UTICAJ PROMENE TEMPERATURE IZVORA KOD ELEKTRIČNIH PODNIH PANELA

INFLUCENCE OF SOURCE TEMPERATURE CHANGE ON ELECTRIC FLOOR HEATING PANELS

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1. Introduction

Among the panel systems, floor heating is the most widely used in Serbia because it offers characteristic advantages in terms of thermal comfort and final energy consumption.

- the uniform distribution of room temperature,
- lower temperature regime,
- easy installation,
- long service life,
- simple control,
- the current low price of electricity

are the reasons for the increasing use of electric heating cables (EHC) in floor heating systems.

From the other side, the application of low-temperature electric floor heating panels (LTEFHP) is limited to hygienic requirements, therefore the surface temperature of the floor should be uniform and within certain limits.

In the first part of the paper, using the finite volume method (FVM) in software ANSYS Workbench 14.5, the field of application of electric heating cables (EHC) in the construction of floor heating panels (FHP) was examined, taking into account their axial spacing and temperature regime. In the second part of the paper, the behavior of LTEFHP was experimentally investigated on a physically constructed model of the test chamber by monitoring the internal air temperature (IAT) depending on the external conditions.

2. Numerical model

2.1 Description of the heating system

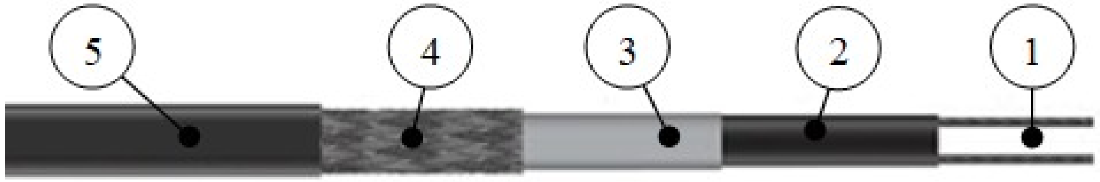


Figure 1. Cross-section of EHC

(1) The multi-core heating core
(2) XLPE layer
(3) PET coating
(4) Thin copper coating
(5) PVC layer

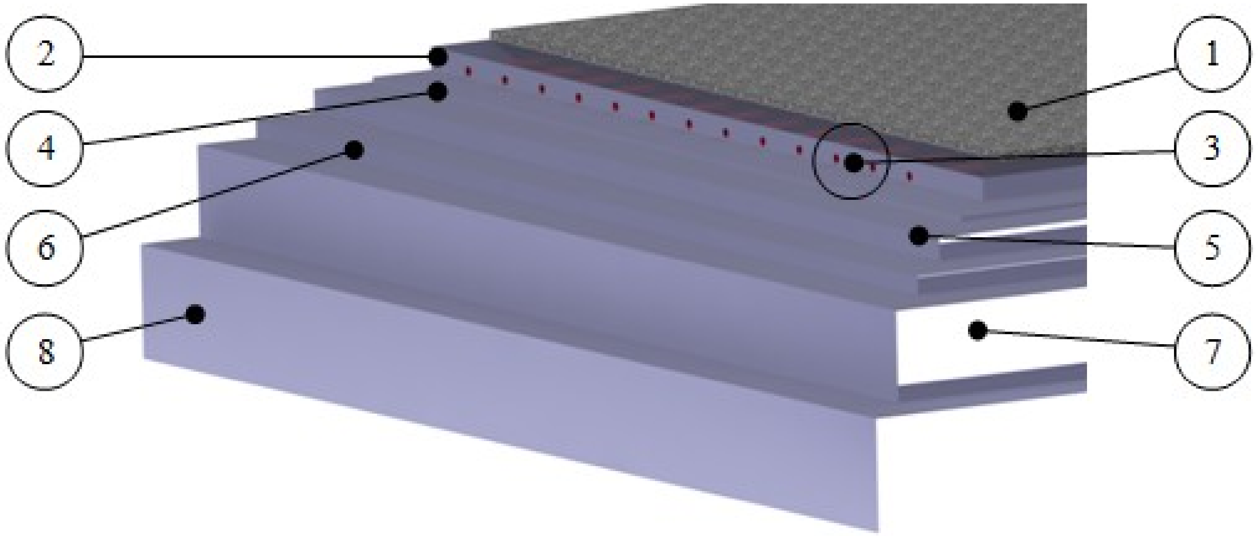


Figure 2. Construction of the floor heating panel

(1) Granite plates
(2) Cement screed
(3) EHC
(4) PVC foil
(5) Styrofoam
(6) Reinforced concrete
(7) Gravel layer
(8) Stone layer

2. Numerical model

2.1 Description of the heating system

Table 1. Characteristics of materials in the construction of the floor heating panel

Ordinal number	Material	H [m]	ρ [kg/m³]	c_p [J/kgK]	λ [W/mK]
1	Granite plates	0.012	2700	920	3.5
2	Cement screed	0.05	2200	1050	1.4
3	EHC	-			
4	PVC foil	0.001	1200	960	0.19
5	Styrofoam	0.05	33	1500	0.035
6	Reinforced concrete	0.04	2400	960	2.04
7	Gravel layer	0.2	1700	840	0.81
8	Stone layer	0.25	1750	840	2.035

2. Numerical model

2.2 Finite volume method

The general principle of conservation in differential form

$$\frac{\partial(\rho\phi)}{\partial t} + \mathrm{div}(\rho\phi\,\mathbf{u}) = \mathrm{div}(\Gamma\ \mathrm{grad}\,\phi) + S_\phi$$

$$S_\phi = 0$$

$$S_\phi = -q_{CON}$$

$$S_\phi = -q_{RAD}$$

$$S_\phi = -(q_{KON} + q_{RAD})$$

$$\mathrm{div}(\Gamma\ \mathrm{grad}\,\phi) + S_\phi = 0$$

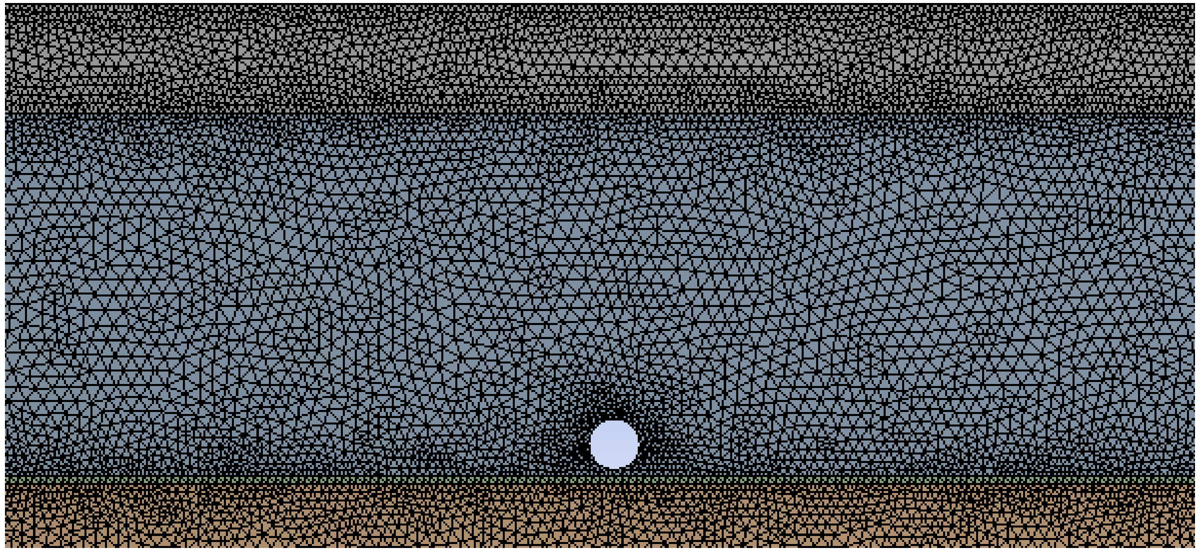


Figure 3. Discretization of the low temperature electric floor heating panels in the heating cable zone

2. Numerical model

2.3 Scenario simulation

Table 2. Simulation scenario

t_{IN} [°C]	30; 35; 40; 45; 50
L [mm]	70; 80; 90; 100; 110; 120; 130; 140; 150; 160; 170; 180; 190; 200

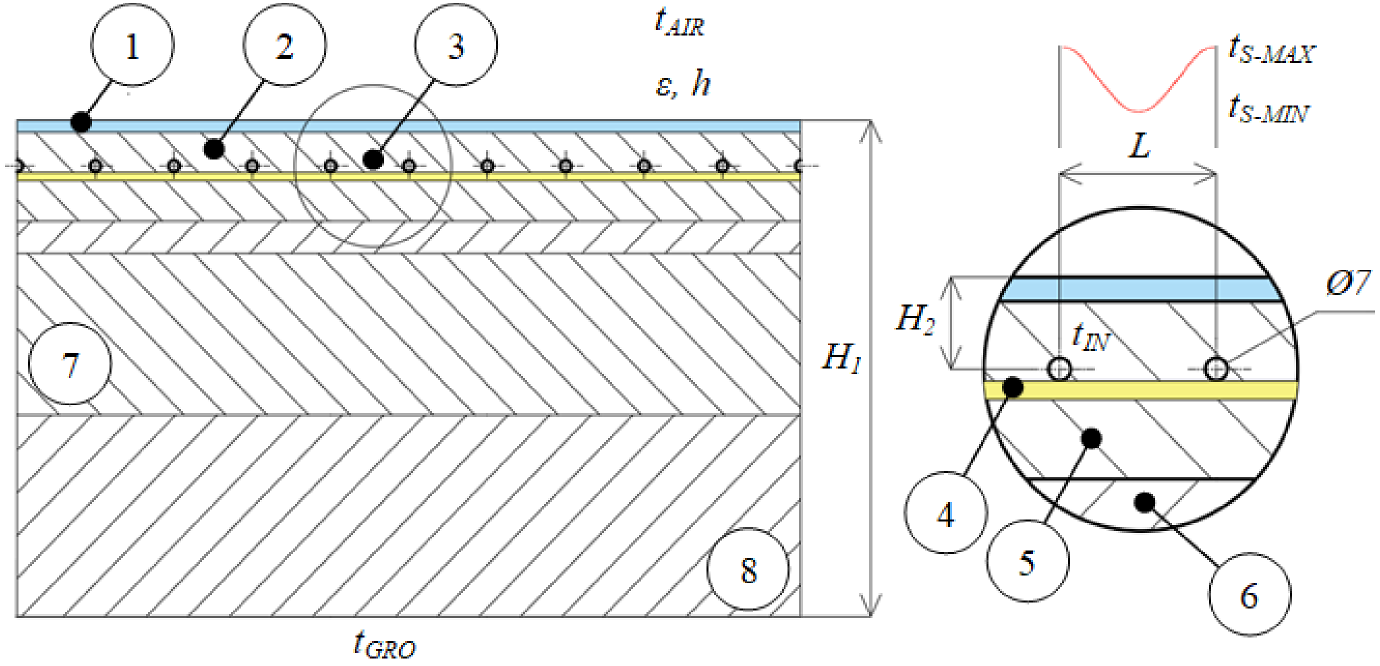


Figure 4. Initial boundary conditions before simulation of LTEFHP

H_1 = 603 mm

H_2 = 57.5 mm

t_{AIR} = 20° C

h = 6 W/m2K

t_{GRO} = 18° C

ε = 0.45

2. Numerical model

2.4 Results and discussion

Table 3. The maximum floor temperature limit values depending on the LTEFHP application

Room category	Type of room	$t_{S\text{-}MAX}$ [°C]
I	In working rooms where a longer period of time is mostly standing	25
II	In residential and office spaces	28
III	In exhibition and similar halls	30
IV	In the bathrooms and swimming pools	32
V	In rooms where short stays, or through which only passes	35

2. Numerical model

2.4 Results and discussion

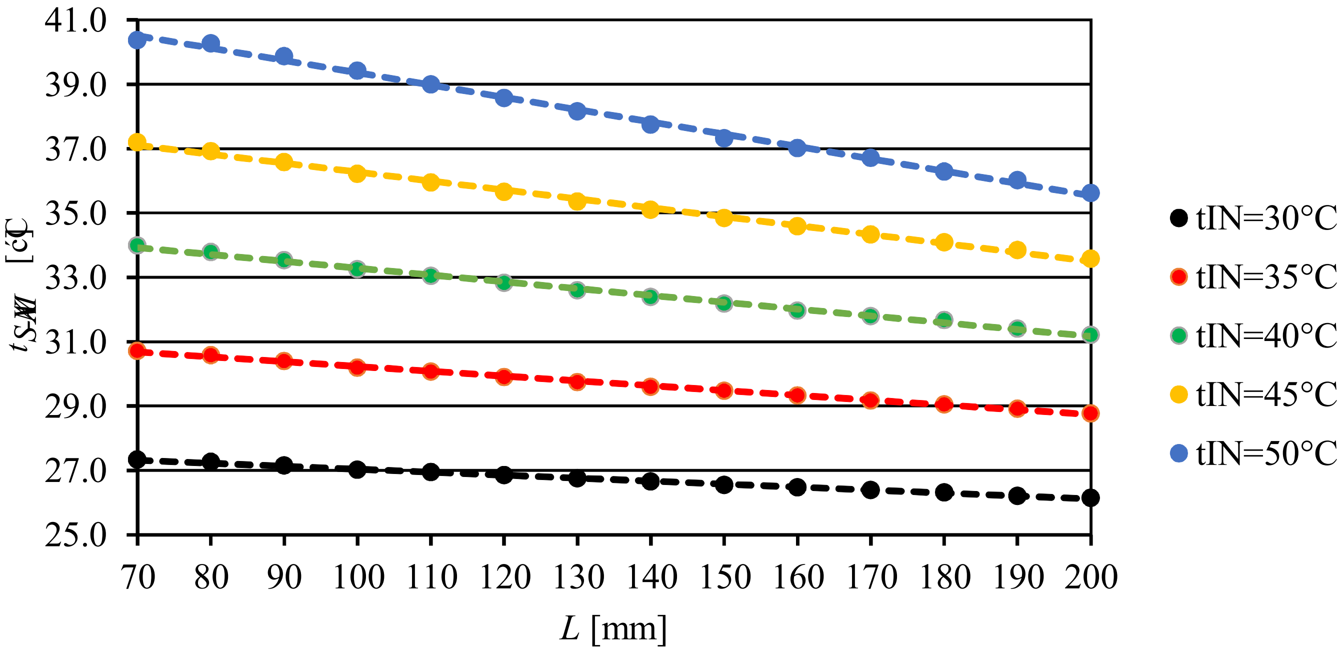


Figure 5. The maximum surface temperature of the LTEFHP depending on the operating temperature and the axial distance of the EHC

$$t_{S-MAX}(t_{IN} = 30^\circ C) = -0.009 \times L + 27.96$$

$$t_{S-MAX}(t_{IN} = 35^\circ C) = -0.015 \times L + 31.72$$

$$t_{S-MAX}(t_{IN} = 40^\circ C) = -0.021 \times L + 35.41$$

$$t_{S-MAX}(t_{IN} = 45^\circ C) = -0.027 \times L + 39.04$$

$$t_{S-MAX}(t_{IN} = 50^\circ C) = -0.038 \times L + 43.18$$

t_{IN} = 30°C → C II

t_{IN} = 35°C → for L = 115-200 mm – C III

t_{IN} = 35°C → for L = 70-114 mm – C IV

t_{IN} = 40°C → for L = 163-200 mm – C IV

t_{IN} = 40°C → for L = 70-162 mm – C V

t_{IN} = 45°C → for L = 150-200 mm – C V

t_{IN} = 50°C → can not be use

3. Experimental model

3.1 The test chamber

Figure 6. The interior of the test model – show the position of the PT100 probe

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

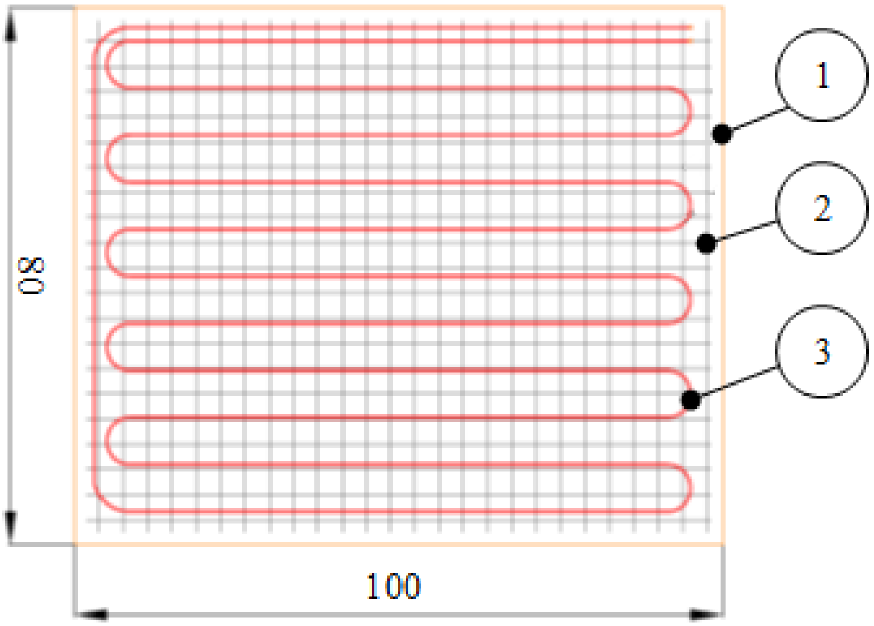
Test chamber: 1500x1500x1800 mm

Dimensions of the test model: 1000x800x650 mm

Window single glazed with Plexiglas: 300x250 mm.

3. Experimental model

3.1 The test chamber



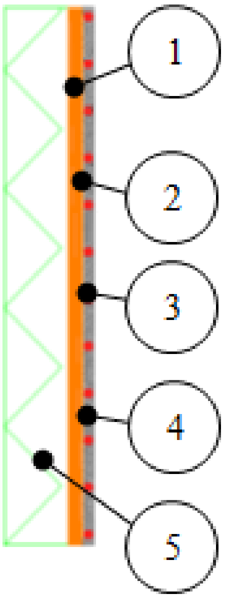


Figure 7. Modify LTEFHP

Figure 8. Detail of installation of the modify LTEFHP

The modify LTEFHP are made of Polystyrene (5) thickness of 50 mm, unrefined Plywood Slab (1) thickness of 18 mm, PVC Mats (2), EHC (3), Cement Mortar (4) thickness of 5mm (Fig. 7).

3. Experimental model

3.2 Results and discussion

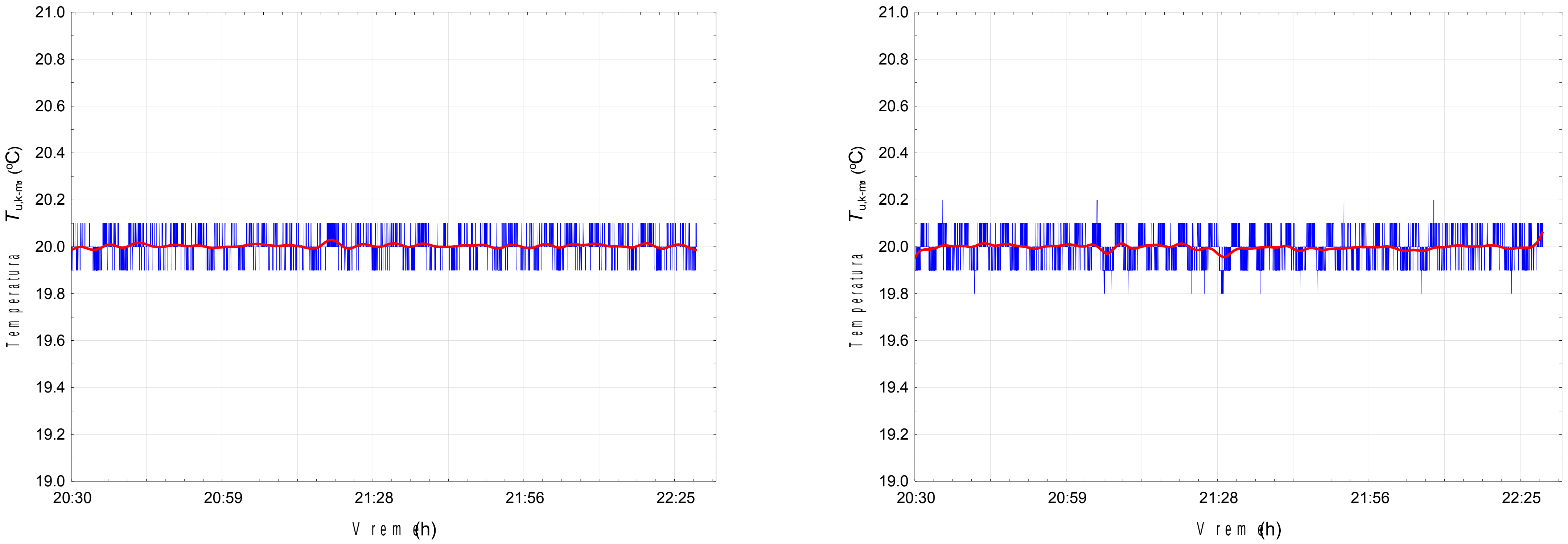


Figure 9. Indoor temperature for t_{OUT} = -5°C
upper floor (left) and lower floor (right)

3. Experimental model

3.2 Results and discussion

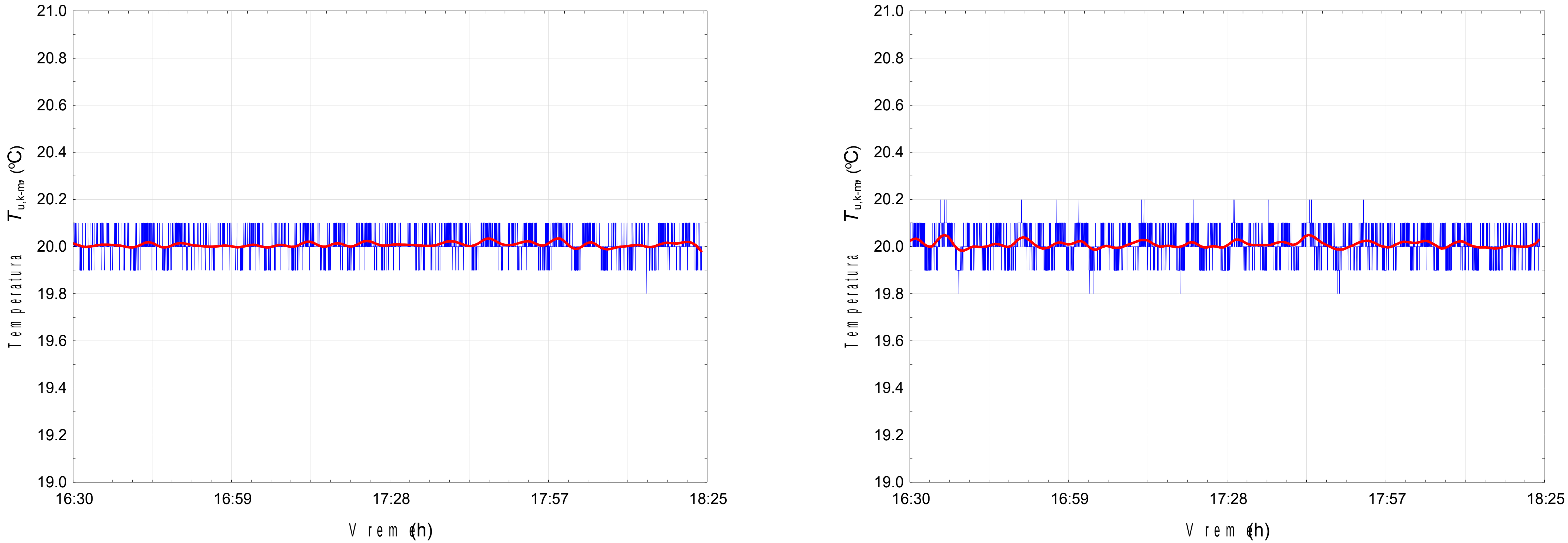
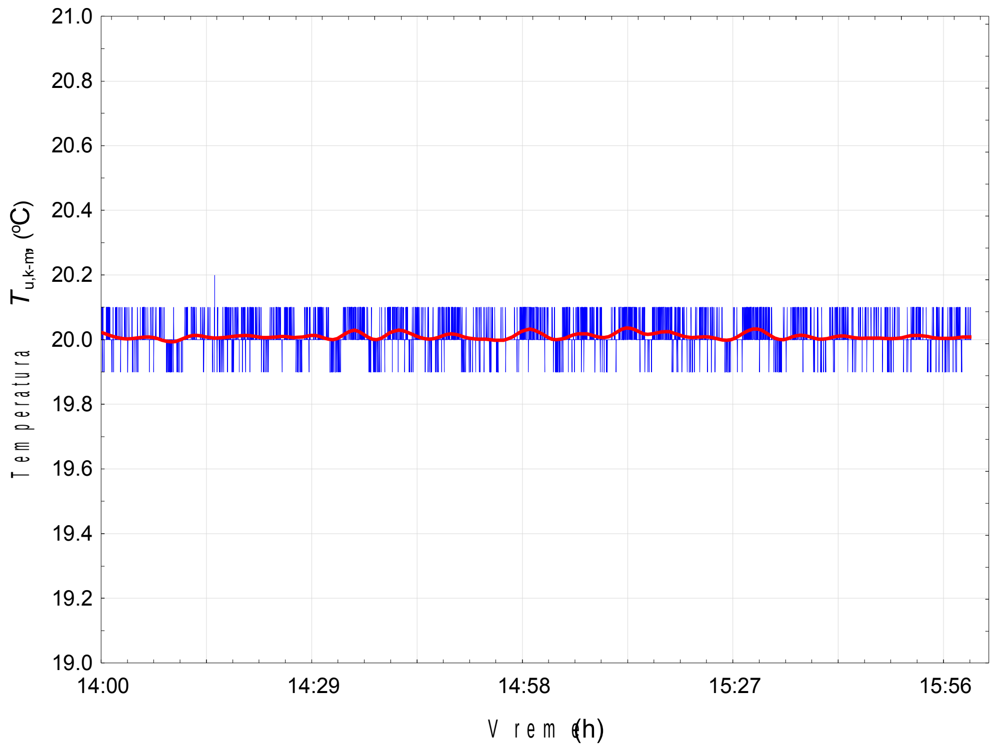


Figure 10. Indoor temperature for t_{OUT} = 0°C
upper floor (left) and lower floor (right)

3. Experimental model

3.2 Results and discussion



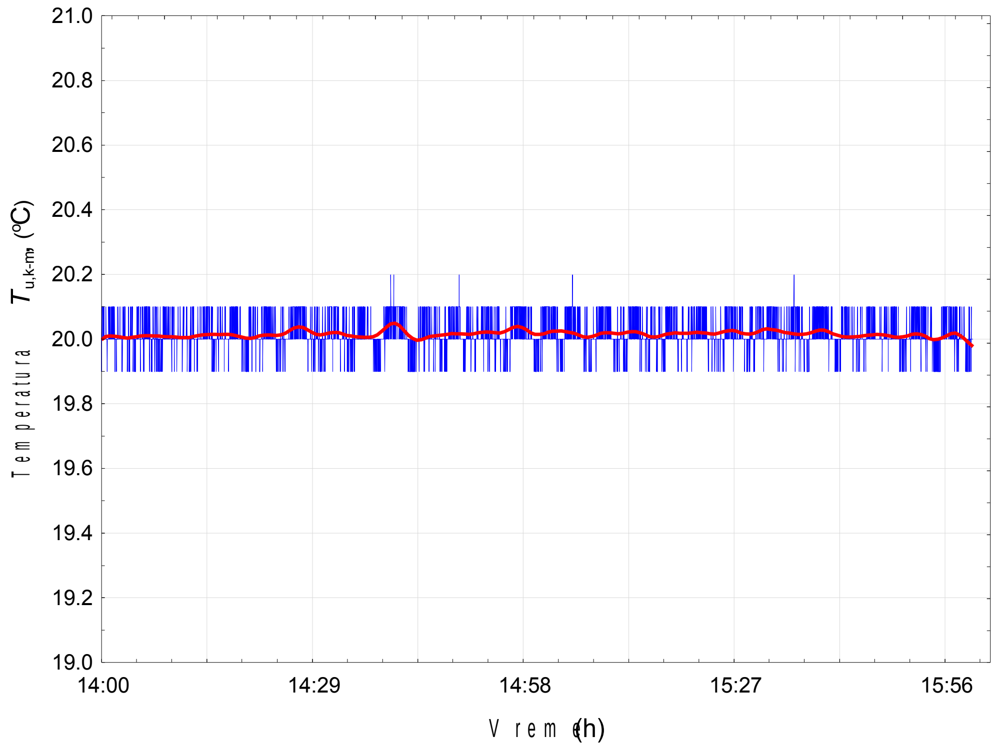


Figure 10. Indoor temperature for t_{OUT} = +4.5°C
upper floor (left) and lower floor (right)

4. Conclusion

LTEFHP are used in Serbia due to a number of advantages: a uniform temperature distribution in height prem-ises, lower temperature regime, easy installation, long service life, simple control, low electricity price, etc. However, the application of LTEFHP is limited to hygienic requirements, which means that the surface temperature of the floor should be uniform and within certain limits, and what needs to be taken into account at the stage of design and dimensioning of the system.

The results showed that EHC can easily be used to heat residential and office space (category II) if the operating temperature is 30°C in the LTEFHP. If the operating temperature is 35°C, then it can be used to heat the exhibition and sports hall (L = 115-200 mm). Heating rooms IV and V category is possible with an operating temperature of 40°C, but the application limit is quite shifted (L = 163-200 mm for category IV). With an operating temperature of 45°C it is possible to heat only the rooms of the V category, if the distance between EHC is 150-200 mm. Due to hygienic requirements, LTEFHP has no application for the operating temperatures in the panel ≥ 50°C.