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Grzegorz Pajchrowski, Andrzej Noskowiak

THERMAL CONDUCTIVITY OF WOODEN FLOORS IN THE CONTEXT OF UNDERFLOOR HEATING SYSTEM APPLICATIONS

Wood, as a traditional flooring material, has fairly low thermal conductivity; hence achieving heat resistance at a level ensuring good heat transfer from the heating system to the room is very important. This can be achieved by selecting the right materials or by applying appropriate design solutions. Determining properties associated with heat transport for construction products usually involves determining the heat transfer coefficients of building envelopes in the context of thermal insulation. However, in the case of buildings with underfloor heating the expectations are reversed – flooring elements should have good thermal conductivity, i.e. low thermal resistance (below 0.15 m^2K/W*). This condition was satisfied by almost all tested types of floorings. On comparison of the test results with the calculations, it was found that the calculated values of thermal resistance were lower than the experimental values, which may suggest that in relation to use on underfloor heating the calculated values imply better properties than are achieved in practice.*

Keywords: underfloor heating, wood flooring, thermal conductivity, thermal resistance

Introduction

Underfloor heating has recently been increasing in popularity both as basic and complementary indoor heating. This is due to many practical advantages, as well as the availability of modern and relatively cheap underfloor heating systems, especially electrical. The most important advantage of underfloor heating is the ease of obtaining the most favourable profile of temperature distribution in a room, which contributes to a better microclimate. Other positive features include the relatively low temperature of the heating medium, lower dust rise, and greater freedom in interior design [Nowicki and Chmielowski 1998; Seo et al. 2011; Woźniak 2016].

Grzegorz Pajchrowski✉ (*g_pajchrowski@itd.poznan.pl*), Andrzej Noskowiak (*a_noskowiak@itd.poznan.pl*), Wood Investigation and Application Department, Wood Technology Institute, Poznan, Poland

While the advantages of underfloor heating are unquestioned in the case of so-called cold finishes such as ceramic tiles or natural stone, doubts may arise if the finishes are inherently good insulators. For example, the argument that heating requires lower energy consumption may not be so obviously valid.

Determination of the thermal properties of construction products is usually related to the determination of heat transfer coefficients of building partitions, serving to determine their thermal insulation ability [Rozins and Iejavs 2014]. In this case the aim is to maximise the value of thermal resistance. Different considerations apply in the case of floorings with underfloor heating. In this case, it is important to transfer heat from the heating system to the room air as effectively as possible. It is therefore important that the thermal resistance of the flooring material should be as low as possible. If underfloor heating is used in the building, the thermal resistance of the floor should not exceed a value of 0.15 m^2 K/W [CEN/TS 15717:2008]. In addition, it is usually assumed that the temperature difference between the top and bottom surfaces of the floor elements should not be greater than 5°C.

Wood, as a traditional flooring material, has fairly low thermal conductivity, usually in the range 0.1-0.2 W/(m·K) for a direction perpendicular to the grain [Krzysik 1975; Suleiman et al. 1999; TenWolde et al. 1988]; hence obtaining thermal resistance at a level ensuring good heat transfer from the heating system to the room is not easy. This can be achieved by choosing suitable materials or by applying appropriate design solutions [Seo et al. 2014].

The harmonised standard EN 14342:2013 gives two methods for the determination of thermal properties of wood flooring: experimental, in accordance with EN 12664:2001; and computational, based on table 2 of EN 14342:2013.

The aim of this study was to assess the suitability for underfloor heating of various types of material and design solutions used in wooden floors. In addition, the differences between the results of the two aforementioned ways determining thermal properties were investigated, along with potential consequences for applications of wooden floors in underfloor heating systems.

Materials and methods

Tests were performed on several types of commercial wooden floors. Detailed descriptions of these solutions are given in table 1.

Testing samples were assembled from flooring elements and cut to dimensions of 300 mm × 300 mm. Three samples were prepared for each floor type.

Measurements of thermal resistance were performed using a Linseis HFM 300 instrument. IRMM-440A glass fibre board was used as a reference material. The temperatures of the hot plate and cold plate were 30°C and 20°C

Table 1. Details of analysed flooring elements

No.	Code	Type and thickness of flooring elements	Cross-section
1	A	Solid wood, 22 mm (oak)	
2	B	Three-layer, 14 mm (oak 2.5 mm – pine slats 9.0 mm – pine veneer 2.5 mm)	
3	C1	Three-layer, 14 mm (oak 3.5 mm – pine veneers 8.0 mm – pine veneer 2.5 mm)	
4	C2	Three-layer, 14 mm (oak 2.5 mm – pine veneers 9.0 mm – pine veneer 2.5 mm)	
5	D1	Two-layer, 22 mm (oak 6.0 mm – plywood 16.0 mm)	
6	D2	Two-layer, 15 mm (oak 3.0 mm – plywood 12.0 mm)	
7	D3	Two-layer, 20 mm (oak 5.0 mm – plywood 15.0 mm)	
8	D4	Two-layer, 16 mm (oak 4.0 mm – plywood 12.0 mm with cuts 2 mm wide and 8 mm deep at a distance of 50 mm)	
9	E1	Three-layer, 21.5 mm (oak 6.0 mm – plywood 9.5 mm – oak 6.0 mm)	
10	E2	Three-layer, 20 mm (oak 5.5 mm – plywood 9.5 mm – oak 5.0 mm)	
11	F	Two-layer, 22 mm (oak 6.0 mm – LVL 16.0 mm)	
12	G	Three-layer, 21.5 mm (oak 6.0 mm – LVL 9.5 mm – oak 6.0 mm)	
13	H1	Three-layer, 10.3 mm (oak veneer 1.5 mm – HDF 7.3 mm – birch veneer 1.5 mm)	
14	H2	Three-layer, 8.4 mm (oak veneer 0.6 mm – HDF 7.3 mm – birch veneer 0.5 mm)	
15	H3	Three-layer, 10.6 mm (oak veneer 1.8 mm – HDF 7.3 mm – birch veneer 1.5 mm)	
16	H4	Three-layer, 13.6 mm (oak veneer 2.8 mm – HDF 9.3 mm – birch veneer 1.5 mm)	

respectively. The direction of heat flow in all cases was perpendicular to the grain direction of the samples.

In addition, the equivalent coefficient of thermal conductivity, which is the coefficient of thermal conductivity for a homogeneous material of a given thickness and thermal resistance, was determined according to the following formula:

$$\lambda^* = \frac{t}{R}$$

where: λ^* is the equivalent coefficient of thermal conductivity,
t is the total thickness of the sample,
R is the thermal resistance of the entire element.

For calculations of thermal resistance, measurements were made of the density and moisture content of each layer of the samples. The thermal conductivity λ for each layer was determined on the basis of the density according to table 2. Moisture content measurements were used for density adjustments.

Table 2. Thermal conductivity values for solid wood and some wood-based panels used for wood flooring products and parquets (according to the EN 14342:2013 standard)

	Mean density at a moisture content of 12% [kg/m^3]	Thermal conductivity [W/(m·K)]
Solid wood and plywood	300	0.09
	500	0.13
	700	0.17
	1000	0.24
Particleboard	300	0.10
	600	0.14
	900	0.18
Fibreboard	400	0.10
	600	0.14
	800	0.18

The total thermal resistance was calculated according to the formula:

$$R = \sum_{i=1}^{n} \frac{t_i}{\lambda_i}$$

where: t_i is the thickness of the i-th layer,
λ_i is the thermal conductivity of the i-th layer.

The overall density of each sample was also determined.

Results and discussion

Results of tests of thermal resistance for flooring elements are presented in table 3. For each type, total thickness, density, equivalent coefficient of thermal conductivity and relative difference of thermal resistance are also summarised in table 3.

Table 3. Results obtained for the thermal resistance of flooring elements

No.	Code	Density [kg/m^3]	Thermal resistance [m^{2}K/W]		Equivalent coefficient of thermal conductivity [W/(m·K)]	Relative difference of thermal resistance [%]
			calculated	experimental		
1	A	647	0.137	0.145	0.156	6
2	B	585	0.094	0.105	0.135	11
3	C1	589	0.094	0.123	0.118	24
4	C2	579	0.095	0.109	0.131	13
5	D1	695	0.128	0.133	0.161	4
6	D2	658	0.092	0.095	0.162	4
7	D3	668	0.121	0.134	0.152	10
8	D4	638	0.100	0.109	0.148	8
9	E1	721	0.121	0.126	0.171	4
10	E2	689	0.118	0.123	0.165	4
11	F	587	0.147	0.154	0.140	4
12	G	639	0.135	0.134	0.154	-1
13	H1	812	0.055	0.079	0.134	31
14	H2	880	0.042	0.054	0.157	23
15	H3	847	0.054	0.076	0.143	29
16	H4	820	0.072	0.093	0.148	23

As table 3 shows, the measured value of thermal resistance for all floor types (except type F) was below the assumed value of 0.15 m^{2}K/W.

On the basis of table 3, the dependence of the equivalent coefficient of thermal conductivity on the density of flooring elements was obtained (fig. 1).

As can be seen from figure 1, the thermal conductivity of flooring elements increases with increasing density, with a clear distinction between two groups: elements constructed from solid wood, plywood or LVL, and elements with HDF as the dominant component. This is consistent with the thermal properties of wood and wood-based materials [MacLean 1941; Kamke and Zylkowski 1989].

Figure 2 shows the dependence of thermal resistance on the total thickness of the elements.

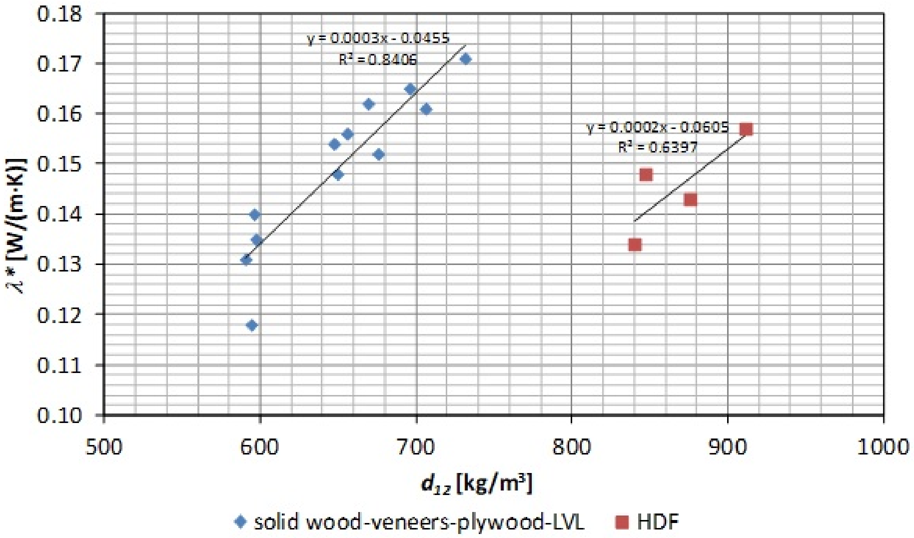

Fig. 1. Influence of density on the thermal conductivity of flooring elements

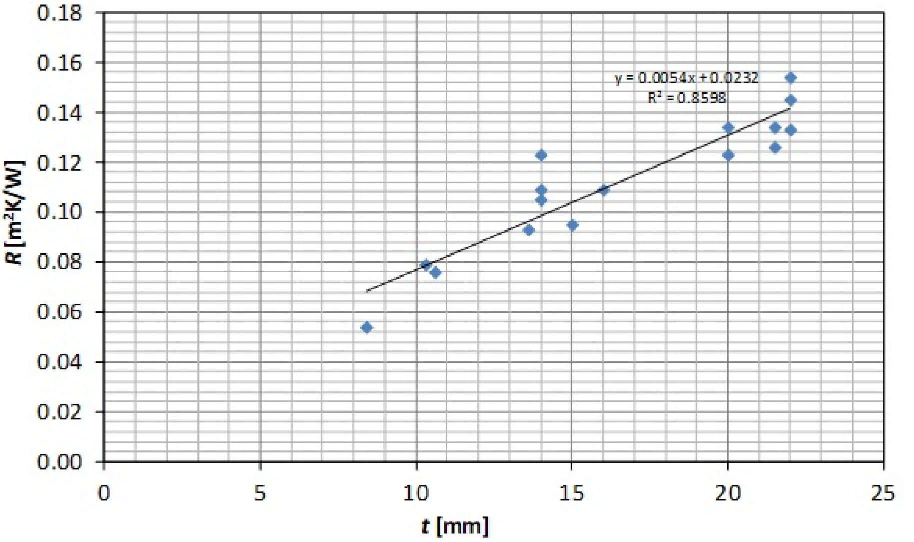

Fig. 2. Correlation between thermal resistance and total thickness of flooring elements

It may be clearly seen that the thickness is the dominant factor affecting the thermal resistance of wooden flooring elements, regardless of their construction.

Comparing thermal resistance values (table 3) it can be seen that the calculated values of thermal resistance were lower than those obtained experimentally. For HDF-based elements, the differences were as high as 30%.

This is acceptable when considering heat insulation – the calculated values are always on the “safe” side. However, in the case of underfloor heating, the situation is reversed: the calculated values of thermal resistance may suggest better properties than those that are obtained in practice.

Assuming the heat demand needed to cover heat losses to be 40 W/m^2, a temperature difference was obtained across the thickness of the flooring board ranging from 2.2 K to 6.2 K for the experimental results and from 1.7 K to 5.9 K for the calculation results. The maximum discrepancy between these two differences was 1.2 K, which is not so significant when considered from a practical point of view. The temperature difference between the top and bottom faces of the flooring elements may affect their dimensional stability and cause gaps between elements or other defects.

Conclusions

The results of thermal resistance testing have shown that all tested floor types (except one) are suitable for underfloor heating in the context of thermal conductivity.

The dominant factor determining the thermal resistance of floor elements is their thickness. However, when reducing the thickness, it is necessary to take into account the behaviour of other operational parameters of the floor at an appropriate level.

Another option is to increase the density of solid elements or a layer in multilayer elements, or to design a structure of such elements.

The different solutions used in the tested wooden floorings led to a wide range of thermal resistance results.

When the results of the tests were compared with the calculations, it was found that the calculated values of thermal resistance were lower than the experimental values, which may suggest that in relation to use on underfloor heating the calculated values imply better properties than are obtained in practice.

References

Kamke F.A., Zylkowski S.C. [1989]: Effects of wood-based panel characteristics on thermal conductivity. Forest Products Journal 39 [5]: 19-24

Krzysik F. [1975]: Nauka o drewnie. Warsaw

MacLean J.D. [1941]: Thermal Conductivity of Wood. Heating, Piping and Air Conditioning 13 [6]: 380-391

Nowicki J., Chmielowski A. [1998]: Ogrzewanie podłogowe. Poradnik. Ośrodek Informacji „Technika Instalacyjna w Budownictwie”, Warsaw

Rozins R., Iejavs J. [2014]: Evaluation of thermal properties of wood based composite panel walls. Research for Rural Development 2: 109-114

Seo J., Jeon J., Lee J-H., Kim S. [2011]: Thermal performance analysis according to wood flooring structure for energy conservation in radiant floor heating systems. Energy and Buildings 43: 2039-2042

Seo J., Park Y., Kim J., Kim Sughwan, Kim Sumin, Kim J.T. [2014]: Comparison of thermal transfer characteristics of wood flooring according to the installation method. Energy and Buildings 70: 422-426

Suleiman B.M., Larfeldt J., Leckner B., Gustavsson M. [1999]: Thermal conductivity and diffusivity of wood. Wood Science and Technology 33: 465-473

TenWolde A., McNatt J.D., Krahn L. [1988]: Thermal properties of wood and wood panel products for use in buildings. Forest Products Laboratory Madison

Woźniak T. [2016]: Posadzki drewniane na podkładach grzewczych z funkcją chłodzenia – podstawowe zależności. Profesjonalny Parkiet no. 3/85

List of standards

EN 12664:2001 Thermal performance of building materials and products – Determination of thermal resistance by means of guarded hot plate and heat flow meter methods – Dry and moist products of medium and low thermal resistance

EN 14342:2013 Wood flooring and parquet – Characteristics, evaluation of conformity and marking

CEN/TS 15717:2008 Parquet flooring – General guideline for installation

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