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Case Study

Correction of the thermal power calculation in the lightweight floor heating based on NT VVS127:2001 standard

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Abstract

There are many possibilities for determining the thermal power (thermal output) of underfloor heating systems. These may be mathematical, experimental, and numerical methods. Some of them are described in standards, manufacturers' guides (e.g. charts or tables based on experimental research), as well as programs with numerical calculations. This article concerns the issue of correct calculation of the thermal power only in lightweight underfloor heating without any screeds. It considers the correct entry of the formula for calculating heat power given in the Norwegian standard NT VVS127:2001, relating to a lightweight floor system with metal lamellas. According to the author of this article, there is a significant error in one of the formulas of this standard, which leads to an incorrect final result. This view was based on the results of the author's calculations and the calculations and conclusions of other scientists. The correction of the incorrectly written formula of the NT VVS127:2001 standard confirms the correctness of the thermal power calculations in a lightweight underfloor heating system with metal lamellas without screeds.

Introduction

The methods for calculating the heat flux density (thermal output) should be selected for the appropriate type of radiant underfloor heating. Lightweight underfloor heating without any screeds is not yet widely known. Therefore, there are not many standards or methods that will allow you to calculate the thermal power of this type of floor construction without screeds. Most of them are dedicated only to the heat power calculation of radiant floor heating using a "wet" or "dry" screed under tile floor. These include for example European standards such as [1-4] or based on country standards many types of manufacturers' guides or catalogues such as Purmo, Upnor, Zurn [5], KanTherm [6], Rehau [7] and others. Only the Norwegian standard NT VVS127:2001, experimental tests, and many numerical programs (such as Abaqus, Algor, Ansys, Femap, the HyperWorks program package, programs from the PAM family, MSC.Software and NEiSoftware) for the analysis of nonlinear problems using the finite element method can be recommended to perform this type of calculation reliably. The article aims to prove that changing the formula in the Norwegian standard leads to correct calculations of thermal power, which can be additionally confirmed by numerical calculations. So far, no one has questioned the formulas of the Norwegian standard, and the author's calculations and numerical calculations by other authors indicate that one of the formulas should be corrected. This way you can achieve the right thermal power results.

Discussion

When there is a lack of heat flux metres in the experimental studies, the computational density of the heat flux emitted from the tested surface can be determined using formula No. 7, point 5.3 recommended in the NT VVS127:2001 standard [8]. This formula has been corrected due to an error in its writing. The author, analysing the formula of the Norwegian standard for the balanced heat transfer coefficient K_H, noticed that in the denominator, instead of the maximum temperature of the

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medium in the heating coil θ_H^{max}, there should be the maximum temperature of the floor surface θ_F^{max}. Hence, the proper form of the formulas from the above-mentioned standard [8] to calculate the theoretical heat flux density should have the form (1) and (2).

$$qi = K_H \cdot D\,\theta_H \ [W/m^2] \quad (1)$$

where:

q_i – computational heat flux density (thermal power) on the floor surface

$$D\,\theta_H = \theta_H - \theta_i$$

θ_H – heating coil supply temperature [°C]

θ_i – air temperature [°C]

$$K_H \frac{q_i^{max}}{\theta_F^{max} - \theta_i} [W / K \cdot m^2] \quad (2)$$

where:

K_H – balanced heat transfer coefficient

θ_F^{max} – maximum floor surface temperature (in the middle zone equals 29 °C)

q_i^{max} – maximum heat flux density depending on heating coil spacing [W/m²]

θ_i – air temperature [°C]

This is evidenced by the results of the calculations and their comparison with other theoretical formulas for calculating the heat flux density on the floor surface, as well as the results of the calculations from the experimental tests made by the author of the monograph [9] and article [10]. Experimental research was conducted simultaneously on three research stations divided into two different parts with XPS or EPS thermal insulation covered with aluminium foil or without such a covering. The heating coils were placed at a spacing of 12.5, 15, and 20 cm. The whole thing was covered with adhesive and ceramic tiles. Diagrams of the measurement stations and their vertical sections are presented in Figure 1,2. Even heat distribution in the coil was ensured by the use of heating pipes with an internal aluminium coating.

Figures 3 and 4 show comparative floor temperature fields at a heating coil at different distances when the supply temperature is 28 °C.

To measure the temperature of the coil and the room, electronic, programmable thermometers ST-500 were used with a measurement accuracy of up to 0.5 K, with two sensors: air temperature and floor surface temperature. The average air temperature of the laboratory hall near the research models and the surface temperature of the partitions was 20 °C. Measurements of the temperature field on the heating surface were made using a FLIR I40 thermal imaging camera and (for

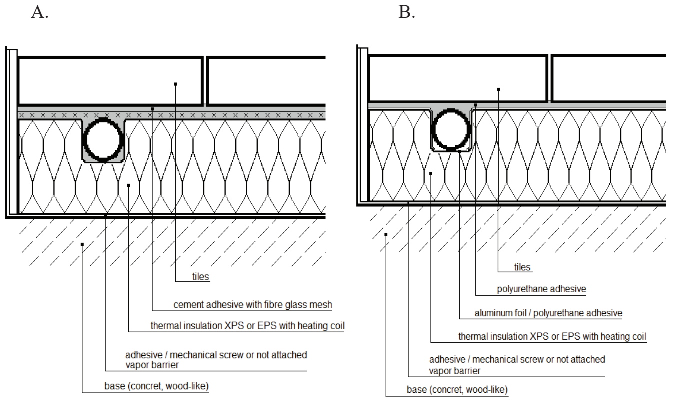

Figure 1: Vertical cross-sections of measurement stands with 9 mm tile thickness.
A. The thickness of 3 mm adhesive with fibre mesh, 40 mm of XPS, and 30 mm of EPS, not attached to the base,
B. The thickness of 2 mm adhesive with aluminium foil, 40 mm of XPS, and 30 mm of EPS, not attached to the base.

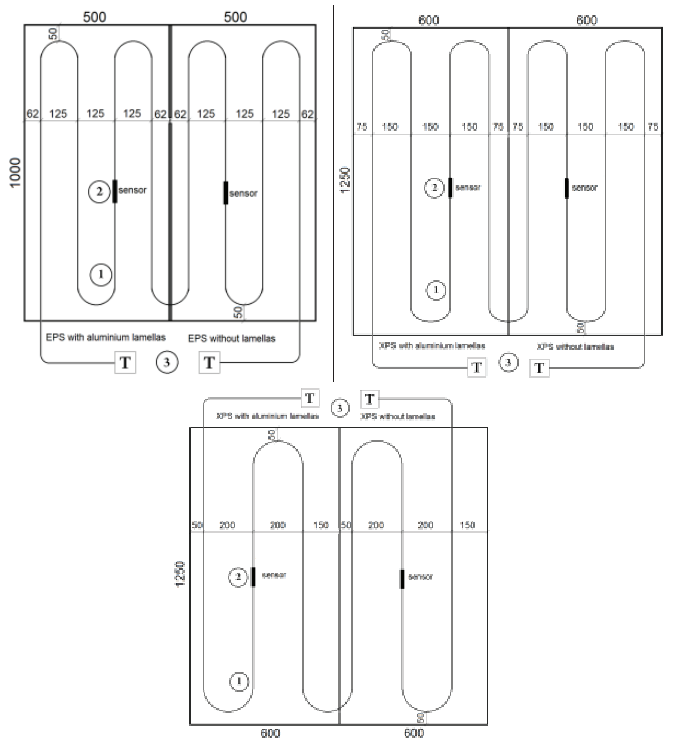

Figure 2: Diagrams of measurement stations ❶Heating coil (top left) ❷Temperature sensor (top right) ❸ Thermostat for measuring air temperature and heating coil (bottom).

verification purposes) a TN1 pyrometer from OJ Electronics with a sensitivity and measurement accuracy identical to that of the thermal imaging camera. Temperature accuracy was ± 2 °C or ± 2% of reading and thermal sensitivity (N.E.T.D) < 0.1 °C at 25 °C. A summary of the results of the computational and experimental thermal power of light floor radiators, based on the formulas from the European standards PN-EN 15377-1:2008, PN EN 12831, PN-EN 15377-2:2008 and the Norwegian standard [8] with the corrected error, is summarised in table 1.

Based on the results of Table 1, it seems that the author's calculation methodology for thermal efficiency with lamellas, defined by formulas (1) and (2), can meet or at least come close

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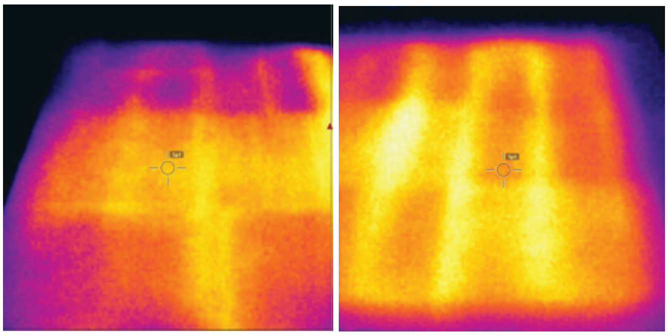
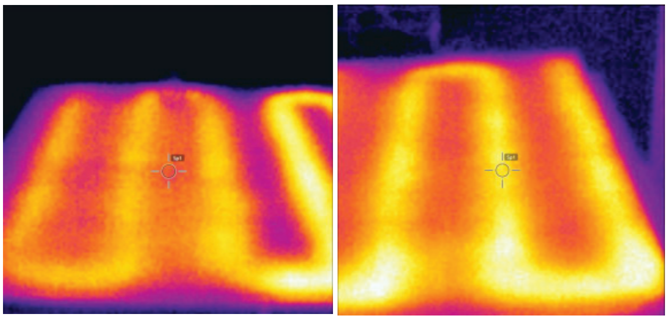
to its appropriate results. This is confirmed by the data from the table, in which the calculated and experimental thermal powers are similar to each other with heating pipe distances up to 15 cm and coil supply temperatures up to 35 ℃. This maximum supply temperature and distance of heating pipes should be sufficient when installing light heating systems using renewable energy sources.

In addition, the incorrect entry in the K_H formula is confirmed by calculations of the efficiency of lightweight floor heating according to the NORDTEST NT VVS 127 method carried out by Werner-Juszczuk [11]. In the article [11], the usefulness of the Nordest Method NT VVS 127 method for determining the operating parameters of light floor heating with a dry screed of 20 and 25 mm thickness on which ceramic tiles were glued was examined. The insulating base for the coil was EPS 30 mm thick, covered with 0.3 mm aluminium lamella. The entire light floor was laid on a 150 mm thick reinforced concrete ceiling. For the model constructed in this way, the methodology for determining the surface temperature and heat flux density according to the Nordest NT VVS 127 method was presented. Calculations were made for lightweight underfloor heating with a dry screed with variable water temperature. The results of calculations using the Nordest method were compared with numerical calculations made using the ANSYS Steady-State Thermal Solver and following the guidelines of the EN 1264 standard [1]. When performing calculations using the Nordest NT VVS 127 method, the correction proposed by the author of the monograph [10] was not made. In the summary of the article [11], it was stated that there are significant differences between the results obtained from numerical calculations and the Nordest NT VVS 127 method. The temperature error is as high as 5.68 K, and the heat flux density error is up to 55.5%. Smaller differences in the results of these parameters were noticed when making calculations using the PN-EN 1264 standard [1] and numerically. In this case, the temperature error did not exceed 0.2 K, and the maximum error of the heat flux density was 8.5%. Therefore, it was found that the EN 1264 standard [1] is more suitable for determining the operating parameters of light floor heating with a dry screed than the Nordest NT VVS 127 method.



With lamellas Without lamellas

Figure 3: Thermal image of the radiator at a supply temperature of 28 ℃ and a coil spacing of 12.5 cm.



With lamellas Without lamellas

Figure 4: Thermal image of the radiator at a supply temperature of 28 ℃ and a coil spacing of 20 cm.

Conclusion

The calculation results and conclusions presented in an article by Werner Juszczuk, et al. and the current research and calculations prove that the methodology for calculating the thermal power of light underfloor heating with lamellas given by the Nordest NT VVS 127 standard may be incorrect. Therefore, it can be concluded that the introduced correction of the formulas from the Nordest NT VVS 127 standard, reflected in formulas (1) and (2), is justified. It is worth to have by other scientists make their calculations taking into account the corrections of the Nordest NT VVS 127 formulas in this paper. Calculations based on the modified formulas of the Norwegian standard (1) and (2) from this article should be supported by your experimental tests. Test models should be prepared following the Nordest standard without using any screeds. This will allow you to reproduce the actual operating conditions of light underfloor heating without screeds. As a result, a comparison of calculations based on modifications to the formula from the Norwegian standard and calculations

Table 1: Computational thermal power according to standard [8] and an experimental according to standard [2] of lightweight heated floor with lamellas.

Heating coils spacing [cm]	Computational thermal power q_{ol} [W/m²]				Experimental thermal power q_{el} [W/m²]			
	Lightweight radiator floor heating with lamellas							
	Heating coil supply temperature [℃]							
	28	35	40	45	28	35	40	45
12.5	69,2	129,7	172,9	216,2	68,4	136,5	187,3	219,5
15	63,4	118,8	158,4	198,0	62,6	124,1	159,4	177,2
20	51,3	96,3	128,3	160,4	45,1	77,8	88,0	96,1
	$q_{12,5}^{max}$ = 77,81, q_{15}^{max} = 71,28, q_{20}^{max} = 57,75 (θ_F^{max} =29 ℃)							

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of experimental research should provide an answer as to the correctness or questioning of the correction of the formula given by the author of this article. Additionally, the response of the scientists who developed this Norwegian standard or their successors may shed new light on the elimination of a probable error. The topic is so interesting that for over half a year the author of the article has been waiting for the opinion of the representative of the Norwegian standard to be expressed, after expressing his comments regarding the correctness of the formula (2).

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