EXPERIMENTAL INVESTIGATION OF PERFOMANCES OF PANEL HEATING SYSTEMS

EKSPERIMENTALNO ISTRAŽIVANJE KARAKTERISTIKA PANELNIH SISTEMA GREJANJA

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This paper aims to conduct the experimental research of energy consumption of panel heating systems. Also, the aim of paper is to examine the performance of the newly developed concept „floor-ceiling "heating. The study was conducted in the laboratory condition in the cooling test chamber that has the ability to work at temperatures lower than 0°C. As output parameters were used: electricity consumption for operating the heating panel and the indoor temperature of test model. Test model was investigated at the Faculty of Engineering at Kragujevac. Also, this research is part of the project „Development of net-zero energy houses. "

Key words: *panel heating; floor-ceiling heating; energy consumption; experimental.*

I. Introduction

In Serbia is increasingly use of panel heating systems. Panel heating systems are typical representatives of low-temperature panel heating systems. From the thermodynamic point of view they are very complex and involve different mechanisms of heat transfer such as: heat conduction through the wall, heat convection from the wall to the surrounding air and radiation from the panel on the surrounding area and the body.

This research is a continuation of previous numerical investigations of panel system. In addition to the standard types of panel heating (floor, wall and ceiling heating) in previous research to come to a new concept of "floor-ceiling" which proved to be more energy efficient compared to other panel heating systems [1].

The main objective of this research is to experimentally verify the previously obtained numerical results. Experimental procedure was conducted on the test model consisted of two rooms (storey). The heating panels are made of the electric heating cables. External conditions are kept constant in the cooling chamber at the temperatures of -5°C, 0°C and 4.5°C. The main parameter for comparison of the performance of these systems was the power consumption of the panel. Also, the changes of the internal temperature of the test model was accompanied.

II. Experimental procedure

Experimental study of the characteristics of panel heating systems were performed at the Faculty of Engineering Sciences in Kragujevac, partly in the Laboratory of Thermodynamics and Thermal Engineering, and partly in the Laboratory of Motor Vehicles.

The experimental installation includes a test chamber, the test model of the house, measuring and control equipment for data collection.

The dimensions of the test chamber was 1500x1500x1800mm and it placed inside the room dimensions 3500x5500x3800mm (Fig. 1). Test chamber works on the cooling chamber principle which contains two evaporators (Fig. 2) associated with air chiller. Chiller on the condenser side uses air from the room located within the test chambers. The test chamber has the ability to cool until -15°C however, due to the work of the chiller inside the building in which the chamber was located and due to the low rate of air change in the room leads to overheating of the air and it is not advisable go to temperatures below -5°C. The temperature of the test chamber was controlled by PID controller (Fig. 3) type XMTF-308 product Yuyao Gongyi Meter Co. Ltd. [2], which is connected to the PT100 probe. The humidity and temperature inside the test chamber was measured by the sensor of temperature and humidity type TSN-TH70E product "AREXX Engineering" Netherlands (Fig. 4) [3]. This sensor used "wireless" connection to communicate with the computer.

Fig. 1. The test chamber

Fig. 2. The interior of the test chamber – preview of evaporator

Fig. 3. The sensor for maintaining the temperature inside the test chamber

Fig. 4. The sensor for the acquisition of temperature and humidity inside the test chamber

The test model was consisted of two stairs that are placed one above the other so that each represent one room which was heated. Dimensions of the test model was 1000x800x650mm where the room height was 650mm. In addition, each stair has one opening on the side which glazed with Plexiglas dimensions 300x250mm. This opening has the function of the window and also has the function of an inspection opening. In this experiment investigated four types of panel heating systems was used: floor heating, wall heating, ceiling heating and floor-ceiling heating. So the test model has the ability of the simulation any of the mentioned systems, and in each of the room the wall panel and floor panel was built and by rotation of the rooms for 180 °C floor panel become to the ceiling and vice versa (Fig. 5)

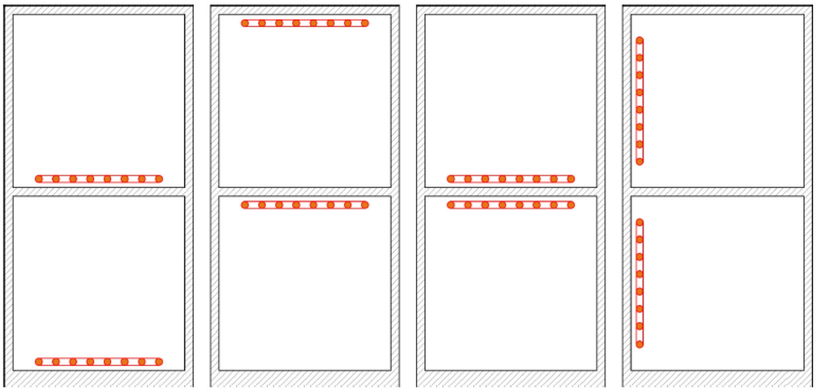


Fig. 5. Analyzed panel heating systems

Fig. 6. The interior of the test model - show the position of the PT100 probe

The heating panels are made of polystyrene thickness of 50mm, unrefined slab of plywood thickness of 18mm, PVC mats, electric heating cable, cement mortar thickness of 5mm and (Fig. 7). Test model in a constructive sense was entirely made by plywood, through which by staples attached PVC mesh with the have the role of laying of the heating cable with raster laying of 50mm (Fig. 8). Over the heating cable the thin layer of cement mortar with thickness 5mm was applied, which contributes to a homogeneous temperature distribution along the heating panels.

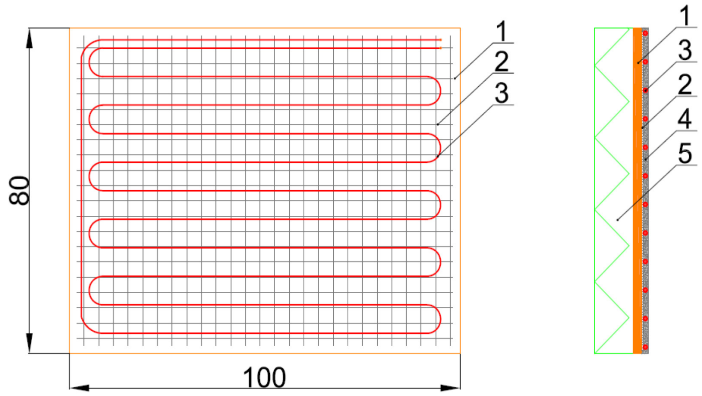


Fig. 7. Details of panel construction
(1) Plywood panel; (2) PVC grid; (3) electric heating cable; (4) cement mortar; (5) polystyrene

Fig. 8. Detail of installation of heating cable

Construction of **eletrici heating cable** consist of the Heating Conductor, Fluoropolymer Dielectric Insulation, Glassceramic Tape, Nickel-Plated Copper Braid (BN), Fluoropolymer Overjacket. Heat output of the heating cable was 17 W/m, the thickness of the electric heating cable was 3.5mm, and the minimum bending radius was 5D.

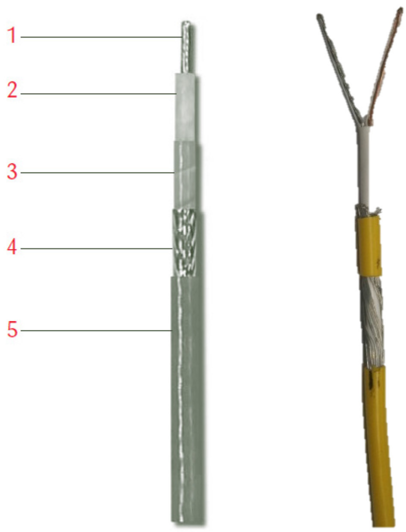


Fig. 9. The construction of electric heating cable
(1) Heating Conductor; (2) Fluoropolymer Dielectric Insulation; (3) Glassceramic Tape; (4) Nickel-Plated Copper Braid (BN); (5) Fluoropolymer Overjacket

Measuring procedure is based on measurement of energy consumed in order to maintain a constant temperature within the test model. The test model is placed inside a test chamber, within which is maintained a constant temperature. For the internal temperature of the test chamber were selected three values as follows: 4.5°C, 0°C, and -5°C. The first value was chosen because the average temperature of the heating period for cities in Serbia mainly about 4.5°C. While temperatures -5°C maximum permissible value in the measurement installation. Temperature 0°C the intermediate value between the two above-mentioned values. The heating panels were connected to a heat regulator that regulates the auto-transformer on the principle on/off. Each room of the test model has its own controller, which measures the value by the PT100 probe placed in the middle of room (Fig. 6). Temperature regulators were connected to a computer where it is logging the temperature inside the test room of the models and exclusion/inclusion of the transformer. The output from the autotransformer to the heating panel was set to 220V and 0.895 ± 0.005A which gives the overall power of the panel about 197 ± 0.5 W. These parameters were kept constant during the measurement and the control by measuring of the temperature inside the room of test model included or excluded operation of autotransformers.

Test the installation was aimed to verify the accuracy and exam performance of the heating panels prior to their installation in the test model. This was necessary in order of accuracy control of the panels as well as for the determination of the temperature gradient of each panels. Temperature gradient was determined by using the thermal IC camera types i7 product "Flir" [4].

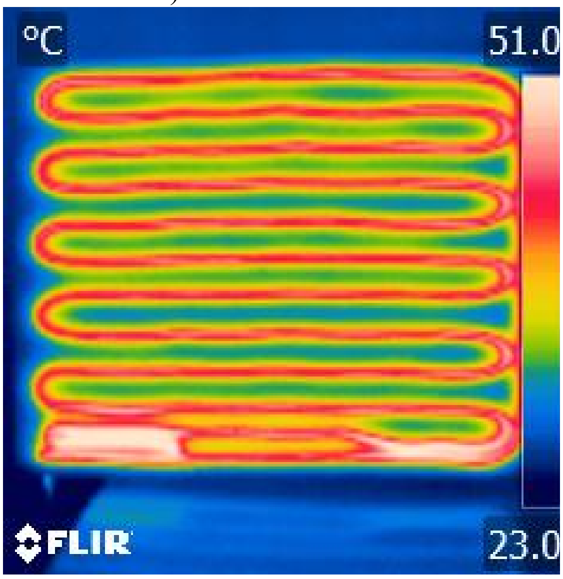
III. Results and discussion

Figure 10 shows the temperature field of used panels. Actually, each rooms has one wall panel and a one ceiling or a floor panel (depending on the position-rotation rooms of models). Also on the figure was shown the set data of the heating panels (a), the output parameters from autotransformer to the panel (b), the temperature field in the range of from 23 to 51°C (c) and temperature field in the range of from 31 to 51°C (d).

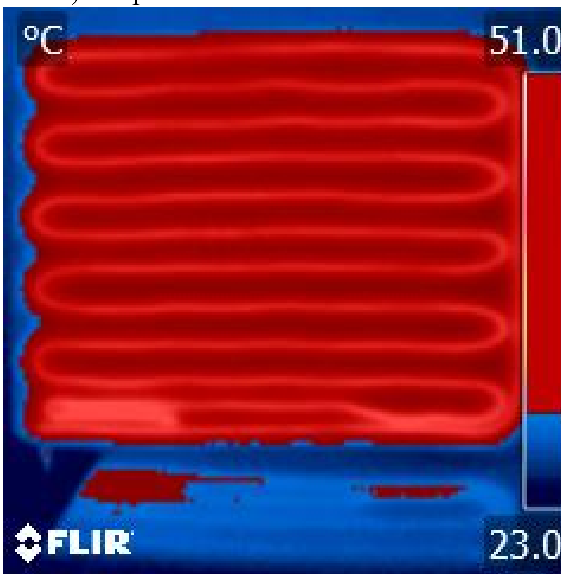
The output from the autotransformer to the heating panel was set to 220V and 0.895 ± 0.005A which gives the overall power of the panel about 197 ± 0.5 W (for floor heating P = 196.7W; for wall heating panels 1 P = 196.9W; for wall heating panels 2 P = 196.9W; for floor-ceiling heating P = 197.4W).

a) Test installation

b) Output value of auto-transformer



c) Thermo graphic view of the heating panel



d) Thermo graphic view of the heating panel with a given threshold is a temperature

Fig. 10. Test measuring of the panels

Figure 11 shows the energy consumption of analyzed heating panels. Consumption are shown at a constant outdoor temperature of -5°C, 0°C and 4.5°C. The ceiling heating has the highest energy consumption: 183.98Wh, 150.64Wh and 122.88Wh at the constant outdoor temperatures of 5°C, 0°C and 4.5°C, respectively. The lowest energy consumption has the floor-ceiling heating about 163.23Wh, 131.71Wh and 97.28Wh at constant outdoor temperatures of -5°C, 0°C and 4.5°C, respectively. Wall heating has a the energy consumption of 180.10Wh, 145.87Wh and 114.89Wh and the floor heating has the energy consumption about 175.04Wh, 141.25Wh and 111.58Wh at constant outdoor temperatures of -5°C, 0°C and 4.5°C, respectively.

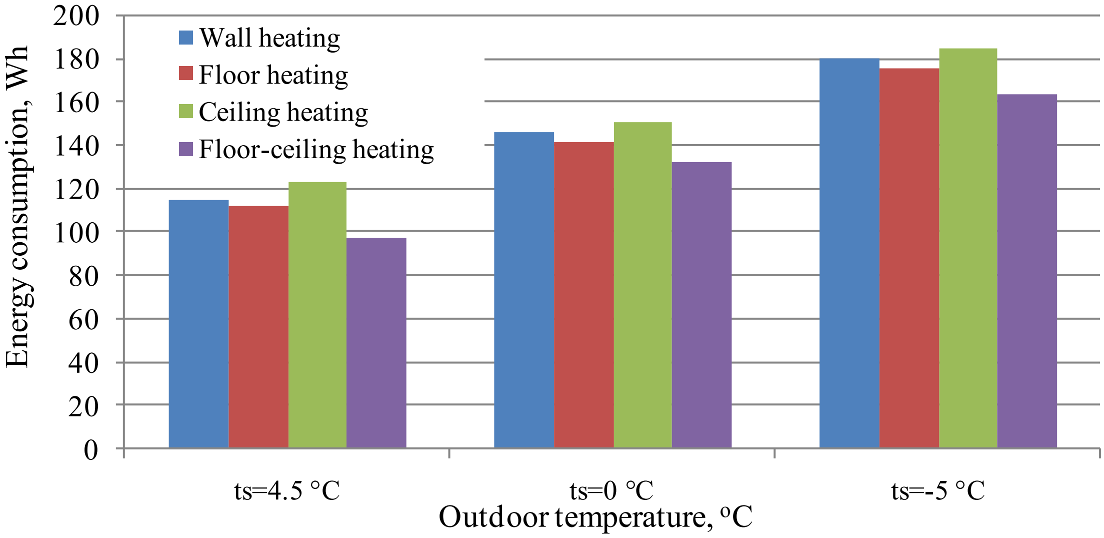


Fig. 11. The comparison of energy consumption of panel heating systems (floor, wall, ceiling and floor-ceiling heating)

Figures 12 and 13 shows the changes of the internal temperature during the analyzed period of the measurement. The measurements are shown during each second a of the total interval of 2 hours. During the constant outdoor temperature of -5°C the changing of the temperature inside the rooms of the test model was measured.

In the case of wall heating the temperature was predominantly in the range of 20±0.1°C with several peaks of ± 0.2°C.

In case of floor heating the temperature of lower rooms of the test model was predominantly in the range of 20±0.1°C with several peaks of ±0.2°C. While the temperature of the upper rooms of the test models except for one measurement sample was exclusively on the range of 20±0.1°C. This can be attributed the movement of the heat flux from the lower toward the upper rooms of the test model.

In the case of ceiling heating the temperature of lower room of the test model was predominantly in the range of 20±0.1°C with several peaks of ±0.2°C. While the temperature of the upper room of the test model was mostly in the range 20±0.1°C with frequent peaks of ±0.2°C and in some peaks of ±0.3°C. Unstable values of temperature inside the upper room of the test models can be attributed to the movement of heat flux up, state of thermal envelope and the position of the heating panels.

In the case of floor-ceiling heating the temperature of lower room of the test model compared to other systems had higher fluctuations of temperature mostly in the range of 20±0.3°C. On the other hand, the temperature of the upper room of the test model was significantly lower than in previous systems and it was in the range of 19°C to 19.5°C.

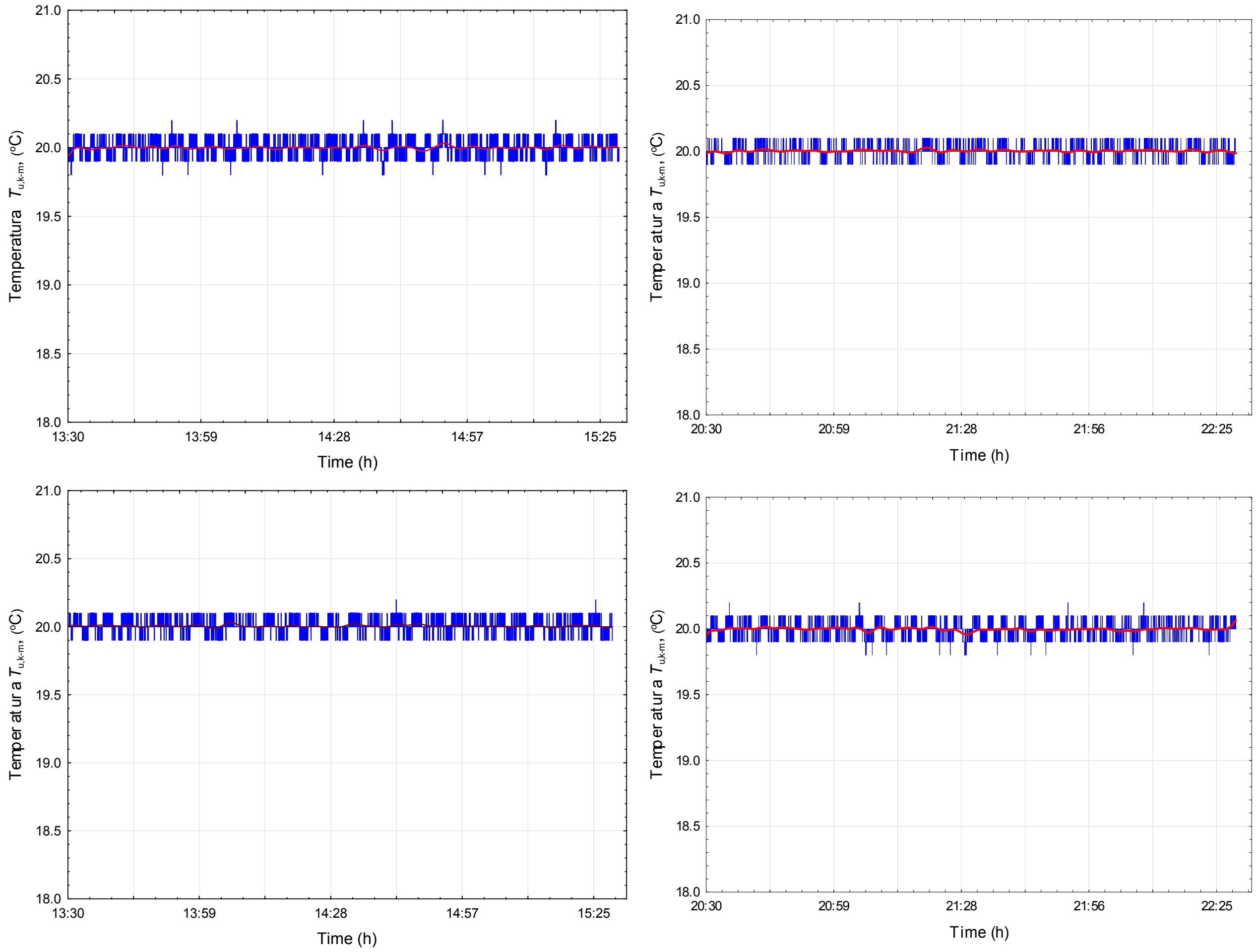
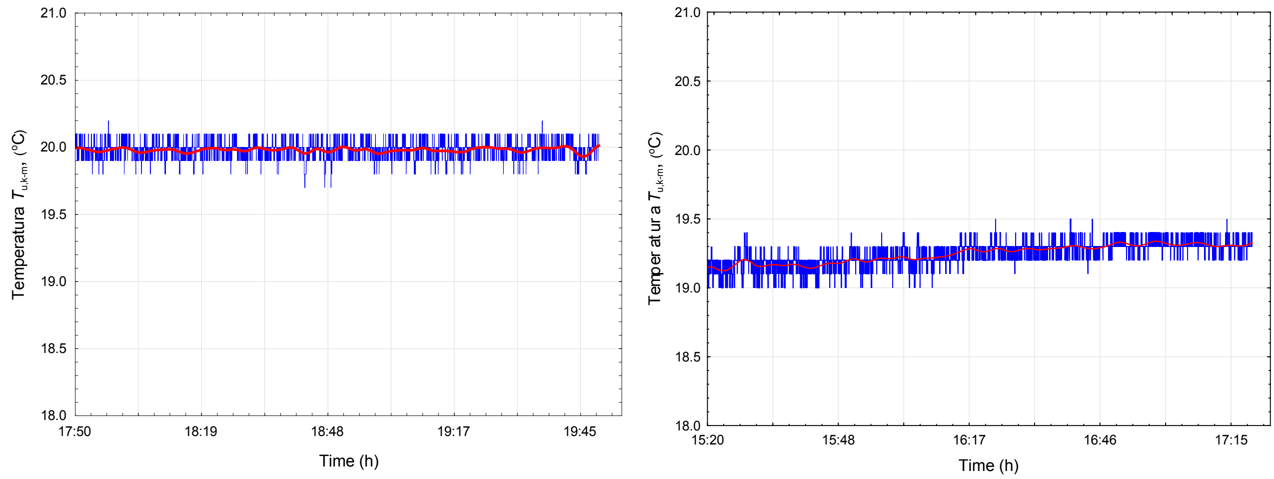


Fig. 12. The internal temperature of the rooms of the test model
for the cases of wall heating (left) and floor heating (right)
upper room (figure above), the lower room (figure below)



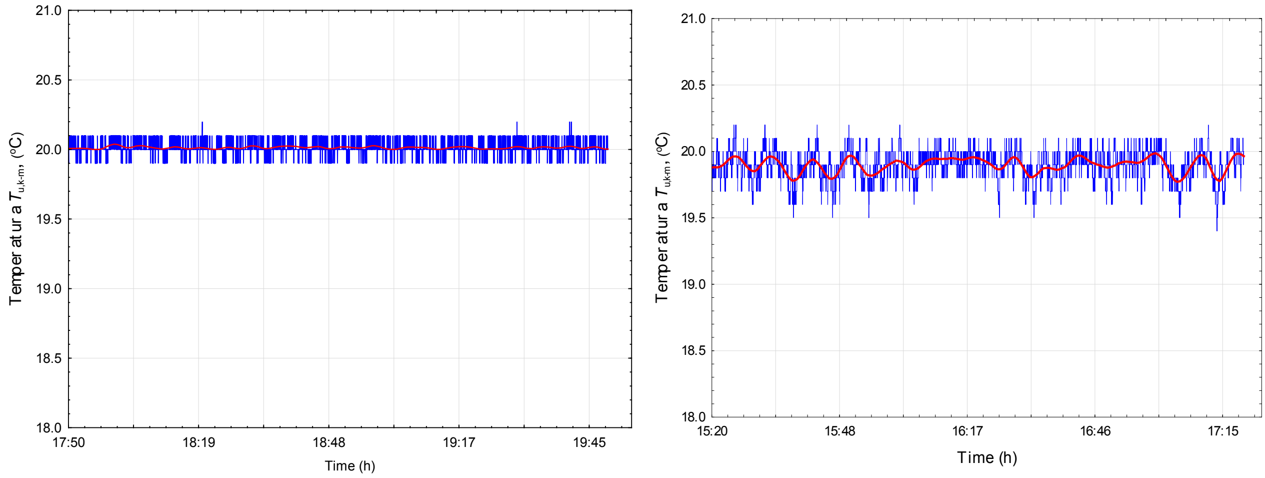


Fig. 13. The internal temperature of the rooms of the test model for the cases of ceiling heating (left) and floor-ceiling heating (right) upper room (figure above), the lower room (figure below)

IV. Conclusions

In the experimental procedure has been conducted up to identical conclusions as in the previous studies based on numerical investigation. So, floor-ceiling heating panels consumes the least energy and ceiling heating panels has the highest consumption. Thus, at outdoor temperatures of -5°C, 0°C and 4.5°C floor-ceiling heating regard to the ceiling heating consumes less energy for 20.83%, 12.57% and 11.28%, respectively. I.e., at higher outdoor temperatures the difference in energy consumption is higher while at lower temperatures this difference decreases. This may be related to the state of the thermal envelope. On the other side the floor and wall heating are similar in energy consumption and consume significantly less power than the ceiling panels. When looking the temperature inside the rooms of the test model the floor, wall and ceiling heating temperatures were maintained within the desired values of temperature without any fluctuations. On the other hand, for the floor-ceiling heating in the room in which the temperature was regulated the temperature fluctuations were present. Also the temperature in the room without regulation was lower than desired temperature about 0.5-1°C.

So it can be concluded that the floor-ceiling panels more energy efficient compared to the others panels. Also, a slightly lower temperature can be solved by a combination of regulation from the upper and lower room with dominating regulation of temperature in the lower room.

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V. Literatures

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