TKB Report 9

Influence of the Flooring Adhesive on the Performance of an Underfloor Heating System

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Summary

Bonded floor coverings and parquet conduct heat better than materials where floating installation was used. In the case of vinyl flooring, thermal resistance is measured to be approx. 0.026 K m²/W. By contrast, the thermal resistance of 3-layer parquet (2.5 mm real wood top layer, HDF middle layer, bottom layer made of Nordic spruce veneer, 13 mm in total) is measured to be 0.023 K m²/W. With the same heat output, the flow temperature of the heating system can thus be reduced by 2 to 3 °C.

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1. Introduction

Underfloor heating has been around for a very long time. During the Roman Empire, wealthy Romans installed underfloor heating in their villas in northern countries. Since last century's oil crisis, there have been a lot of energy-saving efforts, which also included the use of heat pumps. Since then, the use of underfloor heating has experienced a renaissance. Heat pumps usually achieve much lower flow temperatures than conventional heating systems. To introduce sufficient heat into a room, it is necessary to install a heating element with a large surface area. The obvious place of installation is the floor or, less frequently, the walls[1].

Today, the design of floor heating systems as "surface-embedded heating and cooling systems" is described in the standards series DIN EN 1264-1 to -5[2]. These standards also consider the influence of the floor covering on the heating performance. However, the frequently asked question of how the flooring installation method (bonded or floating) influences the performance of the heating system remains unanswered up to now.

When searching the usual sources (specialist books, magazines, internet) for information on the influence of the installation method, one regularly finds the qualitative statement that bonding improves the heat transfer. However, a quantitative description cannot be found. For this reason, the test results for two types of flooring will be presented here that quantify the differences between the two installation methods.

2. DIN EN 1264 and floor coverings

In principle, the standard

DIN EN 1264-2:2013-03: Water-based surface-embedded heating and cooling systems – Part 2: Floor heating: Methods for determining the thermal

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[1] W. Böhl, Estrichgeschichte, Holzmann Medien, Wörishofen 2017, pages 257 ff.

[2] DIN EN 1264 comprises 5 parts:

- DIN EN 1264-1:2011-09: Water-based surface-embedded heating and cooling systems – Part 1: Definitions and symbols; German version EN 1264-1:2011
- DIN EN 1264-2:2013-03: Water-based surface-embedded heating and cooling systems – Part 2: Floor heating: Methods for determining the thermal output using calculation methods and experimental tests; German version EN 1264-2:2008+A1:2012
- DIN EN 1264-3:2009-11: Water-based surface-embedded heating and cooling systems – Part 3: Dimensioning; German version EN 1264-3:2009
- DIN EN 1264-4:2009-11: Water-based surface-embedded heating and cooling systems – Part 4: Installation; German version EN 1264-4:2009
- DIN EN 1264-5:2009-01: Water-based surface-embedded heating and cooling systems – Part 5: Heating and cooling surfaces embedded in floors, ceilings and walls – Determination of the thermal output; German version EN 1264-5:2008

output using calculation methods and experimental tests; German version EN 1264-2:2008+A1:2012

opens up the possibility to determine the thermal output of underfloor heating systems by calculation or by testing. Chapter 1 of this standard explains: "The calculation method is applicable to systems corresponding to the definitions given in EN 1264-1 (type A, type B, type C, type D). For systems not corresponding to these definitions, the test method shall be used".

The construction types defined in DIN EN 1264-1 (chapter 3.1.6, figures A.1 to A.4) all contain only one "floor covering" as top layer, directly followed by the "load and heat distribution layer (screed)". A specific thermal resistance value can be used for the respective floor covering. However, there is no differentiation between "bonded" or "loose lay". Also additional values such as thermal conductivity of the adhesive or heat transfer resistance of the "gap" are missing. The calculation method described in DIN EN 1264-2, chapter 6, considers this point only in a very generic way. In chapter 6.2 for screed types A and C, for instance, the contribution of the top floor construction in the "floor covering factor a_B" is determined as follows according to equation (5):

$$a_B = \frac{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_{u,0}}}{\frac{1}{\alpha} + \frac{s_{u,0}}{\lambda_E} + R_{\lambda,B}}$$

Where:

- α = 10.8 W/(m²K); the same heat transfer coefficient for all situations
- $1/\alpha$ = 0.0926 m²K/W
- $s_{u,0}$ = 0.045 m[3]
- $\lambda_{u,0}$ = 1 W/(m K)[3]
- λ_E = thermal conductivity of the screed indicated in W/(m K)
- $R_{\lambda,B}$ = thermal resistance of the floor covering indicated in m² K / W

Physically speaking, heat transfer around floor coverings can take place in two ways:

a) between the screed and the floor covering if there is an air gap
b) between the floor covering and the room air.

The above formula is apparently based on the assumption that there is no significant air gap between the screed and the floor covering, therefore $1/\alpha = 0$.

[3] The symbols $l_{u,0}$, $s_{u,0}$ are neither explained in part 1 nor in part 2 of DIN EN 1264; only numerical values are given.

However, with the help of the measurement method described in chapter 9 of DIN EN 1264-2, the actually existing effect can be measured.

3. Measurement procedure

Measurements were carried out on test systems according to DIN EN 1264-2:2009 without floor covering, with multi-layer parquet (fig. 1) and with vinyl flooring (fig. 2) – bonded and floating installation for both types of flooring. The Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE) of Stuttgart University was commissioned to perform the measurements[4]. The tests took place in 2019.

Figure 1

Multi-layer parquet installed on a test panel (floating installation)

Figure 2

Vinyl flooring installed on a test panel (bonded installation)

[4] Universität Stuttgart – Institut für Gebäudeenergetik, Thermotechnik und Energiespeicherung (IGTE), Pfaffenwaldring 35, 70569 Stuttgart, "Experimentelle Ermittlung der Wärmestromdichte einer Fußbodenheizung (Sonderkonstruktion) in Anlehnung an DIN EN 1264"; 4 test samples with 4 test reports, test report numbers: L.1910.P.519.UZI, L.1910.P.520.UZI, L.1910.P.521.UZI, L.1910.P.522.UZI, as well as 2 test reports "Aufbau ohne Oberbelag, Rohre in Systemplatte eingebettet" with test report numbers: L.1910.P.517.UZI and L.1910.P.518.UZI, all dated 28 October 2019.

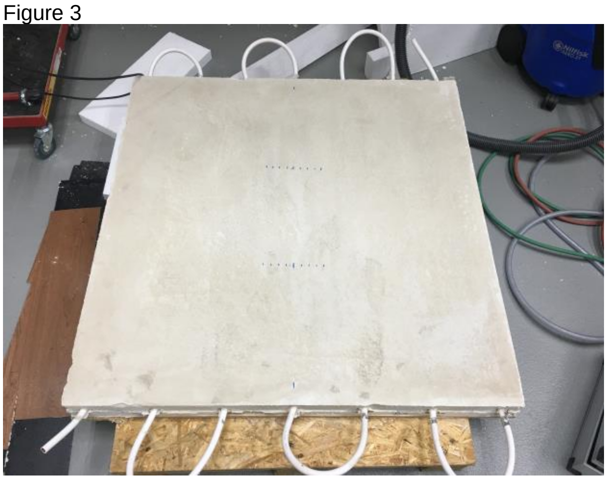
For all measurements, a test setup was created using the following materials:

Type of pipe	Composite pipe (Wieland cuprotherm, 14 mm)
Pipe spacing	150 mm
Pipe fastening	System panel
Screed material	Screed mortar UZIN SC 997
Pipe covering	45 mm
Sample area	1 m² (= 1 m * 1 m)
Master insulation boards	With $R_{\lambda,B}$ = 0.14 and R_{α} = 0.09 m²K/W

3.1 Test setup without floor covering (cement screed with underfloor heating)

As described above, master insulation boards were used for measuring the differential temperature and the heat flow. Two test specimens were prepared and examined: sample 1 and sample 2 (fig. 3). Naturally, the two samples are not identical and show slight differences in the measured values. This is important to note because both samples 1 and 2 were used for the measurements carried out on the vinyl flooring. By contrast, only sample 2 was used as a basis for the measurements performed on the parquet flooring.

Figure 3

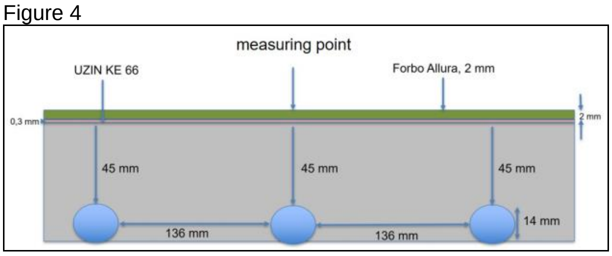


Test sample 2

3.2 Test setup for vinyl flooring

Installation: bonded (see figure 4)
Basis: test sample 1
Flooring: Forbo Allura Dryback vinyl flooring (thickness: 2 mm, thermal conductivity: 0.25 W/m K according to EN 14041:2004/AC:2006
Adhesive: Uzin KE 66, layer thickness approx. 0.3 mm

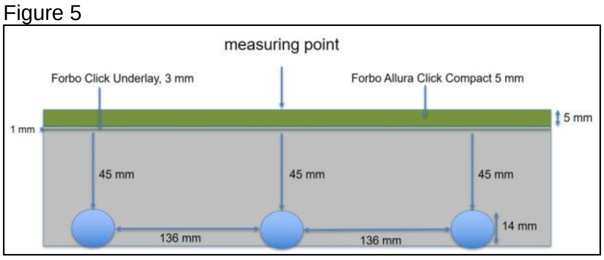
Figure 4



Test setup: vinyl flooring (bonded installation)

Installation: floating (see figure 5)
Basis: test sample 2
Flooring: Forbo Allura Click Compact (thickness: 5 mm, thermal conductivity: 0.25 W/m K according to EN 14041:2004/AC:2006
Underlay: Forbo Click underlay, thickness approx. 1 mm, thermal resistance according to EN 12664: 0.01 m² K/W

Figure 5

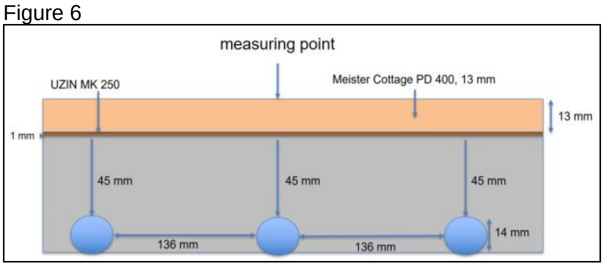


Test setup: vinyl flooring (floating installation)

3.3 Test setup for parquet flooring

Installation: bonded (see figure 6)
Basis: test sample 2
Flooring: Meister Cottage PD 400, 13 mm
Adhesive: Uzin MK 250, layer thickness approx. 1 mm

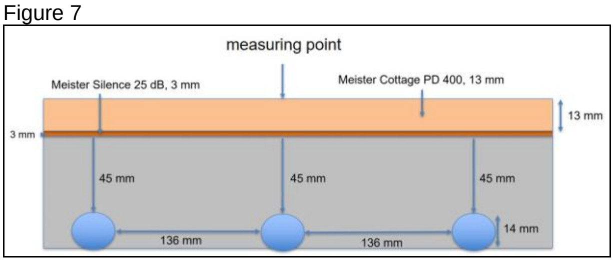
Figure 6



Test setup: multi-layer parquet (bonded installation)

Installation: floating (see figure 7)
Basis: test sample 2
Flooring: Meister Cottage PD 400, 13 mm
Underlay: Meister Silence 25 dB, 3 mm thickness

Figure 7



Test setup: multi-layer parquet (floating installation)

4. Measurement results

The results of the measurements and their evaluation can be found in the following 3 tables.

Table 1: Technical data screed samples

Samples			Test sample 1	Test sample 1			Test sample 2	Test sample 2	
Master insulation boards ($R_{I,B}$ = 0.14 and R_a= 0.09 m²K/W)			without	with			without	with	
Name	**Symbol / identifier**	**Unit**			**Difference**				**Difference**
Standard temperature difference between heating medium + room	$\Delta\theta_{H,N}$	K	18.26	31.52	13.55		18,26	31.27	13.01
Standard heat output	q_N	W/m²	90.9	94.5	3.6		91.4	93.4	2.0
Gradient of the characteristic curve	$K_{H,N} = q_N / Dq_{H,N}$	W / (m² K)	5.0584	2.9968	-2.0616		5.0055	2.9858	-2.0197
Total thermal resistance	$R = 1 / K_{H,N}$	K m²/ W	0.1977	0.3337	0.1360		0.1998	0.3349	0.1351

Table 2: Technical data vinyl flooring

Samples / installation			Test sample 1	Bonded			Test sample 2	Floating		
Floor covering				Forbo Allura Dryback vinyl flooring				Forbo Allura Click Compact		**Difference of the differences (= difference between floating / bonded installation)**
Underlay resp. adhesive				Uzin KE 66				Forbo Click underlay		
Name	**Symbol / identifier**	**Unit**			**Difference**				**Difference**	
Standard temperature difference between heating medium + room	$\Delta\theta_{H,N}$	K	17.97	19.04	1.07		18.26	22.14	3.88	2.81
Standard heat output	q_N	W/m²	90.9	91.1	0.2		91.4	93.4	2.0	1.8
Gradient of the characteristic curve	$K_{H,N} = q_N / Dq_{H,N}$	W / (m² K)	5.058	4.785	-0.2738		5.005	4.219	-0.7869	1.8
Total thermal resistance	$R = 1 / K_{H,N}$	K m²/ W	0.1977	0.2090	0.0113		0.1998	0.2370	0.0373	**0.0260**
Thermal resistance of the floor covering (acc. to the Technical Data Sheet)	$R_{\lambda,B}$	K m² / W		0.0080				0.0200		

Table 3: Technical data parquet flooring

Samples / installation			Test sample 2	Bonded			Test sample 2	Floating		
Floor covering				Meister Cottage PD400, 13 mm				Meister Cottage PD400, 13 mm		**Difference of the differences (= difference between floating / bonded installation)**
Underlay resp. Adhesive				Uzin MK 250, approx. 1 mm				Meister Silence 25 db, 3 mm		
Name	**Symbol / identifier**	**Unit**			**Difference**				**Difference**	
Standard temperature difference between heating medium + room	$\Delta\theta_{H,N}$	K	18.26	29.44	11.18		18.26	31.27	13.01	1.83
Standard heat output	q_N	W/m²	91.4	94.8	3.4		91.4	93.7	2.3	-1.1
Gradient of the characteristic curve	$K_{H,N} = q_N / Dq_{H,N}$	W / (m² K)	5.005	3.220	-1.7854		5.005	2.996	-2.0090	-0.2236
Total thermal resistance	$R = 1 / K_{H,N}$	K m²/ W	0.1998	0.3105	0.1108		0.1998	0.3337	0.1339	**0.0232**
Thermal resistance of the underlay + floor covering (acc. to the TDS)	$R_{\lambda,B}$	K m² / W		0.112				(0.019) + 0.112		

5. Discussion of the results

The total thermal resistance of a component R with i layers is the sum total of the resistances of the individual layers and, if applicable, of the contact resistances r_i:

$$R = \sum_i r_i$$

The individual resistances of the layers can be calculated from the layer thicknesses s_i and the material-specific thermal conductivities λ_i:

$$r_i = \frac{s_i}{\lambda_i}$$

When evaluating test panels 1 and 2, it is noticeable that the thermal resistance of the master insulation boards, which was measured to be 0.136 (test sample 1) and 0.135 m² K/W (test sample 2), is somewhat lower than the nominal value of 0.14 m² K/W ($R_\alpha = 0$ in the test setup).

For both types of flooring, identical floor constructions were tested. For the parquet flooring, the same material with the same thickness was used for both bonded and floating installation. For the vinyl flooring, different base materials were used (samples 1 and 2). Also the thickness of the vinyl flooring was different:

- 2 mm with bonded installation
- 5 mm with floating installation

With floating installation, it is necessary to use a higher material thickness to achieve sufficient stability for the installed vinyl flooring. The higher thickness of this construction significantly increases the thermal resistance. Since, however, the specific thermal conductivity is known, it can be used to help in the calculation of the actual subject matter under investigation (i.e. the difference between bonded and floating installation). On the other hand, it can be argued that only the comparison with the higher layer thickness makes sense. After all, the higher thickness becomes necessary by choosing the floating installation. This is therefore done here.

The improved thermal resistance value achieved by bonded installation is 0.026 (m² K)/W for vinyl flooring and 0.023 (m² K)/W for parquet. In the case of vinyl flooring, this value is in the same range as for the floor covering itself. With parquet, the value corresponds to about 20 % of the thermal resistance that is typical of this flooring material.

Conclusion: With approximately the same heat flow, bonded installation of the vinyl flooring allowed a flow temperature reduction by about 3 °C (of which about 1 °C is due to the greater thickness of the flooring material). With parquet flooring, the flow temperature could be reduced by approx. 2 °C. Lower flow temperatures lead to reduced energy consumption and thus lower heating costs. The actual savings, however, can vary from building to building. Another positive effect is that the stresses acting on the floor construction during the heating and cooling process are significantly reduced.