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Studies on heat-transfer coefficient of wood floor materials used in floor heating

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Abstract: *Studies on heat-transfer coefficient of wood floor materials used in floor heating.* The aim of investigations was to examine heat-transfer coefficients of "Marchewka board", floor boards of 20 mm thickness intended to be used in floor heating systems. In order to increase their heat conductivity, thermal bridges were made in the form of non-passage holes of 20 mm diameter which were filled with: concrete, aluminium discs and a mixture consisting of 95% aluminium filings glued with adhesive. Results of these experiments were compared with the results of investigations of the heat-transfer coefficient in floor boards without holes, with empty holes and floor boards of other manufacturers. The best results were recorded for boards with holes filled with aluminium filings. The heat-transfer coefficient in these boards was by 24% higher in comparison with boards without holes.

Keywords: floor heating, floor boards, heat transfer.

INTRODUCTION

Wood materials intended for floor covering should simultaneously act as thermal insulators preventing heat transfer to the floor/ceiling and, therefore, they should be characterised by the lowest possible value of the heat-transfer coefficient k. On the other hand, however, when floor heating is to be used, they should be characterised by the highest value of this coefficient to allow heat transfer from the heating medium, usually mounted in the concrete floor, to the heated room. However, wood as well as wood-based materials are characterised by good heat insulating power and, hence, possess low value of the heat-transfer coefficient [8, 9]. This coefficient can be increased by the application of thermal bridges placed in holes of a foundation board (consisting of, for example, plywood 15 mm thick). Such bridges should be made from materials of high thermal conductivity. This solution is pending two patents: P-390587 "Layer board and ways of its production" [6] and P-391359 "Method of manufacturing of layer boards" [7].

RESEARCH OBJECTIVE

The aim of investigations was to determine heat-transfer coefficients for some material variants of thermal bridges placed in holes of a foundation plate and to compare the obtained results with heat-transfer coefficients for plates without thermal bridges and with boards of manufacturers offering their products for floor heating.

RESEARCH METHODOLOGY

Heat-transfer coefficients k were determined by measuring the intensity of the heat stream q using, for this purpose, sensors of heat stream intensity of MGS-3 type in the form of discs of 50 mm diameter and 4.3 mm thickness. Inside each disc, there are approximately 650 copper-constantan thermo-elements connected serially. Thermojunctions are placed in the vicinity of their flat surfaces. During measurements of heat stream intensity, the sensor is placed on the examined sample floor with the assistance of a coupling agent, namely machine cup-grease.

Thermoelectric voltage U_T, which develops at the terminals of the sensor when temperature difference occurs on its flat surfaces after placing it in streams of flowing heat, was measured with the assistance of a digital voltage meter of V 530 type. The voltage meter was set at the 100mV range and the accuracy of its readings amounted to ±0.01 mV. The above-described methodology was employed in many earlier studies regarding determination of the heat-transfer coefficient [1, 2, 3, 4, 5].

Figure 1 presents a block diagram of the experimental stand. It consists of a heat chamber in which an electric bulb of 60W power was employed as a source of heat. Constant temperature of 40°C was maintained in the chamber with the assistance of a contact thermometer which switched the source of heat on and off by means of a relay switch. In order to secure a uniform temperature distribution on the internal sample surface, a screen made of 3 mm thick aluminum sheet was applied. The examined sample of the floor material with the heat stream sensor fixed to it constitutes the top wall of the chamber. The sensor is connected to the digital voltage meter. In order to guarantee constant conditions of heat transfer between the sample with the heat sensor and the surroundings, a 'cold chamber' was applied. Temperature measurements of the thermal chamber (under the sample) and cold chamber (above the sample) were taken using laboratory mercury thermometers.

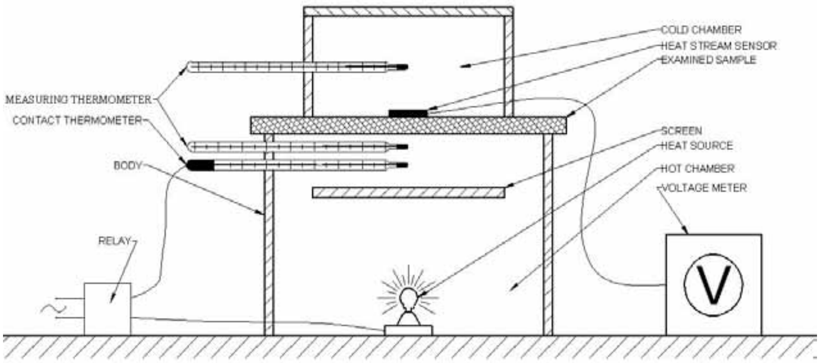

Figure 1. Block diagram of the experimental stand for investigations on heat-transfer coefficient of floor materials from wood.

The intensity of the heat stream q is proportional to the thermoelectric voltage U_T and amounts to:

$$q = CU_T[W/m^2]$$

where: C – sensor calibration constant. For the applied sensor C = 24.7 $Wm^{-2}mV^{-1}$.

The heat-transfer coefficient was calculated from the following formula:

$$k = \frac{q}{T_1 - T_2} = \frac{CU_T}{T_1 - T_2}\left[W/(m^2K)\right]$$

where: T_1 – temperature in the hot chamber,
T_2 – temperature in the cold chamber.

Ten replications of measurements of each sample (once the conditions of heat transfer became constant) were carried out each time changing the position of the sensor of the heat stream on the surface of samples and then mean values, standard deviations and coefficients of variability were calculated.

The following seven different floor samples were investigated: 5 floor samples manufactured by Marchewka Company according to submitted patents, 1 floor board manufactured by Barlinek Company and 1 floor board manufactured from a HDF board of 15 mm thickness:

1. Floor board 20 mm thick of 5 mm noble wood and 15 mm thick plywood foundation,
2. Floor board as in point 1 with φ20 mm holes drilled at 19 mm spacings (Fig. 2),
3. Floor board as in point 2 with holes into which aluminium discs were pressed,
4. Floor board as in point 2 with holes filled with concrete,
5. Floor board as in point 2 with holes filled with aluminium material consisting of 95% aluminium filings and adhesive – 2-component polyester material,
6. "Barlinek" floor board 15 mm thick made of 3 mm thick top noble wood and 12 mm thick foundation of conifer wood,
7. HDF board panels 7 mm thick.

RESEARCH RESULTS

Results of investigations of the heat-transfer coefficient are presented in Table 1 and in Figure 3.

The best results – the highest value of the heat-transfer coefficient *k* – among the examined wood floor boards were obtained for the board with drilled holes filled with aluminium mixture. The recorded heat-transfer coefficient *k* was by about 24% higher than for the board without holes. Quite good results were also obtained in the case of boards with holes filled with concrete (*k* coefficient by almost 22% higher), although this board is heavy and difficult in handling (cutting, shortening).

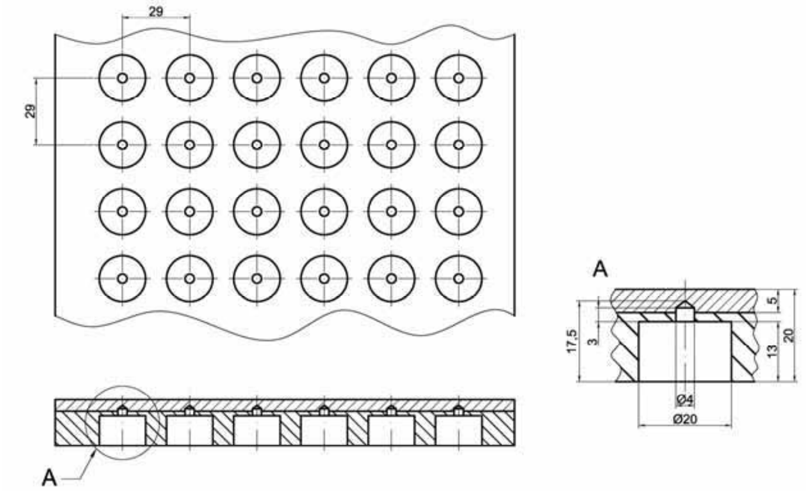

Figure 2. Floor board 20 mm thick consisting of 15 mm plywood and noble wood 5 mm thick with φ20 mm holes drilled at 29 mm spacings (according to point 2 of the above list).

Table 1.

Results of investigations of the heat-transfer coefficient for different kinds of floor materials.

No.	Kind of floor board	Heat-transfer coefficient K [W/m^{2}K]	Standard deviation [W/m^{2}K]	Coefficient of variability [%]	Increase [%]
1	„MARCHEWKA board" 20 mm thick, no holes	2.61	0.13	4.97	0
2	„MARCHEWKA board" 20 mm thick, with holes	2.84	0.17	6.03	8.8
3	„MARCHEWKA board" 20 mm thick, with aluminium discs	2.83	0.19	6.68	8.4

4	„MARCHEWKA board" 20 mm thick, with concrete	3.21	0.10	3.07	21.6
5	„MARCHEWKA board" 20 mm thick, with aluminium material	3.24	0.11	3.28	24.1
6	BARLINEK board 15 mm thick	2.86	0.09	3.27	9.6
7	7 mm HDF panel	4.13	0.11	2.77	58.2

The boards with holes filled with aluminium discs turned out to have unexpectedly low heat-transfer coefficient *k* value which was, practically speaking, equal to the value of *k* in boards with holes without filling.

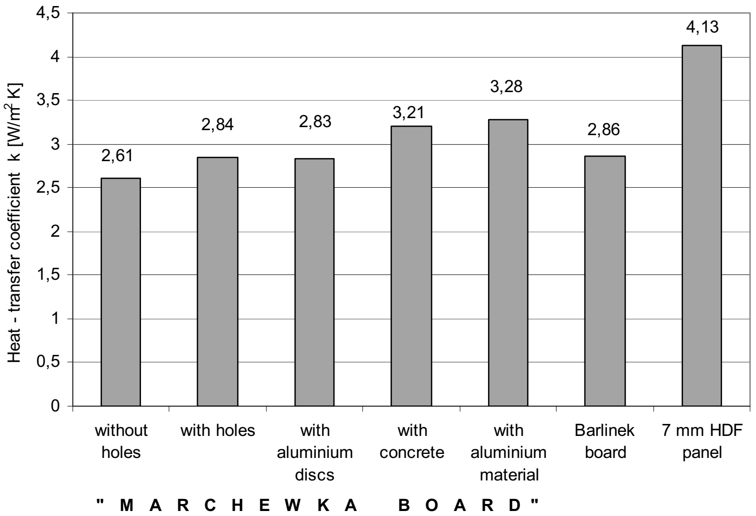

Figure 3. Results of investigations of the heat-transfer coefficient for different kinds of floor materials.

In order to explain this phenomenon, the board was cut with a circular saw along the axis of holes. It turned out that many of the aluminium discs were too short and an air cushion developed between the discs and the bottom of holes which prevented a free air flow (Fig. 4). The fact that not all discs were too short is confirmed by the highest value of the coefficient of variability for this treatment (6.68%) and by Figure 4.

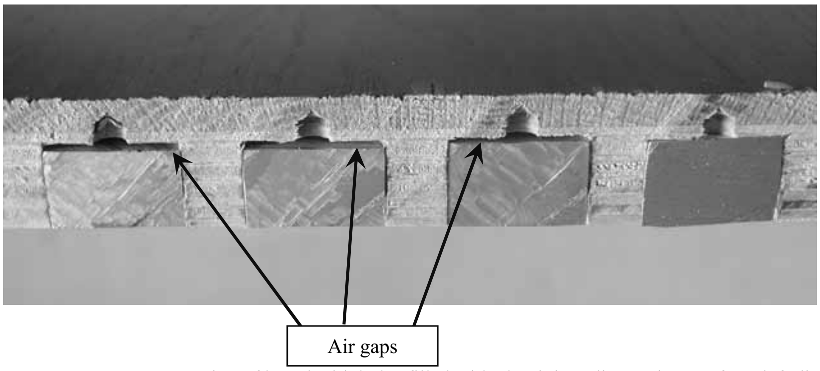

Figure 4. Cross section of board with holes filled with aluminium discs. Air gaps for 3 left discs isolate effectively, right disc is proper.

CONCLUSIONS

1. As expected, the highest heat-transfer coefficient values were determined for the 7 mm HDF board.
2. The highest heat-transfer coefficient values among floor products offered by the Marchewka Company were recorded for boards with holes filled with aluminium mixture and this solution is recommended for application.
3. The use of aluminium discs in drilled holes requires high precision of depth measurements of holes and height of discs. It seems necessary to apply some kind of ‘contact agent’ to be used during their placement at the bottom of holes.
4. The application of concrete is also satisfactory (comparable with the use of aluminium mixture) but such boards are heavier and difficult in handling.
5. Barlinek floor boards intended for floor heating showed heat-transfer coefficient values comparable with those of the Marchewka Company boards with drilled holes but without any heat transferring materials.
6. It is worth considering the application of a thick layer of aluminium foil placed between the plywood and the top layer of noble wood and through-holes made in plywood filled with aluminium mixture.

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Streszczenie: *Badania współczynnika przenikania ciepła materiałów podłogowych z drewna stosowanych przy ogrzewaniu podłogowym***.** W pracy badano współczynniki przewodzenia ciepła desek podłogowych „Deska Marchewka" o grubości 20 mm, przeznaczonych do stosowania przy ogrzewaniu podłogowym. W celu zwiększenia przewodzenia ciepła w deskach tych wykonano mostki termiczne w postaci nieprzelotowych otworów o średnicy 20 mm, które wypełniono betonem, krążkami aluminiowymi i masą złożoną z 95% opiłków aluminiowych połączonych lepiszczem. Wyniki tych badań porównano z wynikami badań współczynnika przewodzenia ciepła desek podłogowych bez otworów, z otworami niewypełnionymi oraz desek innych producentów. Najlepsze wyniki uzyskano dla desek z otworami wypełnionymi masą z opiłek aluminiowych, dla desek tych uzyskano wzrost współczynnika przewodzenia ciepła o 24% w stosunku do desek bez otworów.

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