted from 9 August 2007 to 31 August 2011 (four years). For the entire research period, the room as well as adjoining rooms were utilized in accordance with their purpose, either for student teaching or research activities conducted by the faculty. The heating was turned off during holiday breaks.

The temperature was measured with the help of resistance sensor PT 100, type TOP 1068 [KFAP 2003] with the accuracy margin of 0.15^{o}C. The results were recorded every 15 minutes in the MPS-1 register memory [ProgStar, 2007]. Measurement results were than sent to the computer and analyzed with the help of MS Excel© [Nelson, 2000].

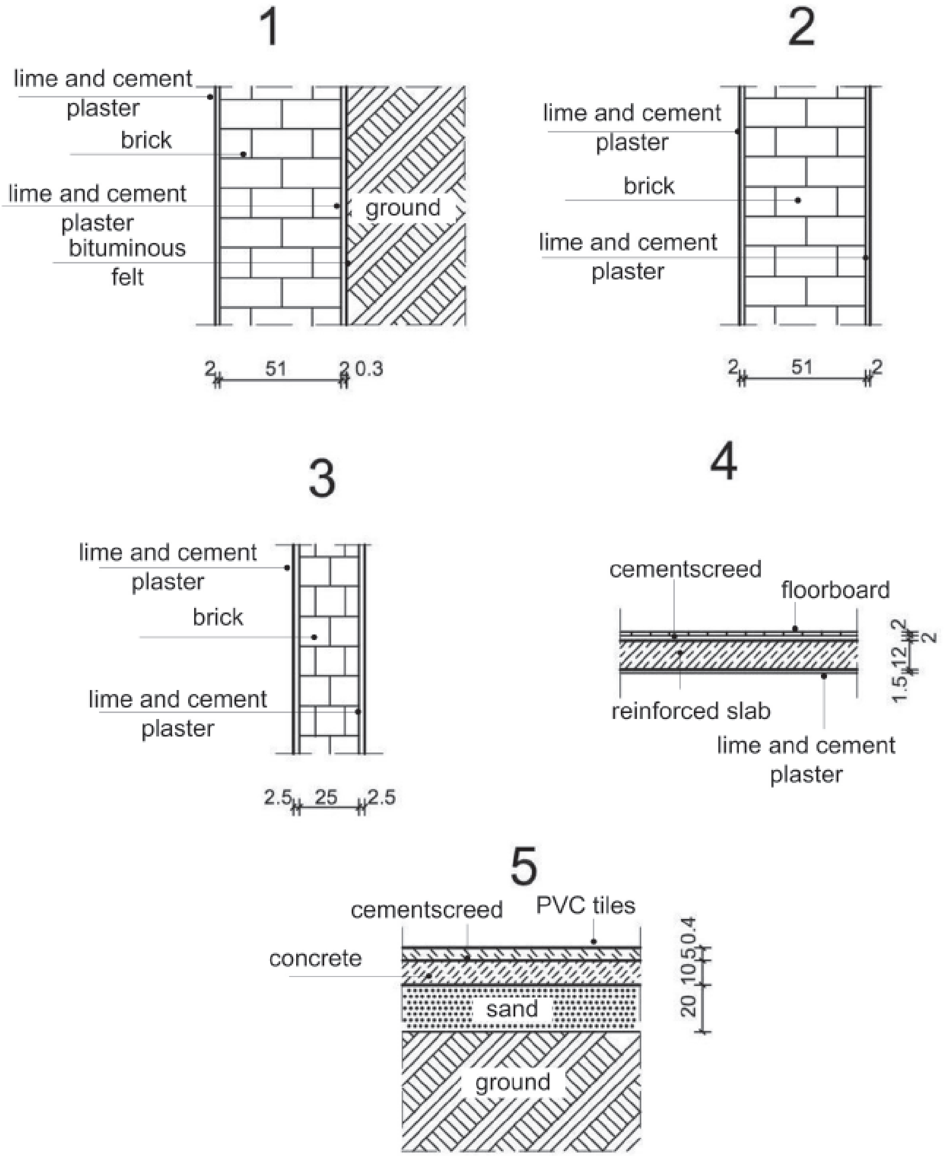

Figure 2. Structure of partitions: 1 – external wall in contact with the ground, 2 – external wall to outside air, 3 – internal wall, 4 – ceiling, 5 – floor

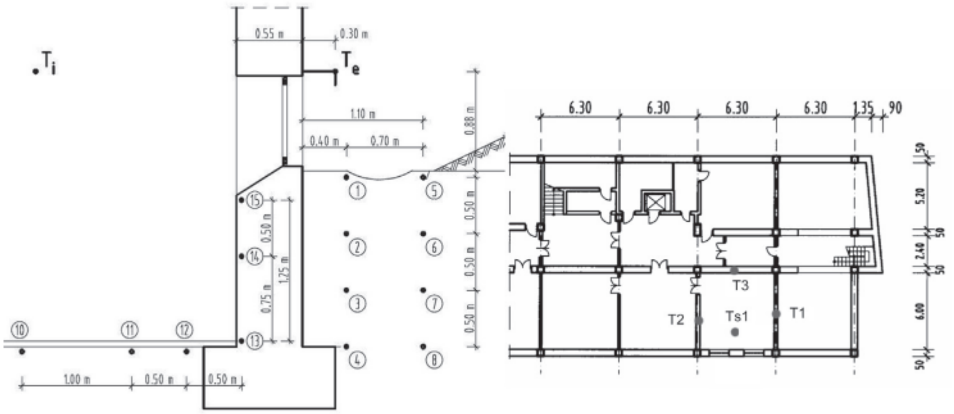

Figure 3. Basement geometry and distribution of measurement points in the researched cross-section

RESEARCH RESULTS AND DISCUSSION

In this paper the results are presented only for the year 2009, for which a complete set of measurement data was available. Moreover, the comparison of climatic conditions during a 4-year cycle allows regarding this year as representative for the entire measurement period. Fig. 4 presents the pattern of indoor air temperature in 2009 against the pattern of outside air temperature, temperature of internal surface of the wall in contact with the ground, temperature of floor surface, temperature of the three internal walls and the ceiling.

The temperature of wall surface in contact with the ground was different at particular heights. The influence of indoor climate and temperature field in the ground is visible. In warmer months, the temperature was lower in the lowest measurement points whilst in the coldest months lower temperature was recorded for higher measurement points, which were under stronger influence of the outside weather. The amplitude of temperature fluctuations in the wall adjacent to the ground decreased with the depth of measurement points (approx. 4 K per 0.6 m). Absolute average temperature difference between measurement points (looking down from the upper level) was about 2 K.

As far as floor surface is concerned, the highest temperatures were recorded at the measurement point situated close to the centre of the room, the lowest were noted close to the external wall. Contrary to the outer wall, the temperature amplitudes at the particular measurement points located on the floor were almost identical. Thus, the average absolute differences between floor measurement points were lower and equaled approx. 0.8 K. This confirms that heat accumulation in the ground has greater influence on the floor than on the external wall. Wall temperature is shaped both under the influence of outside climate and the ground.

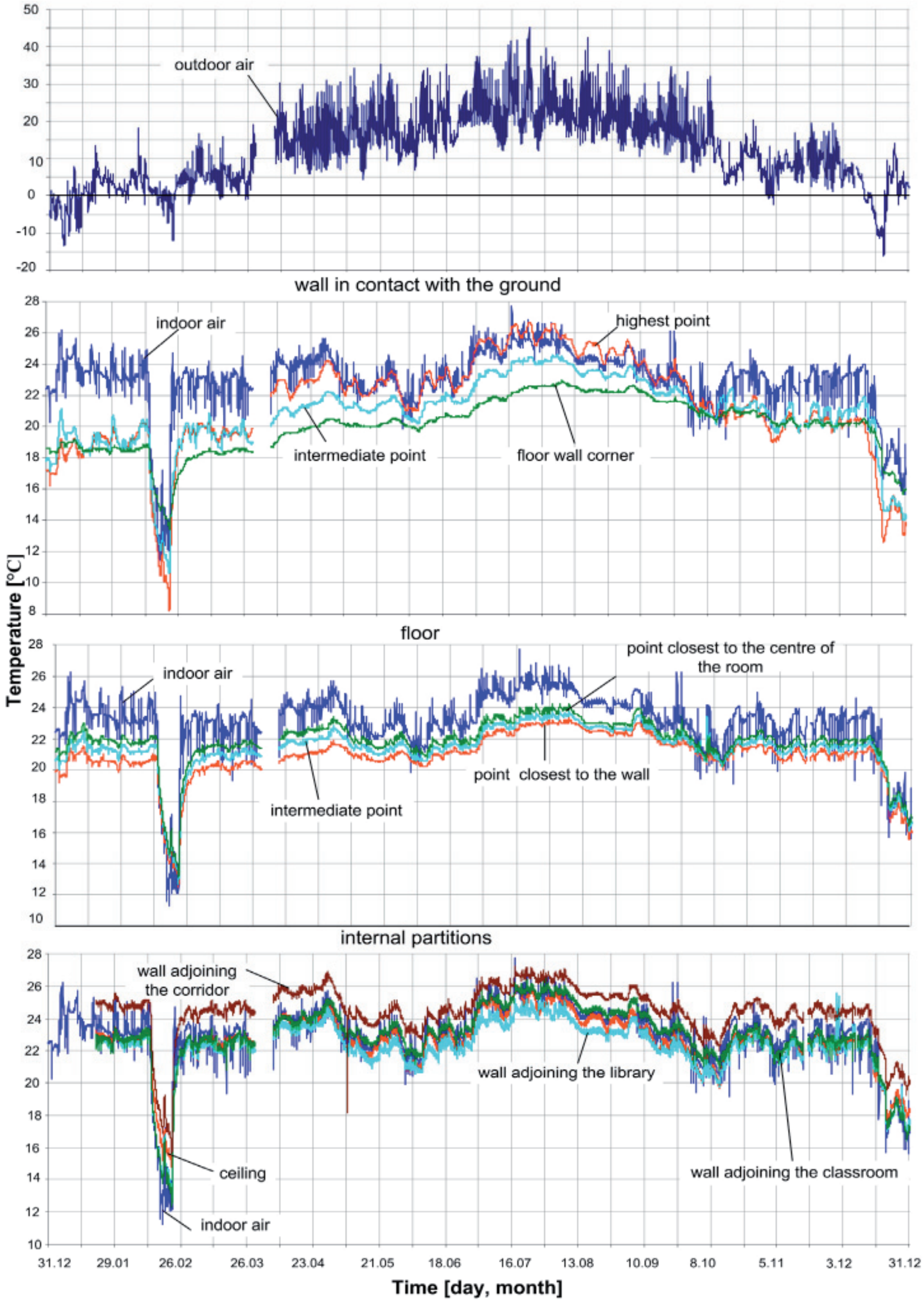

Figure 4. Pattern of outside air temperature, temperature of the wall surface in contact with the ground, temperature of floor surface and the temperature of three internal walls and the ceiling against the pattern of inside air temperature in 2009

The highest temperature values were noted for the wall adjacent to the corridor, slightly lower for the ceiling. Lower temperature was also recorded on the walls adjoining the library and the classroom.

Most interesting periods occurred when the heating did not work continuously. Figure 5 presents the pattern of wall surface temperatures in contact with the ground, floor surface temperatures, internal wall surface temperatures and the ceiling against the temperature of indoor air between 10 and 28 February, 2009. During these 11 days, the heating in the basement room was turned off.

The analysis of the above courses reveals that the floor surface temperature in the centre of the room was higher than indoor air temperature during the entire non-heating period. A similar situation could be observed at the remaining floor measurement points and in the lower parts of the walls. The differences decreased with height. At the measurement point located in the central part of the wall the temperature was very similar to the indoor air temperature. At the highest measurement point, the wall surface temperature was lower than the air temperature.

The indoor temperature decrease was caused by ventilation and heat losses through windows and the partition wall to the outside air. The upper part of the wall in contact with the ground (approx. a half of its height) cooled the room in the non-heating period. All the remaining partitions heated the room at that time because they adjoined other permanently heated rooms. The floor and the lower part of the wall in contact with the ground were heated by the ground. Thanks to this phenomenon, the air temperature inside the basement, after the heating was turned off, decreased slowly and remained higher than the outside air temperature. Only during temporary increase of indoor air temperature caused by heat gains from solar radiation or other short-term heat gain from different sources, the wall surface temperature was temporary lower. However, this does not alter the presented mechanism of temperature distribution and heat transfer when the heating was turned off.

The indoor air temperature in the researched basement decreased by approximately 13 K, floor surface temperature by approx. 9 K, wall in contact with the ground 5.5÷12.3 K (depending on the measurement point) and internal partitions by 9÷11.5 K.

After the heating was turned on, the indoor air temperature quickly returned to the value obtained before the non-heating period (after approx. 1 day). The wall surface temperature reached that value with a significant delay. The floor temperature reached the value of air temperature at the latest, after approx. 12 days. For the wall in contact with the ground this period lasted about 6 days and it was the shortest (2 days) for the remaining internal partitions.

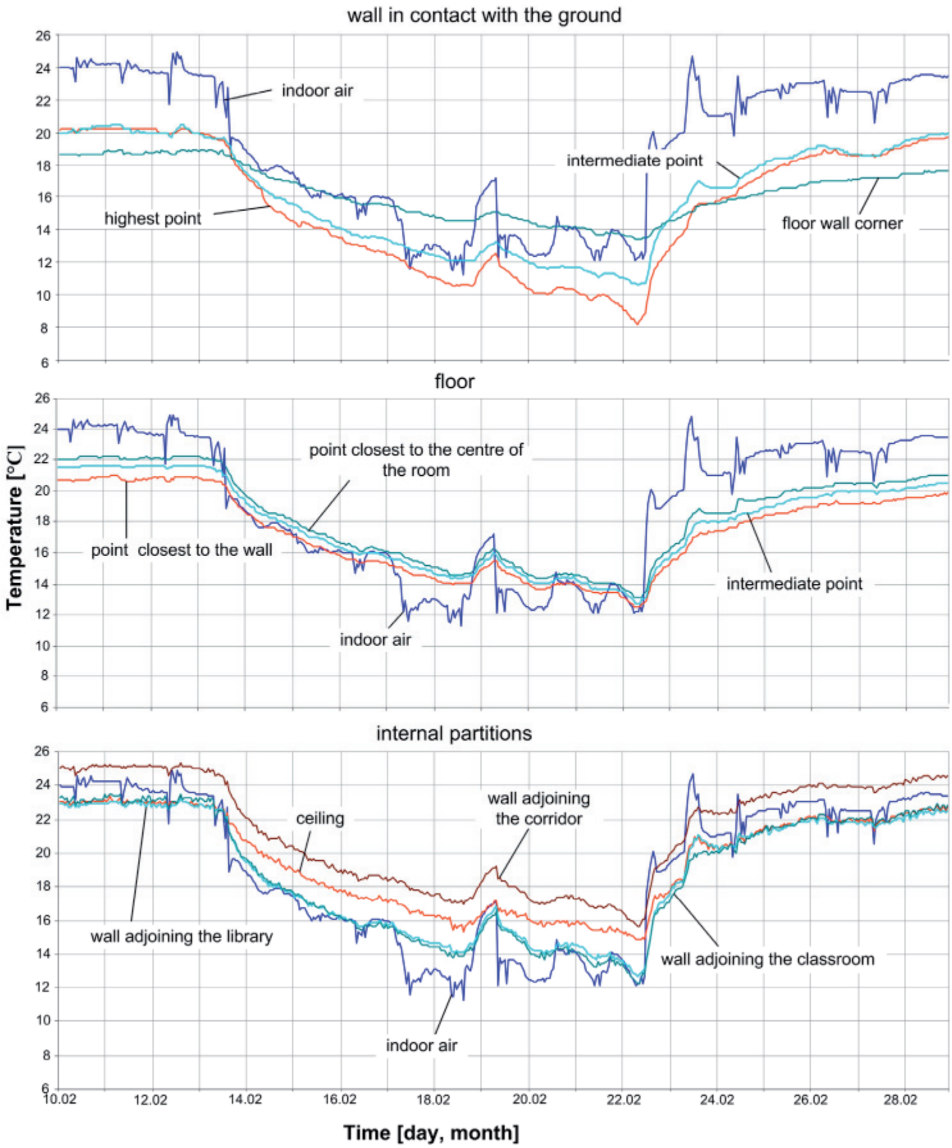

Figure 5. The pattern of wall surface temperatures in contact with the ground, floor surface temperatures, internal wall surface temperatures and the ceiling against the temperature of indoor air before, during and after the period when the heating was turned off

Temperature fluctuation during intermittence period influenced not only the temperature of wall surfaces but also the distribution of temperature in the ground. Fig. 6 presents temperature distribution in the ground against indoor air changes. At the measurement point located closer to the building, the ground temperature decreased faster than at the more distant points. In the uppermost layer, temperatures reached the same level after approx. 3 days, in the lowest layer after approx. 7 days. Afterwards, the temperature at the measurement point located closer to the wall was lower (maximum by 1 K) than at the distant point. This pattern does not refer to the points located uppermost, where further from the wall the temperature was higher by approx. 0.5 K (temporary influence of the outside temperature) and the lowest points, where temperatures only reached the same level. After the heating was turned on, the temperature at the points located closer to the building increased faster. After a certain lapse of time (at least a week), temperature distribution stabilized and reached the level prior to the non-heating period.

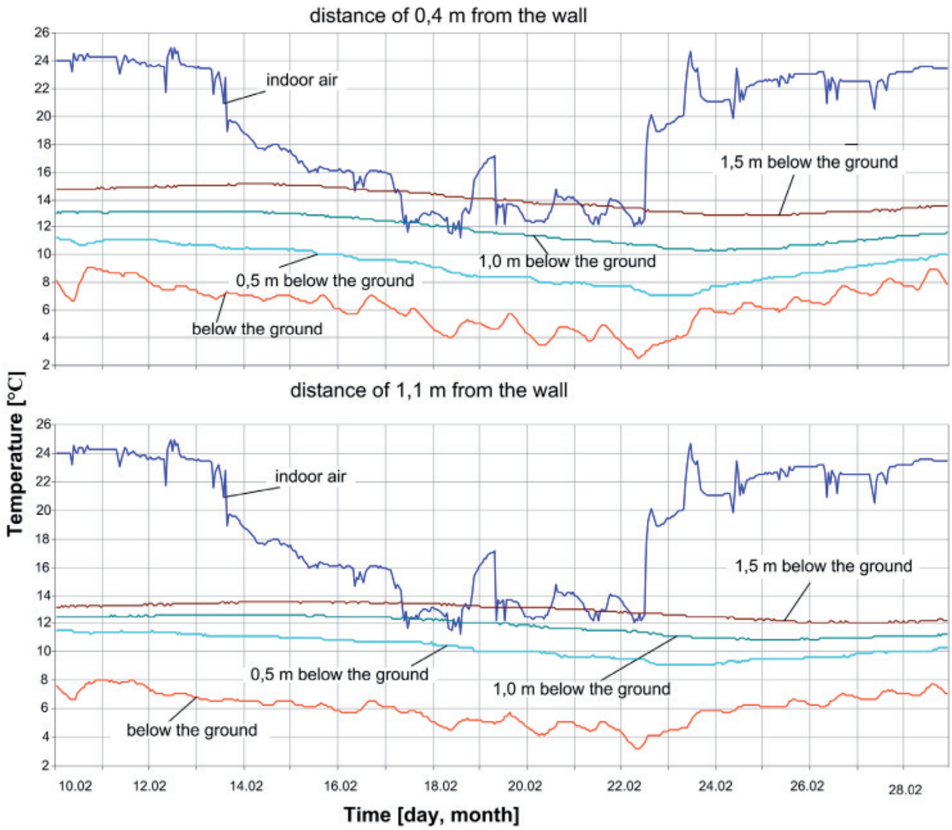

Figure 6. Temperature pattern in the ground against changes of indoor air temperature before the heating was turned off, during that period and after it was turned on again

CONCLUSIONS

The conducted experimental studies made it possible to describe temperature development under real operating conditions taking into consideration all factors that influenced the researched phenomena. Air temperature, temperature of partition surfaces and ground temperature were all measured directly and the results were analyzed in the course of the study. The results of conducted research and analyses yield the following conclusions:

1. Thermal phenomena in basements have different characteristics than in rooms whose partitions are in direct contact with outside air. During non-heating periods the microclimate in such basements develops in a passive way. In the beginning, the temperature drops faster; after a lapse of time the decrease of temperature becomes slower because the heat accumulated in partitions and the ground is returned. The research revealed a decrease of 14 K for an 11-day non-heating period.

2. The highest temperature fall on the internal wall surface in the non-heating period occurred on the wall in contact with the ground. The measurements revealed a decrease of approx. 9.7 K for the wall and 8.8 K for the floor.

3. After the heating was turned off, the floor surface temperature was higher than indoor air temperature at any moment. The floor of such a basement heats the room by heat accumulated in the ground.

4. During the non-heating period, the wall in contact with the ground insignificantly heats the room only to the half of the height. In the upper part, the outside conditions exert larger influence and this surface cools the room already after a few hours after the heating is turned-off.

5. After the heating is turned on, the inside air heats up to the required value after approx. 1.0 day. The partitions reach the surface temperature prior to the non-heating period after a significantly larger lapse of time. For a wall, this lasts about 6 days and for the floor 12 days.

6. Air temperature in the heated room in winter is maintained at the level of approx. 24°C. The surface temperature for the partitions in contact with the ground is lower by 2÷3 K in the heating period.

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