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ENERGETIC EFFECTIVENESS OF A BUILDING WITH A SURFACE HEATING SYSTEM

EFEKTYWNOŚĆ ENERGETYCZNA BUDYNKU Z SYSTEMEM OGRZEWANIA PŁASZCZYZNOWEGO

A b s t r a c t

In the paper authors have undertaken a trial to present energetic effect developed by cooperation of a surface heating system and a building construction on the basis of object modeling using ESP-r software. Performed analyses concern impact of heat capacity of the building construction and different heating panels on final energetic effectiveness taking into consideration the algorithm of heating system operation control. The article is an example of a changing approach to building facilities designing – in case of integrated method of design it allows for obtaining considerable improvement of energetic quality.

Keywords: *panel heating foundation*, *air floor heating system*

S t r e s z c z e n i e

W artykule autorzy podjęli próbę przedstawienia efektu energetycznego wywołanego współpracą pomiędzy systemem ogrzewania płaszczyznowego a konstrukcją budynku na bazie modelowania obiektu w programie ESP-r. Przeprowadzone analizy dotyczą wpływu pojemności cieplnej struktury budynku i rozwiązań płyt grzewczych na końcową efektywność energetyczną w powiązaniu z algorytmem sterowania pracą systemu grzewczego.

Słowa kluczowe: *płytowy fundament grzewczy*, *powietrzny system ogrzewania podłogowego*

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1. Introduction

In every room temperature differences exist in a vertical and horizontal direction. Vertical distribution, the closest to the optimal temperature, is achieved in the case of a floor heating system [1]. Amongst many technical implementations of such a heating system – it is possible to find a solution connecting into a whole a heating system and a building foundation. A heating foundation panel [5] connects features of a construction element and a floor heating panel. Each foundation is designed individually. Foundations are insulated from the ground using foamed polystyrene plates of total thickness $d = 16.0$ cm and heat transfer coefficient $U = 0.16$ [W/m^2 K]. The heating system consists of distribution of heated air in channels placed inside a foundation panel. Hot air is distributed using pipes of "Spiro" type of diameter Ø = 100 mm placed on covered reinforced mesh foamed polystyrene. Next, pipes are poured with concrete. The heating unit in this system is electrical or water heating set placed in metal enclosure placed in the foundation slab (covered by a masking board). Water sets may be supplied from low temperature boilers or from other sources (oil or coal boilers, combined heat and power plant, heat pump). A distance between pipes is of 0.8–1.2 m. Loop length and number of elbows in all circuits must be the same for assuring equal air flow. The system is controlled by thermostats placed in a room [5]. Figure 1 presents an exemplary heating foundation.

Fig. 1. The exemplary heating foundation [5]

2. The subject of analyses

The subject of this paper is the single floor individual building with non-usable attic (not heated), without cellars, with wooden light frame construction. The building is located near Gliwice and is assigned for four persons. It has the ridge roof with slope angle of 40°; the roof is covered by zinc-titanium plates. The building is composed of the living room connected with the kitchen, three bedrooms, two bathrooms, the study, the boiler room, the vestibule (heated part) and the garage and the maintenance room (not heated part). Fig. 2 represents the projection and the façade of the building under consideration. Specification of individual rooms' areas: total area 165.15 m^2; usable heated area 136.03 m^2. Calculations of final energy demand were performed in accordance with the procedure presented in [3]. Annual demand for heat for this building is of 12.280.28 [kWh]; the index of annual demand for final energy: EK = 90.28 [kWh/m^2]. Table 1 represents the heat transfer coefficients of building's partition walls.

Table 1

Heat transfer coefficients of building's partition walls

Type of partition	Heat transfer coefficient U [W/m^{2}K]
floor on ground	0.36
external wall	0.20
ceiling over first level	0.25
roof	0.18

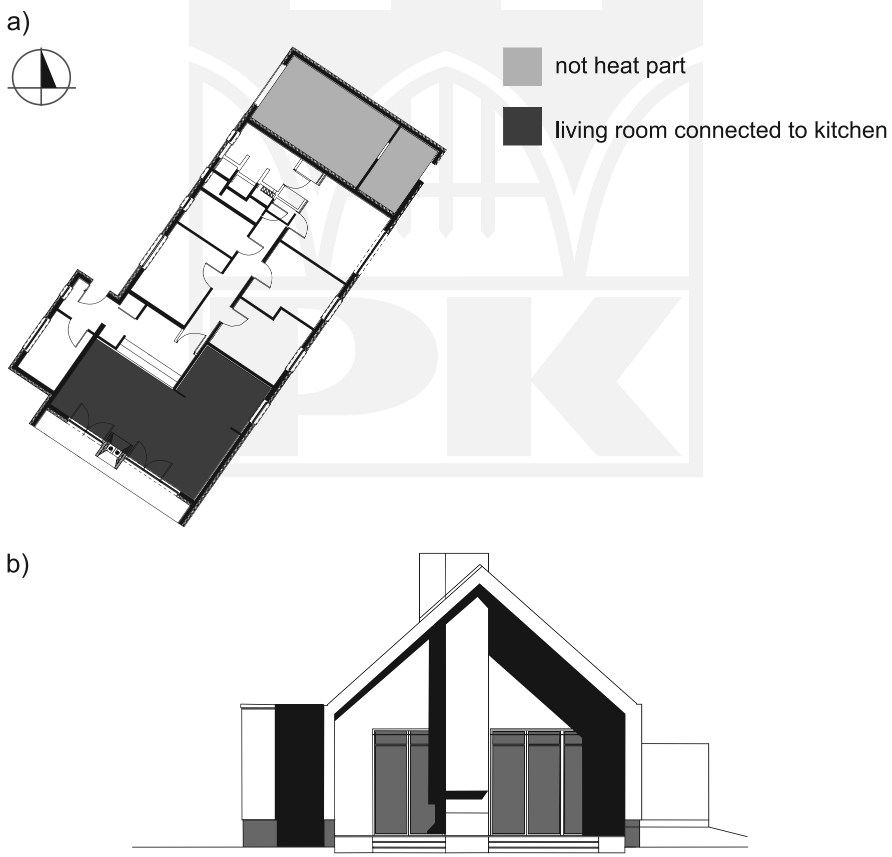

Fig. 2. Analyzed building: a) first level view; façade; b) South-West

3. The model and assumptions of analyses

In calculations the following assumptions were considered:
- climatic data from meteorological station Katowice;
- actinometrical station Chorzów;
- the heating system with the electrical heater operating with breaks determined by availability of electrical energy in accordance with time tariff. Time tariffs were taken in accordance with [6]: day tariff: 6 a.m. – 1 p.m.; 3 p.m. – 10 p.m.; night tariff: 10 p.m. – 6 a.m.; 1 p.m. – 3 p.m.

Figure 3 represents the object model prepared using ESP-r software [7]. Modeling contained two versions of a building construction solution. The first one was accordant to the design assumptions and concerned light skeleton construction; the second – modified – concerned the building with heavy walls made of ceramic bricks with foamed polystyrene insulation. Thermal insulation thickness was taken in the way assuring obtainment of the same heat transfer coefficients. Figure 4 represents values of external air temperatures and in Fig. 5 values of direct solar radiation intensity between 9th January and 15th January.

In order to determine thermal comfort PMV index was used. It refers to average estimation of large persons group in seven-stage scale. "PMV index is based on thermal equilibrium of human body. A man is in thermal equilibrium when internal heat production in his body equals to loss of heat to environment" [4]. Table 2 presents the scale of PMV index valuation.

Table 2

PMV index valuation scale

very cold	cold	chilly	neutral	warm	hot	very hot
–3	–2	–1	0	+1	+2	+3

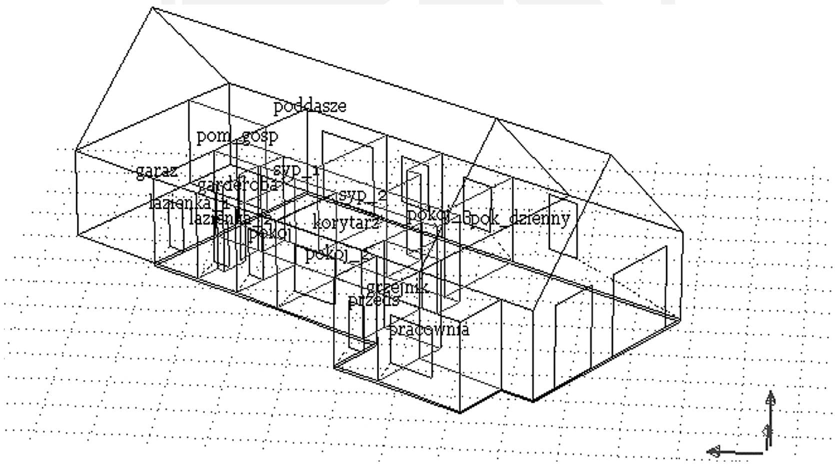

Fig. 3. Building model prepared using esp-r software

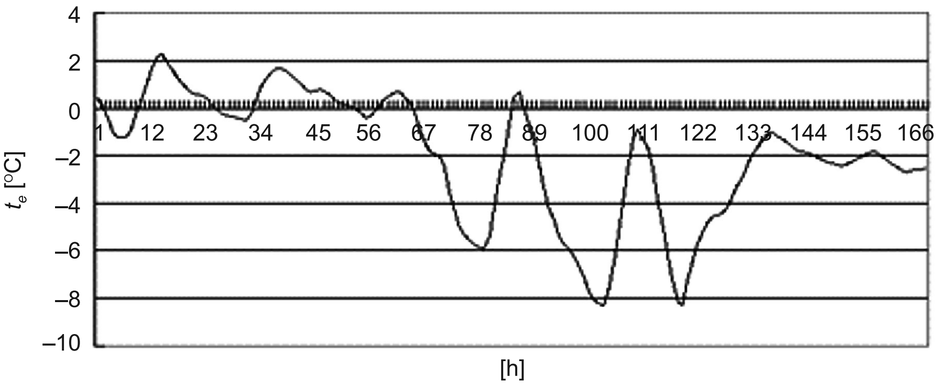

Fig. 4. Long-term values of external air temperatures for Katowice – 09.01-15.01

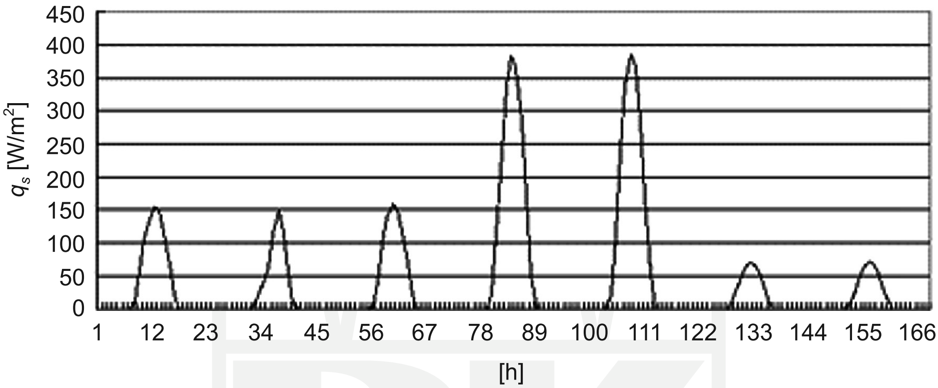

Fig. 5. Long-term average values of direct solar radiation intensity for Katowice – 09.01-15.01

4. Results of analyses

The performed analyses included the determination of the impact of building thermal capacity and breaks in heating at various thickness of slab heating foundation on thermal comfort parameters (PMV index) along with air temperature in rooms and consumption of energy required for building heating. Presented values concern the selected part of the heating season – January; in order to keep proper readability of presented results.

The simulations were performed for the entire building while part of presented results refers to the living room together with the kitchen (orientation: South-West). The living room and the kitchen make one space with greatest area of glass partitions (13.23 m^2) and greatest heated area (47.77 m^2). In calculations assumptions were taken described in paragraphs 2 and 3. In Figures 6–11 results for January are represented and for various thickness of the heating panel (d = 100; 150; 200; 250; 300 and 350 mm). Additionally some consecutive coldest days were selected (12–14 January).

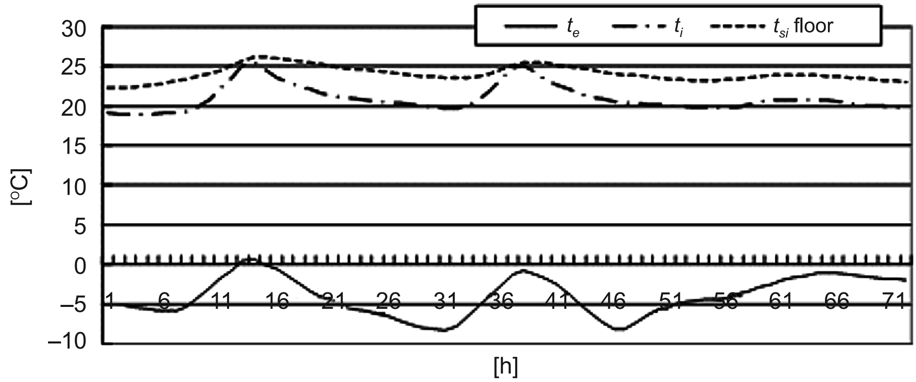

Fig. 6. Air and floor surface temperature in the living room for heavy construction and heating panel thickness d = 300 mm – 12–14.01

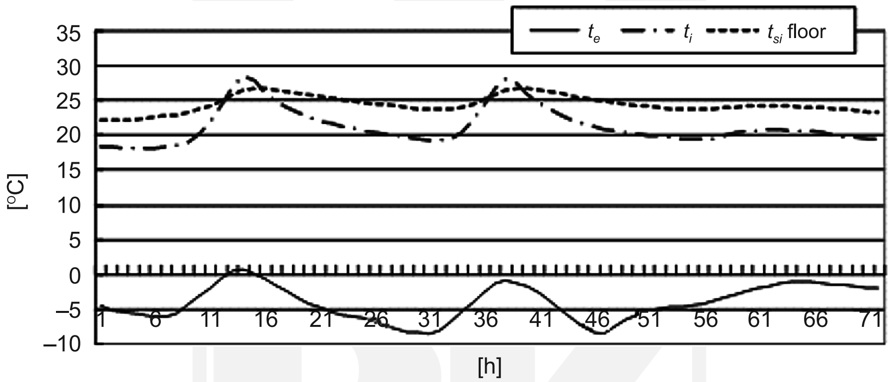

Fig. 7. Air and floor surface temperature in the living room for light construction and heating panel thickness d = 300 mm – 12–14.01

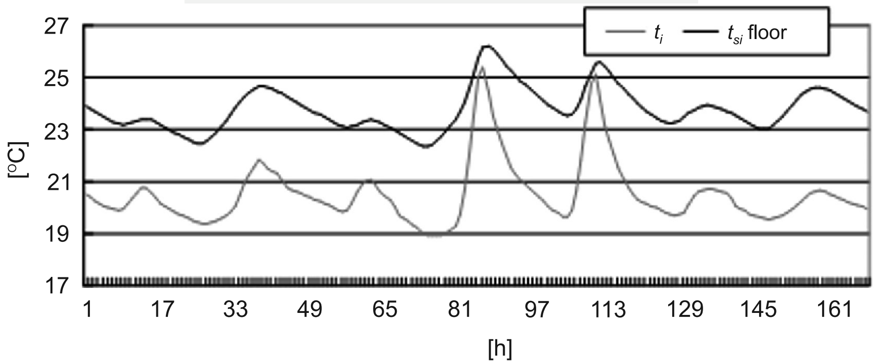

Fig. 8. Air and heating panel temperature in the living room for heavy construction and heating panel thickness d = 300 mm – 9–15.01

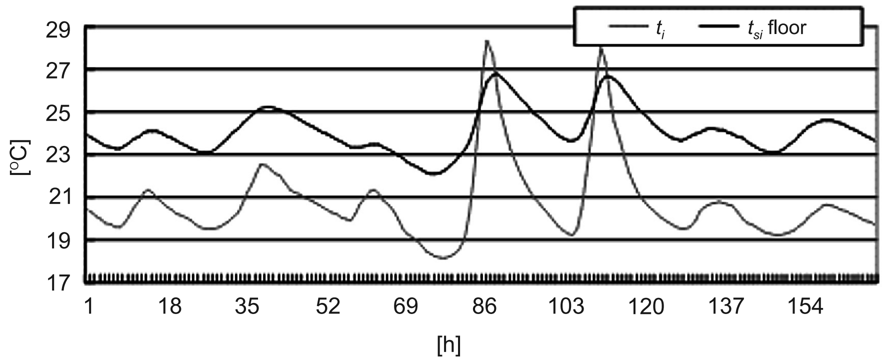

Fig. 9. Air and heating panel temperature in the living room for light construction and heating panel thickness d = 300 mm – 9–15.01

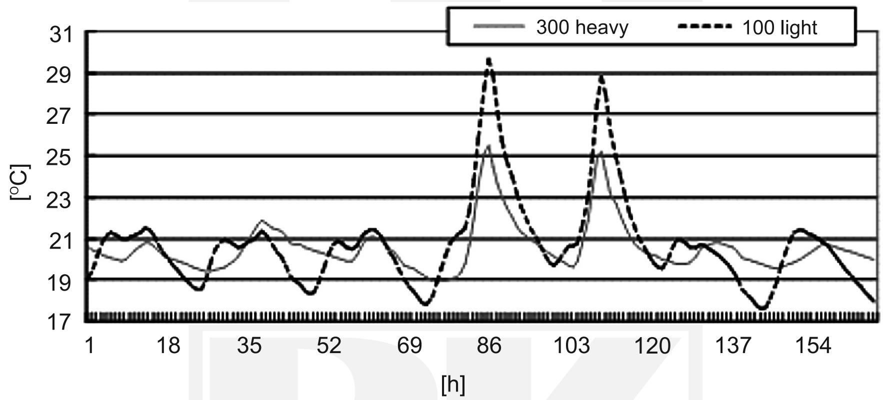

Fig. 10. Air temperature in the living room at heating panel thickness d = 300 mm – for heavy construction and d = 100 mm for light construction – 9–15.01

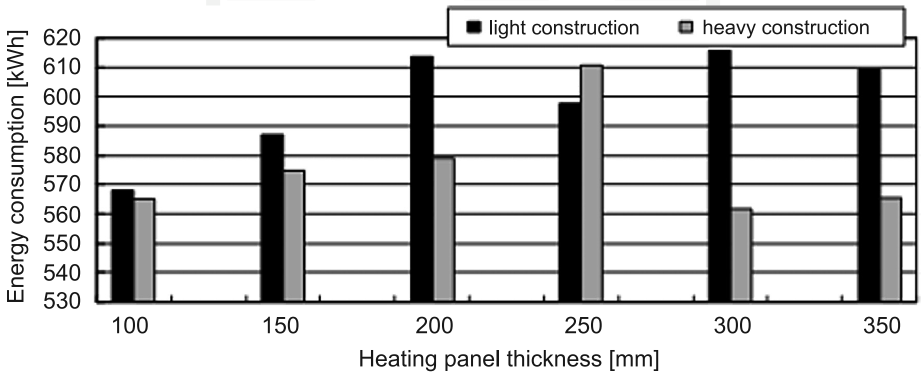

Fig. 11. Energy consumption for the building depending on partitions construction and heating panel thickness – 9–15.01

The analysis of calculations results allows for the following statements:

- air temperature in the room for the selected month (January) fluctuates between 16–28°C;
- floor surface temperature fluctuates between 21–24°C in coldest consecutive days (14–18 of February). Comparing above values with floor surface temperature in rooms like: living room, bedroom, kitchen for floor heating system that cannot exceed 29°C [1], obtained values are satisfying;
- for the coldest day (1–2 of February) air temperature in the largest room fluctuates between 19.5–21°C (the design temperature has been assured);
- appraisal of thermal comfort is more advantageous for the building in heavier version with great thermal capacity; PMV values fluctuate between –0.47 to +0.93 – see Table 2; independently of heating panel thickness;
- comparing versions with lowest energy consumption for heavy and light building in aspect of thermal comfort its clearly visible (Fig. 11) that the building with heavy construction has lower temperature fluctuations assuming the same scheme of energy supply;
- if thermal capacity of the heating panel is the same then changes of temperature are more advantageous for the heavy building (Fig. 6 and 7);
- energy consumption depends on thermal capacity of the heating panel and thermal capacity of the entire building (Fig. 11).

5. Conclusions

Performed simulations prove the necessity for making precise analyses for obtaining effective cooperation of the heating system and the building facility. It is especially important in case of low-energy housing. Annual consumption of energy assigned for heating of a heavy and light building is presented: heavy building: 13494.54 kWh; light building: 14216.24 kWh (heating capacity of the heating panel for both buildings is the same).

Analyses of obtained results proved that use of breaks in heating (heating only during time of night tariff) assured temperature above 18.5°C. Only during the period when external temperatures were lowest in the room under analysis, temperature falls to approx. 18°C. Obtained calculations results allow to state that the computer simulation method gives such heating capacity of the heating panel that in connection with the building heating capacity could assure required thermal comfort and minimize energy consumption.

References

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