Wood flooring in combination with underfloor heating systems

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Abstract. The main objective of the article is to inform about the wood flooring in combination with underfloor water heating systems. Wood is a very sensitive material that responds to its surroundings. For this reason, it is necessary to select a suitable wood, meeting the criteria of suitability for laying as flooring in combination with underfloor heating systems. It is also important to comply with the conditions of storage of wooden flooring and its installation under acceptable climatic conditions at the construction site, together with the technical regulations for the installation of wooden flooring in combination with underfloor heating systems, during the whole life cycle of the wood flooring. This article defines the basic input premise for the implementation of wooden floors in combination with underfloor heating systems, regarding the relevant technical standards and technological procedures valid in the Czech Republic. At the same time, the article describes possible failures of wooden floors in case of non-compliance with the above conditions. In the conclusion, we propose measures based on the described installation process failures of the wooden flooring in combination with underfloor heating systems, and after its use.

1. Introduction
Wood as a flooring layer has been a part of interiors and exteriors constructions for centuries, which is mainly due to its mechanical and physical properties, together with its exquisite appearance. However, due to the organic origin of wood, it is necessary to properly design, install, use and maintain wooden elements, otherwise, failures of various characters may occur. Especially nowadays, when standard constructions are supplemented by modern technologies, such as wooden floors in combination with underfloor heating, it is necessary to comply with technical regulations and standards during the installation and operation of the floor as a whole. At the same time it is necessary to choose a suitable type of wood in terms of physical and mechanical properties together with dimensional parameters of the wooden element and the method of its anchoring to the base layer. It is important to observe the required climatic conditions at the place of laying the floor (humidity and temperature of a room, base layer, wood elements), the quality of the wood material, the storage of the wood material, the design of underfloor heating systems, and its start-up process. For structural assessment, a structural and technical survey is required to perform detailed tests, take samples, etc. [1]

Failure to comply with these conditions can lead to partial or complete degradation of the wood floor layer in the form of larger than tolerated joints and height elevations between individual wooden elements, or crack, troughing and delamination of wooden elements. These faults occur mainly due to
shrinkage or swelling of wooden elements due to excess moisture contained in the air, wood, or base layer.

It is important to choose a wood with excellent mechanical properties and durability. It is better to choose hard and shape-stable wood, with resistance to substances with adverse effects, plant and wood-destroying pests. [2] In the case of wood with small shrinkage values in both tangential and radial directions during slow drying, the risk of the wood tends to dry and crack is low. For this reason, it can be considered as a stable wood suitable for laying as a flooring layer in combination with underfloor heating. The use of wood floor in combination with underfloor heating is possible provided that the appropriate floor structure is selected and created in high quality, and the relevant standards and technical procedures are respected.

2. Wooden floors in combination with underfloor heating

The suitability of wood as a walking layer in combination with underfloor heating is not clearly determined in the professional community, due to the physical properties of wood and the demands on the technology of floor design and construction, when a wooden floor with underfloor heating requires a specific technological procedure. Wood is an organic, inhomogeneous, hygroscopic, and anisotropic material, which means that it responds to climatic changes in the environment (especially humidity and temperature), is heterogeneous, tends to retain its moisture in the equilibrium state, and also that the wooden element has different geometric directions various properties.

2.1 Physical properties of wood

In general, wood has higher thermal resistance \( R \) [m²KW⁻¹], a low heat capacity \( C \) [J K⁻¹] and is, due to the action of heat and humidity, prone to volume changes in the form of shrinkage or swelling. The wood’s low storage capacity is a disadvantage in the winter when it is difficult to accumulate excess heat (e.g. from solar gains, operation, etc.). At the same time, the wood has a high coefficient of heat radiance, which means that after a heating break, the building is heated very quickly. This feature, together with the appearance of the wood used and the underfloor heating, creates a pleasant feeling in the interior and the air in the room is not as dry as in classically tempered rooms. The advantage of low heat capacity in the summer is that in case of overheating the floor, it is difficult to accumulate the obtained heat in the wood, and therefore it is easy to ventilate the interior during the night. In terms of thermal conductivity \( \lambda \) [W m⁻¹ K⁻¹], wood is a more suitable material than, for example, concrete, but it cannot be compared to modern thermal insulators.

2.2 Suitable wood for underfloor heating

Wooden floors can be used for floors in combination with underfloor heating, however, it is important to observe certain conditions regarding the properties (especially stability) and parameters of the wooden floor, the technology of design, and operation of underfloor heating, and the floor itself. Failure to comply with the conditions increases the risk of volume changes of wooden parts resulting in shape and dimensional deformations. At the same time, the wood can be stabilized with special technology, such as Thermowood. [3] The most suitable construction of a wooden floor is two-layer or three-layer floor panels, due to the low construction height and good dimensional stability, ensured by their composition. Solid or massive wooden floors can also be used at the same time. With the increasing parameters of the wooden floor panel, the risk of shape deformations (especially the joints between the individual wooden elements) increases analogously, with values exceeding the standards tolerance (in the case of Czech technical standards ČSN 74 4505 and ČSN 49 2120). The floor thermal resistance increases with the wooden panel's height, so the underfloor heating consequently may appear inefficient with the higher element, due to the increase in energy consumption, to ensure a higher operating temperature of the underfloor heating. Which, of course, may not be beneficial for a wooden floor.
3. Underfloor heating systems in combination with wooden floor

Underfloor heating can be divided according to the used heating medium and according to the type of distribution, into electrical and water systems. To better ensure even distribution of humidity and temperature it is more appropriate to use water-based underfloor heating under wooden floors. The water underfloor heating pipe system is laid inside the floor construction and can be placed on reflective foils or in installation/system boards. The underfloor water heating system must be switched off before laying the floor layers.

During the preparation of the construction project, it is appropriate to consider that the walking layer of the floor will be formed by a wooden floor with the identification of the proposed wood. Furthermore, the method (technological procedure) of floor installation and the maximum permissible floor surface temperature should be considered. If the manufacturer of wooden floor elements does not state this value, the temperature limit value is set by a technical standard, for example according to ČSN 49 2120 (effective from 10/2012 until now) at 28 °C (82.4 °F). Another example can be the technical standard ČSN EN 1264-3 regulating the limit temperatures for underfloor heating without distinguishing the type of floor walking layer allows the highest surface temperature of the living area of 29 °C (84.2 °F) and the edge area of 35 °C (95 °F).

Another technical standard ČSN 49 2120 states, that if a wooden walking layer is installed for underfloor water heating, the heating must be started in good time before laying the floor, and the start of the underfloor heating must be documented. The wood floor surface temperature must not exceed the value, which is specified by the flooring manufacturer, but not more than 28 °C (82.4 °F). The temperature of the heating medium should not exceed 40 °C (104 °F). The start up of the underfloor heating is expressed by the graph in figure 1.

![Figure 1. Start-up diagram of underfloor heating.](image)

Czech technical standard ČSN EN 1264-3 prescribes, after 21 days after laying the screed, to turn on underfloor heating with a heating medium temperature between 20 °C and 25 °C for three days, then for four days with the highest design temperature. The entire start-up cycle lasts 28 days. However, unlike the previous start-up, this method is not sufficient for wooden flooring, according to technical standard ČSN 49 2120. The standard diagram is not binding, a different method may be chosen, but it must ensure a moisture content of ≤ 2.0 % in cement screed or ≤ 0.5 % in screed based on calcium sulphate.

If the start-up is not made, the wooden floor may be destroyed by leaking moisture. Another cause of the destruction of the wooden floor may be too much underfloor heating performance inherently high surface temperatures of the flooring layer.
4. Conditions for storage and installation of wooden floors

Wood and wood-based flooring must be stored in acceptable temperature and humidity conditions so that it cannot be damaged. It must be stored at the installation site until the same temperature as the installation premises is obtained. The floor coverings are opened gradually as the assembly proceeds.

Before starting to lay the floor, it is necessary to measure the humidity of the base layer, which in the case of using a cement screed in combination with a tread layer of wooden floor, parquet, and laminate flooring, must be less than 2.5% (according to ČSN 74 4505). In the case of design a floor heating system, the highest requirement humidity for cement screed shall be reduced by 0.5 %. Humidity measurement should be carried out continuously and in multiple locations, preferably using a non-destructive method, to eliminate possible damage to heating distribution systems.

According to ČSN 49 2120, the prefabricated flooring humidity and temperature shall be in equilibrium with temperature \((20 \pm 3)^\circ C\) and relative humidity \((50 \pm 10)\%\). This corresponds to the humidity of the flooring at the time of delivery from the manufacturer. Flooring must also be stored in such an environment. If the humidity of the flooring is within the appropriate range, the acclimatization is useless. Acclimatization is necessary for no less than 48 hours, provided that the temperature of the flooring has decreased during transport to the construction site at low outdoor temperatures and if prescribed by the flooring supplier. The flooring humidity should be verified before installation and material with different humidity from the expected equilibrium humidity should not be installed. The assembly of wood flooring is permitted at an air and treasure temperature of at least \(15^\circ C\) and relative air humidity in the range of 40-60 %. These conditions must be ensured at least 24 hours before the start, throughout the installation, and until the floor is handed over. It is recommended, even for future use, to equip the room with a regulated humidifier. Before laying underfloor heating must be switched off.

Interesting is that the Czech technical standard ČSN 49 2120 states that larger joints may occur if underfloor heating is used. Their occurrence is influenced not only by air parameters, but also by the heat flow through the flooring, the action of different surface temperatures and airflow, and the microclimate above the floor. For wooden flooring joints above underfloor heating, there are no maximum permissible deviations of shapes and dimensions. The basic requirement is that layers of multilayered and laminate flooring must not be delaminated.

The quality of the wooden product should comply with the relevant product standards and the declaration of characteristics given by the manufacturer, including the technical data sheet of the product.

Wooden flooring in combination with underfloor water heating can be installed in two ways, in a floating way or by gluing on the base layer. The installation of the floor by gluing is a method more convenient from a practical point of view, due to the shape and dimensional stabilization of the wood flooring with smaller thickness. In general, adhesives intended for floor-to-surface bonding must not negatively affect the properties of wood layers by their composition (e.g. water content). In the case of gluing elements of the wooden floor to the base layer, it is necessary to use glue declared suitable for underfloor heating. From ordinary wood flooring must be glued Double-layer parquet floors and parquet of hardwood (parquets with pen and groove).

It is recommended to require a tensile strength test of surface layers due to provide the strength stress exerted on the treasure due to the transfer of stress from the flooring. The forces are generated in the glued gap when the humidity changes during underfloor heating operation and they are greater than the forces for unheated floors. The tear-off target is glued directly to the test layer.
5. Disorders of wooden floors

Wood is a material that reacts throughout its service life to environmental conditions, especially humidity and temperature, because of its organic origin. Due to climatic changes in the environment in which the wood is located, due to the adaptation of the wood to the given environment, volume changes can occur, which are manifested by swelling or drying of the wood element. Wooden elements should be carefully dried by the manufacturer and delivered with the declared moisture content, according to the relevant technical standards (in the case of wooden floors, e.g. according to ČSN 49 2120, ČSN EN 13226, etc.).

Volume and shape changes can occur with carefully dried wood in the case of extreme conditions of fluctuations in relative humidity (RH - Relative Humidity), i.e. RH <30% or RH > 70%. In the winter months, RH decreases, while without the use of an additional moisture source (e.g. evaporator) RH can fall below 30%, which can lead to shrinkage of the wood element and subsequent formation of larger than tolerated joints between floor elements, as well as deformations in the form troughing, cracking, delamination of individual layers, etc. In the summer months, RH increases. In the case of new buildings, where adequate ventilation is not provided, increased RH can exceed 70%. Increased RH results in moisture absorption by the wooden element, which can lead to its swelling and subsequent deformations.

The level of drying or swelling of wooden floor panels is greatest in the tangential direction of fiber growth, so wooden floor panels are most often prone to movement in their width, which means that the wider the panel, the higher the risk of deformation due to volume changes. This process of wood movement is not sudden and can be slowed down by treating the floor surface, for example with paint. [4] However, the risk of individual wood volume changes depends on their volume stability. Stable wood species have smaller deformations compared to unstable wood species. Long-term fluctuations in RH values in the interior (35% - 70%) affects, among other things, the equilibrium range of moisture of the wood type exposed in this environment, which has an effect on the volume changes of the wooden element in the tangential direction according to the used wood.

If we convert this theory into a specific case (Doussie exotic hardwood floor, tangential shrinkage value 3.9 %) it means, that when the RH decreases (below the limit of a healthy climate, i.e. 35%), the used 90 mm wide wooden parquets may dry out and subsequently reduce the width of individual parquet by up to 3.51 mm. Even when laying exactly according to the recommended requirements of technical standards. This phenomenon results in several enlargements of the joints between the parquets, which by their dimensions greatly exceed the tolerance values of the joint widths according to the relevant technical standards.

6. Conclusion

The underfloor heating system has an effect on the possible behavior of the wooden floor, which can lead to damage to the wooden floor if the design in the project documentation is incorrect. The underfloor heating system limits the possible range of wood types suitable for laying as a wooden floor. The choice of a suitable wooden floor should balance the issue of the strength of the used wooden elements. From the point of view of heat transfer, it is suitable to use the thinnest possible wooden elements. From the point of view of dimensional stability, it is suitable to use wooden elements of much thickness. It is also necessary to remove excess moisture and ensure optimal temperatures at the construction site (air moisture), in the material of the wooden floor (moisture from manufacture), in the base layer (moisture from wet construction processes). In the case of underfloor heating, it is necessary to start it before laying the wooden floor, due to the stabilization of the base layer.
Possible aspects leading to a failure of a wooden floor in combination with underfloor heating systems can be considered as:

- Non-compliance with microclimatic conditions and technological procedures for stabilizing the base layer and wood floor before laying, during laying, and after finished it.

- Inadequate quality of the delivered material and non-compliance with the technological laying procedure.

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