

Hot-air heating of family houses with accumulation of energy in the floor

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Abstract: This article shows the results of measurements of a hot-air floor system utilising accumulation of energy, which is based on the use of excessive heat from the fireplace. The energy from the fireplace first directly heats the house and then is stored in a special system in the concrete floor. During the heating in the fireplace the room is not overheated which is very suitable for low-energy houses. The main principle is based on specially designed accumulative floors, consisting of a set of special chambers, which enables hot air from the fireplace to flow through. The layer of concrete floor is installed on the surface of these chambers. Special measuring methods were used to monitor the course of heating and cooling of the floors and the resulting room temperature. The results of measurements in the experimental room showed that the accumulation of heat in the floor compensates temperature differences. Heat can be intensively distributed around the house over time. A large proportion of the radiant component of heat transfer very favourably influences the thermal comfort of the indoor environment.

Key word: energy, heat radiation, concrete, thermal comfort.

INTRODUCTION

The current development of construction and continuously increasing prices of energy, compels owners and designers of all types of houses to look for high-quality integrated solutions of buildings including heating optimisation, especially to reduce energy consumption.

The basic mission of a residential building is to create a healthy and pleasant environment for its residents. For a human organism ‘radiation comfort’ is very important, which means that one should take the heat from the environment predominantly by radiation or remove excess heat from the body by convection (cooling by the flow of ambient air).

The first heating methods, such as fireplaces and tiled stoves, were based on the radiant effect. Radiation, based on the heating surfaces, impacts the other surfaces surrounding the room and the objects that are inside the room. They are heated and they transmit the heat to people and warm the air in the room (Cihelka, 1961). Now there are advantages with the utilisation of new modern techniques designed (Vio, 2011), but also in their economical operation with automatic control, according to user requirements.

Nowadays people come back to these historically proven principles of heating in a modern form, as this heating provides its residents with a consistently pleasant

environment characterised by energy savings. It is a very simple system, based on virtually ‘invisible radiators’. This article shows the results of measurements of radiant heating equipped with a hot-air floor system with accumulation of energy, which is based on the use of excessive heat from the fireplace.

The normal installation and the use of fireplaces in modern family houses are usually supposed to be an additional source of energy and also an aesthetic complement to the interior of a room. This system is particularly suited for rural areas, as it is possible to use wood or other biofuels for heating.

The presented heating system is based on the accumulation of excessive energy in the floor with accumulation capacity, which enables the reduction of overheating during the heating period and subsequently the longer maintaining of required temperature inside the rooms. This floor heating system with hot air distribution can be installed in combination with other classical heating systems, e.g. electrical, hot water with pipelines, etc. Another advantage of this floor heating system is that it can be used also during the summer period with the opposite function. The hot air is sucked from the room and flowing through the cold floor is cooled and again distributed into the room.

The main attention in this research was paid to the function of hot air distribution through the special AKU elements, developed especially for this purpose. Another important aim of the experiments was the control and measurement of heat accumulation in the floor during the hot air supply. The transfer of energy to the heated space was measured after the stopping of heating as well as the influence of the radiant heating from the large floor area on the indoor thermal conditions.

MATERIALS AND METHODS

The basic assumption of this research is to perform measurements in the conditions of the room with radiant heating. The experimental room was constructed and equipped by the company which developed this type of floor heating system and which provides the designing and installation of this heating system in family houses. Interior of the experimental room is shown in Fig. 1.



Figure 1. The experimental room used for the research.

All measurements were carried out on the model in the experimental room equipped with a hot air distribution system under the floor, with electric heating simulating the energy source, which in a real building is usually a fireplace. Cold air from the room is sucked through the inlet into the pipeline, there it is heated by an electric heater and the hot air flows into the distribution system, formed by special AKU elements under the floor. There the heat flux is transferred into the accumulation layer and cooled air is passed through the outlet and back into the room.

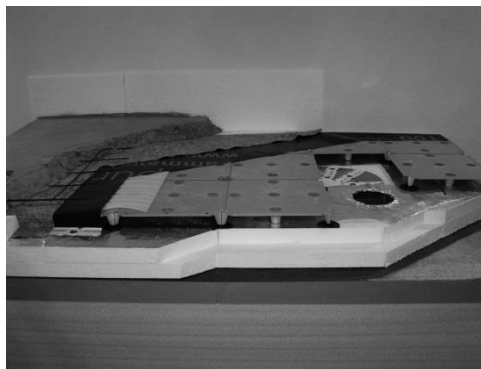


Figure 2. The floor construction with hot-air distribution AKU elements.

The airflow through the whole hot-air distribution system was calculated from the airspeed measured by the anemometer CFM 8901 and the cross-section of the tube. The average airflow was $264 \text{ m}^3 \text{ h}^{-1}$. Air temperatures were measured by thermocouples NiCr-Ni type K of the airflow throughout the whole system (in the inlet, after the heating, also in different parts of distribution systems of the under-floor heating) and in the outlet from the pipeline at the end of the heating system.

Furthermore, there was measured by thermocouples the temperature at the bottom of the concrete layer (between distribution element and the concrete). Under the concrete layer was measured the heat flux passing into the accumulation mass of the floor by the heat flow plates type FQA 017C and there was measured also the heat flux on the surface transferred from the floor surface to the air by the heat flow plates type FQA 018C. The temperature of the upper surface of the concrete was measured by thermographic camera IR Flexcam Pro.

Thermal comfort in the space heated by radiant heating is necessary to evaluate by globe temperature (measured by globe thermometer FPA 805 GTS) together with air temperature. All data were measured continuously and stored at intervals of three minutes by measuring instrument ALMEMO 2590-9.

RESULTS AND DISCUSSION

The results of measurements in the experimental room equipped with the radiant heating system and with an artificial source of heat (electric heating), simulating the fireplace are shown in Figs 3–6.

Cold air from the room is sucked into the pipeline, where it is heated. The hot air flows in the distribution system consisting of the AKU elements in the floor. There the

thermal energy passes into the concrete storage layer and cooled air flows back from the outlet into the room. The difference between temperature in the inlet and exhaust air is approximately 20 °C. The heat corresponding to this temperature difference is accumulated in the floor and slowly transferred into the room.

The course of air temperatures at the inlet, hot air after heating and air temperature in the outlet from the floor distribution system is presented in Fig. 3. There it is noticeable from the start of heating after 20 minutes there is a steady airflow without heating. There is an obvious 2 hours of heating, followed by a gradual cooling (transfer of accumulated energy in the room) since the 200th minute until the end of measurement.

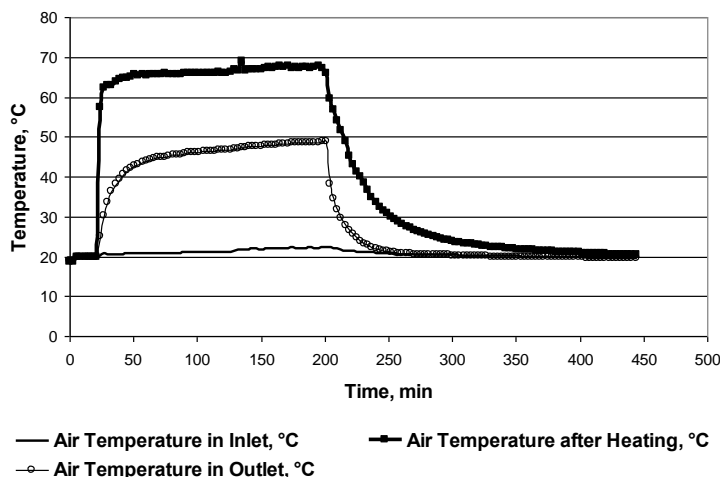


Figure 3. The course of air temperature at the inlet, hot air after heating and air temperature in the outlet from the floor distribution system.

Conduction of the heat flux through the distribution elements into the concrete is very intensive. It means that the heat transfer from the distribution elements AKU into the concrete accumulation layer is very good. The specific heat fluxes inside the floor (from hot air to the concrete) and on the surface from the concrete to the air inside the room are presented in Fig. 4.

Heat flux shared by convection and radiation in the indoor environment from the concrete surface has a gradual course in both the heating and cooling phase. It results from the gradually changing parameters affecting heat convection and radiation. The temperature of the upper surface of the floor was measured by thermographic camera in 3 minutes intervals during the whole time of measurement (heating and cooling).

Thermograms of the concrete floor surface at the beginning and the end of heating period are presented in Fig. 5. The maximal surface temperature was 32.8 °C, which is slightly over the 30 °C recommended as a maximum for floor surface temperature in literature (Cihelka, 1961).

But it should be mentioned, that this higher floor temperature lasts a short time at the end of heating and after this moment starts again the cooling period. For this reason this aspect of the indoor environment is not so important. The floor of a normal living

room would be covered by a wood floating floor, tiles, linoleum, carpet or usually a combination of these materials, which very probably results in lower surface temperatures of less than 30 °C.

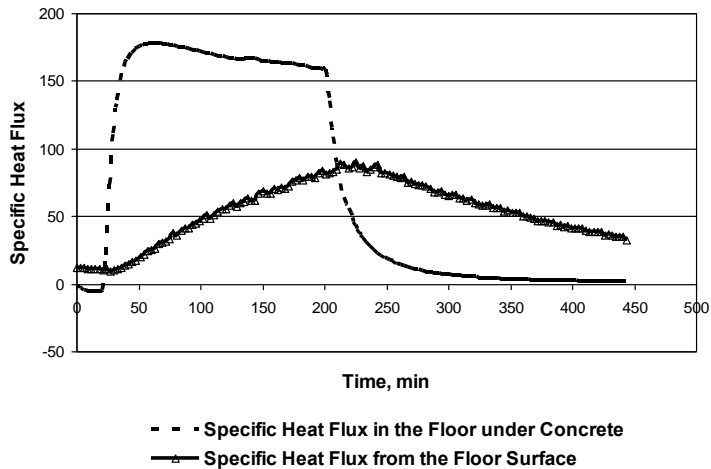


Figure 4. The specific heat flux ($W m^{-2}$) in the floor and from the surface to the air.

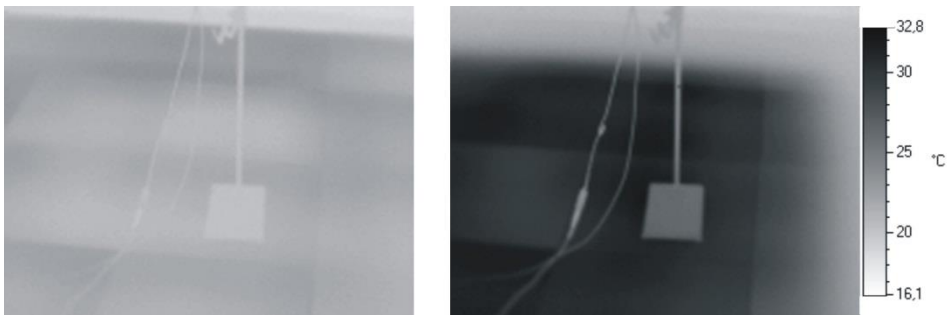


Figure 5. The thermograms of the floor surface at the beginning and end of the heating period.

The gradual increase of the surface temperature of the floor heating system and slow cooling was positively reflected in the indoor interior environment that is free of the heat shocks and corresponds very well to the physiological needs of inhabitants. The course of the globe temperature and air temperature in the experimental room during the heating and cooling time is in Fig. 6.

The difference between the air temperature and globe temperature is obvious especially during the cooling period, when the floor is not heated. Final globe temperature is higher than the air temperature, which is an effect of the radiant heating method. This is achieved by the higher proportion of heat transferred by radiation than by convection. In particular, this factor of the indoor environment corresponds very well to the physiological needs of people.

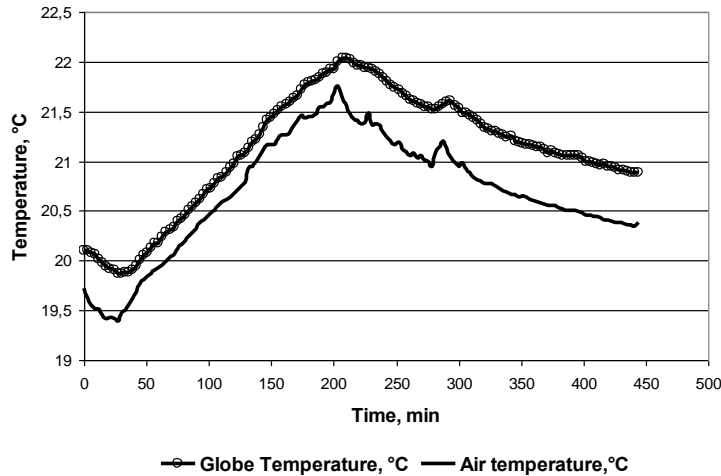


Figure 6. The course of the globe temperature and air temperature.

CONCLUSIONS

The results of measurements in the experimental room showed that the radiant heating with accumulation of energy in the floor compensates temperature differences. The accumulation of excessive heat into the floor with accumulation capacity enables the reduction of overheating during the heating period and subsequently longer maintaining of required temperature inside the rooms.

This floor heating system with hot air distribution can be installed in combination with other classical heating systems, e.g. electrical, hot water with pipelines, etc. Radiant component of heat transfer very favourably influences the thermal comfort of the indoor environment. The heat can be intensively distributed around the house with a time shift. The result is more stable thermal comfort inside the rooms and savings on heating costs. The system can be used also during the summer days without heating, when the house can be cooled from the floor. As there are no visible radiators inside the room, there is reduced risk of injury and it allows achieving easily an aesthetically impressive interior room. It is suitable for new or modernised rural family houses.

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