

Modern research on the use of underfloor heating

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Abstract. The present article is devoted to the application and recent research of underfloor heating. As underfloor heating is used all over the world, there is a great deal of various studies on the topic. In the current article different types of underfloor heating as well as modern scientific developments and research are presented. Also, regulatory documentation that normalizes the parameters of the system under consideration is described. The studies of A.O. Stimakov and Waldemar Scheller who invented panels for underfloor water heating system are described. The theoretical work of E.P. Bazunov and V.U.Kravchuk who conducted a study on underfloor heating using an economic method has been considered and, as a result, a comparison of two types of underfloor heating depending on the area of the premise was performed. The results of Yu Wang, Zhigang Zhang, Falong Hea and Xueli Liub who carried out an experimental study on the step of laying a warm floor using a special installation that enables us to reproduce the real parameters of the microclimate of the premise have been studied. **Keywords:** Underfloor Heating, Structural Solutions, Regulatory Restrictions, Economic Method, Underfloor Heating Panel, Laying Step.

1 Introduction

In order to improve the standard of living, it is vitally important to increase the level of comfort of a person's stay in a building. This problem can be solved by using electric and water underfloor heating. The underfloor heating system can be applied both as an independent heating system and in combination with an existing water heating system. Moreover, underfloor heating can provide a high level of comfort in conjunction with

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ventilation and air conditioning systems [1]. Modern scientists have been studying underfloor heating inventing various laboratory installations, software systems and different system elements. [2-4] Underfloor heating system is improved by creating special devices for its installation, operation, repair and dismantling. A great variety of experiments is carried out to compare the present heating system and its subtypes with the traditional one [5-12].

In their article Guoqing Yu, Zhaoji Gu, Zhenye Yan and Hengtao Chen have conducted a study and comparison of the thermal comfort and energy consumption of four personalized seat heating systems based on underfloor heating panels. The advantage of the system is that it provides a comfortable stay in the room for each person compared to an air conditioner and, moreover, it is a more economical system [13].

The system under consideration is used in the construction industry as well as in other areas. For example, Chawki Lahoud, Marwan, Marina F. Lahoud, Chisty Lahoud described the application of underfloor heating for combined solar drying of different products. This solution is essential for rainy and cloudy days. Having compared a combined solar dryer to a direct one, scientists concluded that the combined system is more productive due to the use of underfloor heating [14].

Researches on underfloor heating are continuously associated with building thermal physics studies [15–17], temperature distribution [18–20] and medical aspects of a person's stay in a room [21–26].

2 Classification of Underfloor Heating Systems

Underfloor heating has its own classification and is divided into electric and water underfloor heating. Electric underfloor heating can be presented as a single-core cable floor and two-core cable floor which are different from each other by the need to loop the cable for the first subtypes and by the absence of this action for the second one (see Fig. 1 and Fig. 2) [27].

Also, electric underfloor heating can be represented as heating mats that are a cable system fixed on a polymer mesh with a certain step of laying [27].

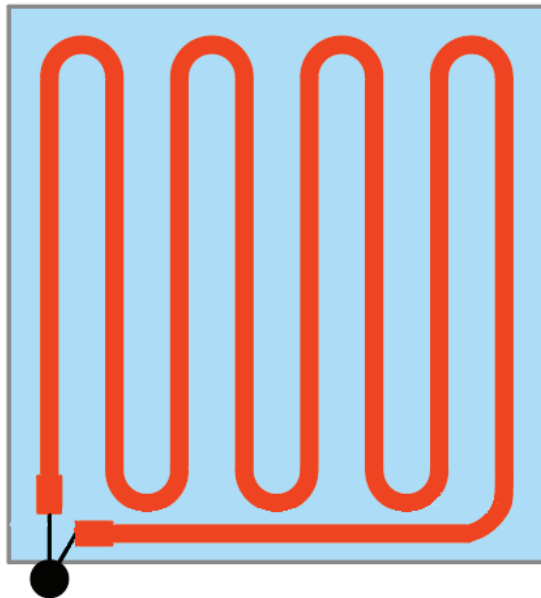


Fig. 1. Layout features of a two-core cable.

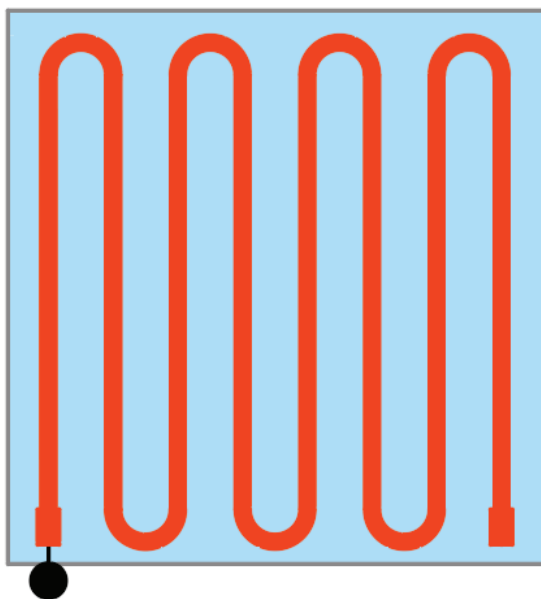


Fig. 2. Layout features of a single-core cable.

Electric underfloor heating can be performed as an infrared film system and infrared heating rods as well. As to the water underfloor heating, it is classified by the method of laying. Thereafter, it can be laid in the floor screed, in heat-insulating material as well as on profiled mounting mats [28].

3 Constructive Scientific Developments of Underfloor Heating

In addition to the classical systems, there are different scientific developments of underfloor heating.

As an example, let us take A.O. Stimakov's underfloor heating panel that can be applied both for floor and walls. The technical task of this model is the possibility of laying heating pipes with a smaller step of laying. Due to the universal pattern of the tracks, laying and reliable fixation of pipes in various ways is provided. The base is made of extruded polystyrene foam, on the top of which there are rows of protrusions and on the cross section there is an ellipse. Between these four adjacent protrusions there are four protrusions in the form of a rectangular triangle which are additional channels for laying pipes (see Fig. 3) (Patent of Russia No. 2020119327 "Panel for a warm water floor").

Waldemar Scheller also introduced a slab for the water underfloor heating system. It consists of a base covered with a high-strength polymer film material with rows of bosses. The upper part of this element has a form of a multifaceted figure with beveled corners protruding relative to the body of the boss for fixing the system tubes to the base. Thus, the rows of the bosses form U-shaped channels for pipe laying. The furthest row is made in a smaller size. This model makes it possible to reduce labor costs, which in turn will save installation time and help to securely fix and protect the pipes of the heating system from external influences (see Fig. 4) (Patent of Russia No. 2016103523 "Slab for the heating system").

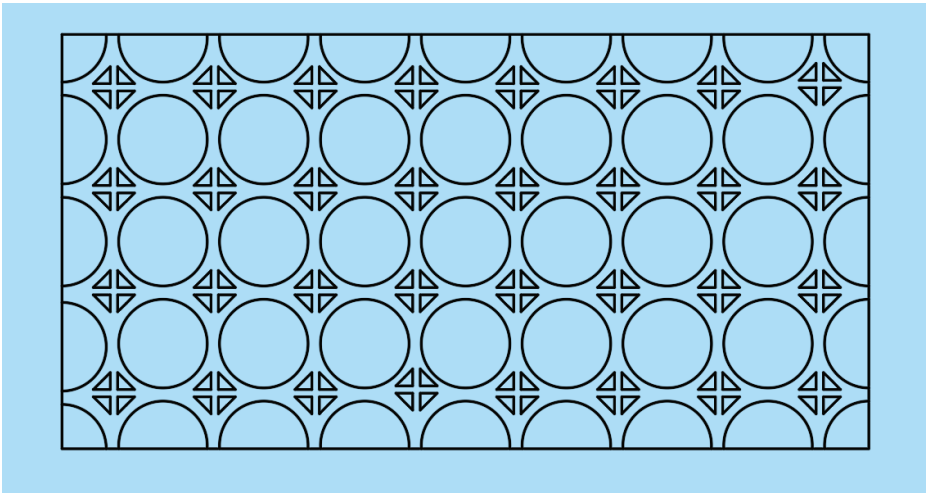


Fig. 3. A panel for a water underfloor heating.

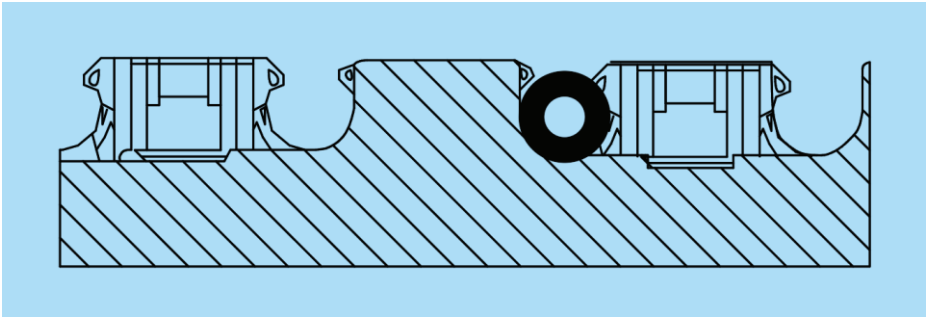


Fig. 4. Sectional view of a slab.

4 Regulatory Restrictions in the Application of Underfloor Heating

The need for the installation and design features of underfloor heating are given in the regulatory documentation. All the necessary information is presented in table 1 according to Russian regulatory documents SP 60.13330.2020 "Heating, ventilation and air conditioning", SP 29. 13330.2011 "Floors".

Table 1. Regulatory restrictions.

Regulatory document	
SP 60. 13330. 2020 "Heating, ventilation and air conditioning"	
Paragraph	Content
p. 6.2.6	In the premises on the first floor of residential buildings as well as in public, industrial and administrative buildings with permanent workplaces located in the I climatic region with an outside temperature of minus 40 ° C (parameters B) and below, it is necessary to provide an auxiliary heating system in the form of a heated floor.
p. 14.18	Accepted average temperature of the floor surface should not exceed: 1) 29 °C for rooms with permanent residence of people; 2) 23 °C for buildings of preschool educational organizations; 3) 31 °C for rooms with temporary stay of people as well as for bypass paths, benches of

	indoor swimming pools; 4) 35 °C for floor in preschool buildings, residential buildings and swimming pools.
Appendix B. Table B1	Preliminary heating systems for various categories of premises where it is noted that the temperature of the coolant in the water system with heating elements made of plastic pipelines built into the floor is assumed to be no more than 50 °C are presented
SP 29. 13330.2011 "Floors"	
p. 4.18	The temperature of heated floor covered with ceramic tiles, which are provided for in areas where people walk barefoot, should be maintained in the range of 21-23 °C
p. 4.19	Floor in rooms where negative temperatures are observed must be artificially heated to prevent soil freezing.

5 Economic Method of Underfloor Heating Research

In the article written by E. P. Bazunov and V.Yu. Kravchuk, an economic comparison of water and electric underfloor heating in terms of operating and capital costs for premises of 5, 10, 20 m² located in a cottage in the city of Moscow has been considered [29]. The comparison mentioned was conducted using the formulas below.

The heat flux density for an underfloor heating system is determined by the formula, [29]:

$$q = 8.92 \cdot (t_{fl.av} - t_{a.e}). \tag{1}$$

where q – heat flux density for underfloor heating system, W / m^2 ; $t_{fl.av}$ — average floor surface temperature, °C; $t_{a.e}$ — calculated room air temperature, °C.

The heat flux transferred by the floor surface to the room air is determined by the formula [29]:

$$Q_{hf} = q \cdot A_{sq}. \tag{2}$$

where Q_{hf} – heat flux transferred by the floor surface to the room air, W ; A_{sq} — floor surface area, m².

The annual costs of heat for heating were estimated by the formula [29]:

$$Q_{year} = 2.39 \cdot 10^{-10} \cdot 86400 \cdot z_{hp} Q_{hf} \frac{t_{a.e} - t_{hp}^{av}}{t_{a.e} - t_o^5}. \tag{3}$$

where Q_{year} – annual cost of heat for heating, $Gcal$; z_{hp} — duration of the period with average daily air temperature < 8 °C; t_{hp}^{av} — the average temperature of the period with the average daily air temperature < 8 °C; t_o^5 — air temperature of the coldest five-day period with security 0.92, °C.

The transfer of annual costs was carried out according to the formula [29]:

$$Q_{year} = 4.184 \cdot 10^6 \cdot Q_{year}. \tag{4}$$

Annual gas consumption is determined by the formula [29]:

$$G_{year} = \frac{Q_{year}}{Q_{w.l.} \cdot \eta}. \quad (5)$$

where G_{year} – annual gas consumption, $GCAL$; $Q_{w.l.}$ — operating net calorific value of gas, W ; η — efficiency of a gas boiler.

Annual operating costs were found by the formula [29]:

$$K_{expl} = G_{year} \cdot C_{gas}. \quad (6)$$

where K_{expl} – annual operating costs, $rub./year$; C_{gas} — cost of 1 m^3 of gas, $rub.$

The consumption of electricity required for the operation of electric mats is determined with the formula [29]:

$$Q_{year}^{el} = 1,1622 \cdot Q_{year} \cdot 1000. \quad (7)$$

where Q_{year}^{el} – consumption of electricity required for the operation of electric mats, $kW \cdot hr$

Annual operating costs for electricity are determined by the formula [29]:

$$K_{expl}^{el} = Q_{year}^{el} \cdot C_{el}. \quad (8)$$

where K_{expl}^{el} – annual operating costs for electricity, rub ; C_{el} — cost of electricity, $rub.$ for $1kW \cdot h$.

The results demonstrating that the effective use of water or electric underfloor heating depends on the premise area were displayed on a graph. It can be seen that with a small room area of 5 m^2 , the total costs of the electric and water floor for the period of 20 years are comparable, whereas with a larger area of the room the costs of water floor are far less (see Fig. 5) [29].

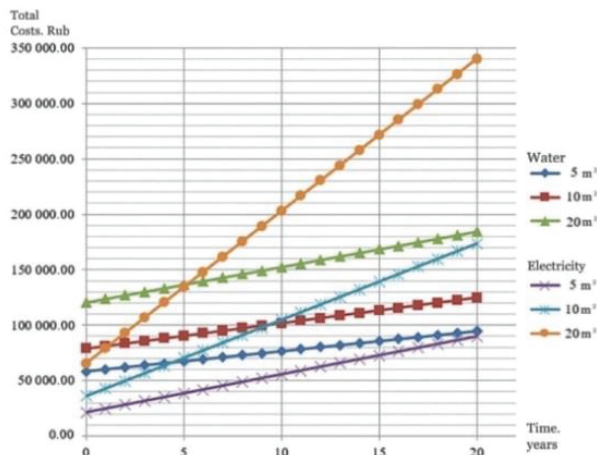


Fig. 5. Distribution of total costs by years.

6 Experimental Study of the Step of Laying the Warm Floor

In the article by Yu Wanga, Zhigang Zhanga, Falong Hea and Xueli Liub experimental studies on the thermal performance of the new floor heating device are conducted. This experiment was carried out in a special chamber that makes it possible to reproduce the real parameters of the microclimate of the room using a new floor heating device [30].

The device under consideration is able to satisfy the need for heating at lower temperature of the coolant in it compared to the traditional water underfloor heating system. The current heating system is highly efficient and it may perfectly replace the traditional one [30].

Thus, authors state that the present system allows us to achieve the required thermal comfort with the supply of a coolant at a lower temperature compared to the traditional one. The heat transfer of the device at a coolant temperature of 30-35 °C ranges from 46 to 54 W/m². The device is also suitable for a combined heating system [30].

7 Conclusion

Nowadays interest in alternative heating systems is rapidly growing every year as human life requires a higher level of comfort. A large number of scientists have been conducting their researches that give an opportunity to learn more about this system as well as to get new materials and components for its design. It is likely that in the near future all residential buildings will have the present system as an additional source of heat, which will provide greater comfort for people. Therefore, the system needs to be studied and improved.

The described economic method of studying underfloor heating makes it possible to understand what type of system is suitable for the designed room, which simplifies the work of engineers. Furthermore, the device used in the experiment on studying the step of laying the warm floor is very promising, since the traditional device is not able to achieve thermal comfort at a lower coolant temperature. In my opinion, it is necessary to find cost-effective and least time-consuming solutions for designing an underfloor heating system.

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