

Research Article

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Technical analysis of the renovation works of the wooden palace floors

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Abstract: The paper presents technical analysis of two aspects of palace wooden floors – the first example describes renovation works in a historical building, while the second presents assembly of a new floor in the contemporary building. In case of both examples technology of construction works is discussed in details with a special focus on issues specific for wooden palace floors. The authors paid special attention to introduce problems that occurred during the performance of the works. Both cases are compared. The restoration of the antique mosaic is significantly different from the implementation of the palace mosaic (tile) from bottom-up. Restoration works required more effort, mostly due to the fact that the antique mosaic floor experienced many years of use and needed specific repairs. On the other hand making the palace mosaic from scratch is burdened with a much smaller number of unforeseen situations. Due to the high aesthetic requirements, decorative functions and unique character of both discussed examples of flooring works, each of the tasks was labour-consuming and needed highly specialized works.

Keywords: wooden floors, renovation, wood technology

1 Introduction

Renovation of antique wooden floors is marked by the considerable character of the works due to the need to preserve their unique character. In historic buildings before the renovation, it is vital to get familiar with the history of the building, which is the basis for further renovation work. The analysis of the structure and technological requirements of the floors is to provide information on subfloor and other base surface compositions for

wooden floors. The process of restoring wooden floors requires a lot of work and money, which private investors are not always aware of while purchasing palace properties. They need work related to antique material, its processing, manual skills and precision of workmanship. Any difficulties occurring during the renovation can be eliminated by early and detailed historical research, as well as by experience and skills of people performing renovation. The arguments presented confirm the validity of the claim that the processes associated with the renovation of antique wooden floors show a certain character of works connected with the appearance of unexpected situations that often change the initial assumptions of the works. Working with wooden floors is an art of balance between modern techniques of renovations and historical appearance of the floors. The aspect of the diagnostics of wood used as a floor was discussed in publication [1]. The authors analyze wood defects that may affect floor properties and also describe the reasons for their formation. Kim discusses the problem of formaldehyde and TVOC emission from composites of wooden floors in various stages of production of surface finishing materials [2]. The studies suggest that the emission of formaldehyde and volatile organic compounds from floors can be controlled in the production stages to finish the surface. The preferences of architects regarding the selection of wooden flooring were analyzed in articles [3, 4]. Three factors were defined: environmental certification, origin of timber and prices. The data was obtained from a survey conducted among architects in Oregon and Washington. They showed that the most important criteria for choosing a type of wooden flooring is the price and origin of the material. The wooden floor as an element of the historic building was submitted for research by Diaferio, Foti, Giannoccaro and Ivorra [5]. Dynamic tests with the usage of vibrations from the environment were developed to identify the building's resistance to destruction. Due to the presence of wooden floors, the analysis showed some irregularities in the determination of modal parameters. The dynamic characteristics of wooden floor structures were also described by Jiang [6]. It was shown that the finite element model is reliable in determining the expected deflections, including gaps perpendicular to the

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joists or flexible supports. Works on historic buildings are also described by Swaczyna [7], Raposo [8], Vahtikari [9]. The first one contains a review of wooden flooring projects, whereas the publication [9] is a case study of a historic medieval building, as an analysis of its wooden floor and its conservation methods. In the publication [10], wooden floors were tested in four historic buildings. The authors suggest that the test method described in the article allows to effectively determine the stiffness of the existing floors. Orłowski and Walichnowski discuss the results of the analyses of the linear efficiency and overall cost structure of the cutting processes of engineered flooring [11]. The operations of the self-tensioning system and analysis of its behaviour in wooden floors with a large span describes the work by Otero-Chans [12]. In combination with conventional pre-tensioning, the self-tensioning system improves particularly deformation behavior. Because of the problems caused by noise and time limits, Zhang Yizhuo proposed a novel method using morphological reconstruction technique to conduct on-line defects detection for wood floors [13]. Clouston and Schreyer describe the construction and use of wood-concrete composites in an existing or new floor construction [14]. The presented examples of scientific studies confirm the validity of continuing further analysis of the problems of renovation of wooden antique floors, showing the unconventional procedures dependent on the given renovation case.

The aim of the work is a technical analysis of renovation works on wooden palace floors. The examples discussed illustrate detailed technology of renovation works and assembly of a new palace floor, taking into account the problems that occurred during the performance of the works. The comparison of two technologies (namely, the process of renovation of the existing wooden floors and building a new palace floor) will allow to visualize the differences resulting from the renovation processes in the monastery in Kalwaria Zebrzydowska and the execution of new palace floors commissioned by a private investor. Works on the wooden palace floors are characterized by their difficult character caused by either the historic material or its processing. As a result of the analysis, conclusions regarding the processes, including labor input, material resources and other factors accompanying renovation works, will be provided.

2 General requirements and preparation of the process of renovation of the wooden floors

2.1 General technological requirements

Proper execution and renovation of wooden floors requires knowledge of their technical properties and features which they must possess in order to perform their functions correctly [15]. The floor should maintain a horizontal surface throughout the entire area which it occupies, unless the design does not allow it otherwise. Wood is an anisotropic and hygroscopic material with uneven and variable structure [15]. Examination of the mechanical properties of wood requires to take into account many factors, such as the anatomical direction and humidity of wood, as well as the number and distribution of structural defects having a big impact on the strength of wood and the possibility of its use. Mechanical strength means the strength of the wood against compression, tensioning and bending. It depends on the direction of forces in relation to the fibers. Thermal properties of floors depend on the type of material used [15]. The authors of the paper [16] described new materials and modifications of solutions for flooring in a residential house. Wood as a construction material is subject to tests in terms of the heat transfer coefficient. Works [17, 18] analyzed wooden flooring materials used in underfloor heating. The topic of thermal insulation of wood was also presented by Ujma [19, 20]. The table below (Table 1) presents the heat characteristics of the touch of particular types of floor materials, including wooden floors [19].

Another important feature that must characterize a wooden floor includes its resistance to biological corrosion [15]. Wood as an organic material is significantly exposed to biological corrosion from insects and other microorganisms, including fungi and mold. In order to properly protect the floor against biological corrosion, it is necessary to pay attention to the ambient humidity and heat conditions, to use only materials with appropriate normative humidity, to impregnate wood by the pressure method or bath method performed before installation, and to protect it against ground humidity [15].

Table 1: Characteristics of the touch heat of particular types of floor materials

Floor description	Type of floor material
very warm	floor laths; parquet tiles; floorboards; laminated boards (> 15mm); wooden cube; cork flooring; carpets
warm	tiles of mosaic parquet; thin parquet (10 mm); multi-layer PVC lining; woven flat carpet
cold	laminated panels; single-layer linoleum; PVC floor covering; linings made of elastomers

2.2 Preparation of works in the presented examples from the process of renovation of the wooden floors and implementing a new palace floor

To analyze the scope of works in the presented examples it was necessary to carefully check both the condition of the floor and the building itself. Finding all potential problems before starting the renovation and making the floor saved time and unnecessary work. The parquet executors evaluated the technical condition of joists, beams and wooden ceiling. Any interference with the existing floor without proper checking of its subfloor could lead to a greater destruction of the floor. To avoid this, part of the floor was pulled down to assess the functional properties of the subfloor. A wooden floor had been destroyed not only by the action of time in historic buildings, but also as a result of mistakes made during its execution. This was confirmed in paper [21], the authors of which proved that the floor works properly in the permissible humidity range and poor performance at lower relative humidity results from the arrangement of the structure under the floor, the method of installation and the building environmental conditions. The first stage of the projects was the evaluation of the subfloor and later of the actual condition of the floor and its usable layer. Depending on the amount of floor grinding in the past, the thickness of the utility layer could be small, requiring a complete surface replacement. In the case of a problem connected with a larger area of the floor, a complete replacement of the floor turned out to be a better solution. When renovating a historic floor, it is necessary to take into account the original elements that keep the historical value of the floor.

3 Technology for the restoration of wooden palace floors

After a thorough analysis of the condition of the floor and the building objects, the next stage was to start renovation works. The technology used to restore the wooden floor of

this palace was specially selected for the condition of the floor. Because of the unique character of the floor, there was no single correct scheme of renovation. To illustrate this, a restoration process of the antique floor will be presented on the example of the palace mosaic located in the monastery building in Kalwaria Zebrzydowska (Figure 1). The origins of the Sanctuary of Kalwaria Zebrzydowska go back to the beginning of the 17th century, when Mikołaj Zebrzydowski constructed a chapel, consecrated as a church on the 4th of October 1601.

The case study was developed based on the completed renovation process. After the initial inspection, significant damage and abrasions of the varnish on the entire surface of the room were found. The execution of the local excavation made it possible to notice the laying of the palace floor on a sandy ground with wooden joists supporting the palace panels (Figure 1). The investor and the contractor decided to completely demolish the palace tiles, replace the subfloor with a new one, restore the palace panels in the workshop conditions, re-arrange and then finish them. The contractor decided to take all the sand out of the ground and clean it after all other cleaning works had been done, then they installed joists in order to level the entire room and a load-bearing grid for the “blind” floor, made of OSB board with a thickness of 22mm. Next, the boards were transported to the workshop and the process of dimensioning of each element took place. The dimensioning showed significant deviations of the plates with respect to each other. Dimensional deviations could be as large as 1 cm, so the decision was made to reformat each sheet into format files and give it dimensions 98×98 cm from the original of about 100×100 cm. After the formatting, there was a problem with the consistency of the pattern that the floor showed before dismantling and the formatting process. Steps were taken to add a frame around each plate to change the target dimensions of the element. Originally, the palace panels had a thickness of approx. 28 mm, yet the inspection showed significant differences between individual elements of the sheet reaching 4mm. Plate thickness was therefore reduced to 23 mm to level individual components. The process of exchanging components proved to be very laborious, because each element



Figure 1: a) Palace floor in the monastery building in Kalwaria Zebrzydowska before renovation; b) The local excavation; c) Matching individual elements of the sheet

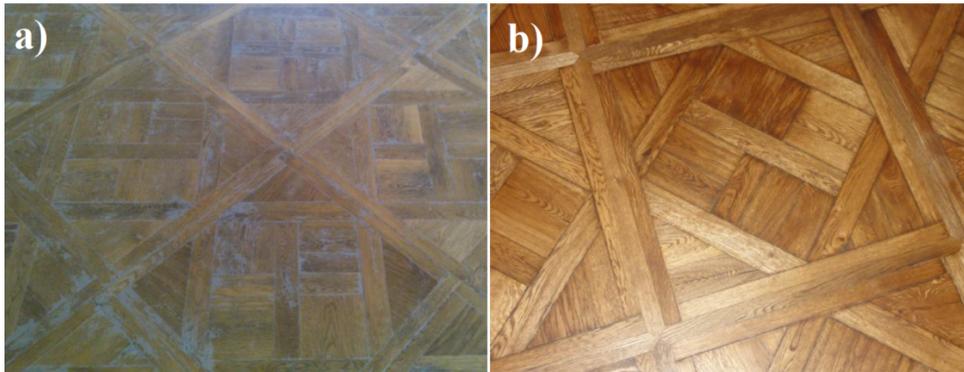


Figure 2: a) Palace floor before renovation; b) The final effect of the renovation

had its own tongue and groove. It was therefore necessary to prepare new elements of exactly the same shape as the old ones.

There was also a problem of material nature because all the original panels were made of oak, which over time, due to natural processes and use, had become darker. The idea was to use elements made of oak wood which had undergone the smoking process making the wood look older. Then surface grinding with a belt grinder began in order to obtain equal sizes of individual elements, after which it was necessary to clean the edges connecting the individual elements manually from the accumulated sand and other impurities.

After the restoration phase of the palace floor in the workshop and the execution of the “blind floor” in the Monastery in Kalwaria Zebrzydowska, the contractor proceeded to install the floor. The investor accepted the diagonal layout of the panels in the room and the gluing of the floor using resin-synthetic adhesive. Gluing required accuracy and commitment from the workers because of the diverse shapes of the panels to install, which made it hard to put them in a straight line. Next, the mutual convergence of individual elements was checked, in order to adjust the individual plates in relation to each other and find them

a proper place on the floor surface. The work took more time than anticipated due to the dimensions of individual elements and their minimal differences in dimensions (Figure 1).

After finishing the work, the floor was left for a period of about 2 weeks for the adhesive to fully bond. Subsequently, the whole surface of the room was sanded using a drum grinder, gradually reducing the graininess of the paper, until smoothing. Coloring stain and primer were applied to give depth to the color and visually age the floor. The purpose of using a two-component topcoat was to increase the strength and abrasion resistance of the floor surface (Figure 2).

4 The process of executing and installing the palace floor

The process of making a new antique floor will be presented on the example of works performed on behalf of a private investor in a contemporary residential building. The case study was developed based on the completed implementation process. Before starting the works related to

the construction of the new palace wooden floor, it was necessary to prepare the subfloor which plays an essential role in proper operation. The basic criterion that should be fulfilled by the subfloor was its moisture level, which was examined by means of a specialized chemical CM-Garet device. The test result obtained determined whether the subfloor met the requirements for laying a wooden floor on it.

The recommended humidity levels according to the device manufacturer's data are presented in (Table 2).

Table 2: Recommended humidity levels of subfloor under wooden floor

	ordinary subfloor	heated subfloor
cement subfloor	< 2,0%	< 1,0%
anhydrite subfloor	< 0,5%	< 0,3%

The palace mosaic required the use of a moisture barrier since the moisture norm of the subfloor was exceeded by about 1%. The use of epoxy resin allowed to close the moisture of the subfloor and additionally fulfilled the strengthening and priming role before pouring the leveling compound. The resin was laid in two layers in a cross, while adding dye facilitated the proper implementation of the moisture barrier to the second layer. The last stage involved sprinkling the resin layer with quartz sand with a grain size of 0.8 mm in order to provide a bonding layer for the leveling compound. Application of a primed self-leveling cement mass resulted in leveling the surface. Polyurethane adhesives were used, which, due to their flexibility, additionally transferred all loads to the levelling layer. The applied mass under the wooden floor had adequate strength to resist breaking and shearing forces thanks to added refiners and reinforcement made of fiberglass about 2-3mm long. Then expansion joints, cracks and gaps were secured. For this purpose, repair resins, reinforced with steel braces, were used. The reinforcement was sprinkled with quartz sand to increase its adhesion.

After the investor had selected the floor pattern of the palace floor, the components of each palace sheet were obtained. They were made either of solid elements obtained directly from the processed wood of proper timber or of veneered elements glued on a load-bearing subfloor in order to reduce material costs. Despite the application of CNC machines thanks to which the original designs could be obtained, the traditional method of making palace mosaics in the conditions of craft workshops was chosen for making the floor. It gave individuality and the unique character of the floor. In the analyzed implementation process,

tile elements for the palace mosaic were prepared earlier in the workshop. Due to aesthetic and technological requirements, a 10 mm thick laminated parquet made of several exotic wood types was applied, which were later glued onto 5 mm thick plywood. Joining was made using a polyurethane contact adhesive, additionally with waterproof properties. The cubes were formatted to the dimensions imposed in the project. Internal elements, connecting frames and decors were made separately and then fastened during laying on the construction site (Figure 3).

The laying process began with determining the center of the floor according to strict guidelines regarding the arrangement of the individual elements of the patterns throughout the room. Before gluing the floor, the panels were adjusted to each other to find a suitable place on the floor plane. Since it was necessary to insert the panels into the existing marble, edge cuts were made right next to the edge of the marble, while all expansion joints were cut after sticking the tiles to the subfloor. Given the layered nature of the floor, for gluing particular parts one-component polyurethane adhesive was used. After the assembly, grinding works started. Due to the very delicate nature of the material and its previous workshop treatment, the grinding process did not start with the paper of the highest granularity. Instead, smoothing sanding was applied using abrasive paper with a smaller grain size, which made it possible to give the entire surface evenness and homogeneous appearance. Prior to painting, small corrections had to be made locally, which was primarily required for decors. Parts of the surface were individually laid, for individual types of wood to prevent edge discoloration caused by the filling putty. Before applying the primer varnish, the whole surface had to be thoroughly vacuumed from dust and impurities (Figure 3).

The floor was varnished with a water-based system which, thanks to its fast drying, made it possible to shorten the service time. The basecoat consisted of alcohol, thus preventing the possibility of discoloration on the surface of the timber, which could appear only after the application of topcoat. In the case of expensive jobs, as in the example of the palace floor implementation, the use of ordinary base coat varnish would be a risky solution as discolorations could occur. The next layer was a two-component varnish giving the floor greater strength and abrasion resistance. The use of matt tones allowed to obtain a natural character of the floor and emphasis on the variety of the wood species.

The varnish was applied in three layers with an inter-layer gel between them, in order to achieve the greatest adhesion of individual layers of varnish. After finishing the painting and drying of all the layers of varnish, the con-



Figure 3: a) Decor on a parquet joining b) Vacuuming the grinded surface c) The painting



Figure 4: The final effect of surface of the wooden palace floor

tractor made additional floor care using a matte preservative to prolong the life of the floor without the necessary regeneration (Figure 4).

5 Conclusions

The restoration of the antique mosaic is significantly different from the implementation of the palace mosaic (tile) from bottom-up. The historic mosaic is a material that has existed for a long time and has experienced many years of use. All repair works require a lot of effort and awareness of unforeseeable situations arising from the age of the material being repaired and its condition. In the case of the restored floor, after assessing the actual condition of the subfloor, the investor decided to replace it due to the significant damage to the primary subfloor. This process aimed to ensure relatively low costs with a relatively short time of executing a new subfloor and a minimum load on the old slab. During the restoration of the palace mosaic, all additional and new products required the arrangement of the panels to the basic elements and the milling of new elements in order to adjust the elements to a tongue-groove joint. Only after all the machining operations ended, the

mosaic could be re-applied. Despite a large commitment to the work, it was not possible to systematize all the dimensions of individual panels.

Making the palace mosaic from scratch is also a labour-intensive activity, but it is burdened with a much smaller number of unforeseen situations that appear in the machining process. The execution of the new floor required the contractor to interfere in the ground and after its assessment a significant exceeding of the permissible humidity in the screed was found. The execution and assembly of both mosaics took place in an analogous way to the previously prepared subfloors glued with adhesive. In the case of a restored floor, it is a resin-synthetic adhesive and with a floor made from scratch – a polyurethane adhesive. Finishing the surface in both cases is based on water-based varnishes, including the use of chemically curing topcoats with increased abrasion resistance. The only difference is the use of a primer system, which in the case of an antique renovated floor contains stains and primer enhancing the color of wood and in the wooden floor made from scratch, undercoat alcoholic varnish for exotic wood was used.

Both examples were characterized by high aesthetic requirements caused by the decorative function of palaces. The possibility of restoring the historic palace floor compared to making it from scratch is a more advantageous option, because of smaller material consumption and preservation of the original floor elements. The comparison of technologies has shown that despite the same type of floor, work related to the renovation and construction of a new surface requires the use of a different organization and implementation processes. It depends on many factors: requirements and expectations of investors, working conditions, characteristics of the building object, its structure and elements, experience of people performing works, unforeseen situations during works and further use of the building, construction and environmental requirements.

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