COMPARATIVE STUDY ON THE PHYSICO-MECHANICAL CHARACTERISTICS FOR FIVE TYPES OF WOOD FLOORING

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ABSTRACT

During the period 1600-1700, the first works with parquet elements at Versailles Palace were performed, but the high cost has made that the wooden floor to be an exclusivist product for a long time. Currently, in the last 30 years, the most innovations in flooring industry were aimed to improve the technological process, the easing of work, to reduce the losses of raw materials and to reduce the production costs. The experimental research conducted worldwide has shown that the wood processing technology, up to the flooring finite element, plays an important role in achieving a superior quality and durability and that the finishing systems have to be applied depending on the conditions of the area of use. This paper is a comparative study regarding the physico-mechanical characteristics for five types of wood flooring manufactured and marketed in Romania. In the experimental research, there were analyzed: the behavior of the floor assemblies under linearly distributed and concentrated loads, the thermal insulation characteristics and the slip resistance. The experimental results have shown that these characteristics are influenced by the wood species, the type of product (massive one or subjected to stratification technological processing), the thickness of lamellar flooring elements, and the chosen finishing method (varnishing, oiling).

Keywords: wood, parquet; mechanical strengths; thermal conductivity; slip resistance

REZUMAT

În perioada anilor 1600-1700 au fost efectuate primele lucrări cu elemente de parchet din lemn la Palatul Versailles; costul ridicat a făcut însă ca pardoseala din lemn să fie mult timp un produs exclusivist. În prezent, în ultimii 30 de ani, majoritatea inovaţiilor din industria parchetului au avut drept obiectiv îmbunătățirea procesului tehnologic, uşurarea muncii, reducerea pierderilor de materie primă şi reducerea costurilor de producție. Cercetările experimentale desfăşurate la nivel mondial au arătat că tehnologia de prelucrare a lemnului până la elementul finit de parchet are un rol important în obținerea unei calități şi durabilități superioare, iar sistemele de finisare trebuie să fie aplicate în funcție de condițiile din zona de utilizare. Lucrarea este un studiu comparativ privind caracteristicile fizico-mecanice pentru cinci tipuri de parchet de lemn fabricat şi comercializat in România. În cadrul cercetărilor experimentale au fost analizate: comportarea ansamblelor de parchet la solicitări distribuite şi concentrate, caracteristicile de izolare termică şi rezistența la alunecare. Rezultatele experimentale au arătat faptul că aceste caracteristici sunt influențate de: specia lemnoasă, tipul produsului (masiv sau supus prelucrărilor tehnologice de stratificare), grosimea elementelor de parchet lamelar, precum şi de metoda de finisaj aleasă (lăcuire, uleiere).

Cuvinte cheie: lemn; parchet; rezistente mecanice; conductivitate termica; rezistenta la alunecare

1. INTRODUCTION

Over the time, there was a conflict between the concept of parquet as an art and the concept of parquet as a functional interior finishing material. During the years 1600-1700 the first works with parquet elements were performed. The floors finishing at Versailles Palace shaped, at that time, a real revolution in the field. For a long time, the high cost of the wooden floors made them an exclusive product. At present, due to the technological progress, this finishing material has become one of the most elegant and largely used materials, which can compete with similar products in terms of price/quality. Starting with the 1980-1990 period, the parquet has become very popular in hot floor finishes in Europe [1, 4, 13]. Beauregard [2] indicated that, from all flooring materials in West Europe, in 1996, the parquet represented 4.6%.

Due to the technical properties, the floors made of wood elements, laminated or not, the so-called warm floors, gained more ground in New Zealand too, in comparison with other types of floor finishing material (Vinyl ceramic tile etc.) [9, 14]. During the last 30 years, most innovations in the flooring industry were aimed to improve the technological process, which led to an easier work, to reduce the losses of raw material, to reduce the production costs, to make it more accessible to the users [8, 13, 15].

There is a tradition in Romania in woodworking, due to the rich forest resource; the area covered by forests in the early 2000 was about 26% of the total area of the country [17]. The mainly wood species that are in our country are the beech, about 30%, resinous 30% and oak 19.2% of the total forest fund. In the recent years, there was an increase of the timber harvested volume: coniferous species 43%, beech 28% and oak 9% [17].

In 1938, Romania exported wood products amounting to 2,465 million lei [16].

A representative example of a country that has grown strongly in the flooring industry is Turkey, where are known and marketed 33 types of parquet and hardwood floors and four types of multilayer [5, 6, 10]. The most used species grown in order to exploit flooring industry are oak 50 %, beech 21.4 % and red pine 21.4 %, percentage values from all species used in the flooring manufacture [7]. During 2001 - 2006, the solid wood flooring averaged to about 2,000,000 m^2 per year. The more frequent floor thickness is 16 mm, in an amount of 60.7% of the total annual production of Turkey [5, 6, 10 18, 19].

The experimental research conducted worldwide has shown that finishing systems should be applied depending on their area of use (temperature, humidity or industrial environment, traffic intensity) [11, 12]. The experimental results have shown that the wood processing technology, up to the finite parquet element, plays an important role in getting a superior quality and durability. For example, adding aluminum oxide powder in the finishing material (lacquer) increases the durability and the abrasion resistance of the flooring [1, 3].

According to EN 14342:2013, for products or elements and hardwood flooring for indoor use, including enclosed spaces for public transport, the following performance characteristics are imposed: reaction to fire, formaldehyde content, pentachlorophenol emission, tensile strength, slip resistance, thermal conductivity and biological sustainability.

In this paper, comparative results for five types of flooring are presented and analyzed. Comparative tests were performed at INCD URBAN-INCERC, Cluj-Napoca Branch, regarding the tensile strength, the slip resistance and the thermal conductivity.

2. MATHERIAL AND WORKING METHOD

Five types of oak and walnut lamellar parquet, manufactured and marketed in Romania, with untreated surface and treated by oiling or varnishing, UV resistant products, respectively, were used for the tests, as shown in Table 1.

Table 1. *Types and sized of used lamellar parquet*

Material	L x l (mm)	Thickness (mm)
solid oak	700 x 125	20
baking oak	700 x 180	15
stratified oak	700 x 180	15
solid walnut	700 x 125	20
stratified walnut	700 x 150	18

2.1. Determination of flexural properties

The tests were performed on an ensemble compound, according to SR EN 1533, consisting of several elements joined together according to manufacturer's instructions. They were assembled as in Figure 1, with an element on each side and two elements in the middle.

Figure 1. Assembly floor conducted to test [21]

2.1.1. Linear static load

Bending stiffness per meter and bending load capacity per meter were determined by applying a linear static load at the center of the assembly. The bending stiffness was calculated from the deflection under load.

The linear static load was applied using a steel hammer, which had a rounded contact area with a radius of 15 ± 0.05 mm and whose length exceeded the width of the load assembly (Fig. 2).

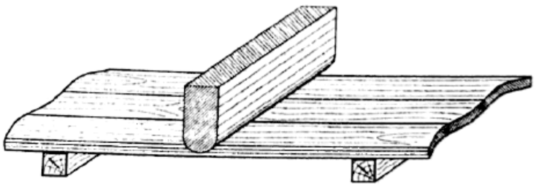

Figure 2. Schematic representation of the linear static load test [21]

To determine the average value of the maximum load, the load was applied with uniform speed until the failure. The speed was chosen so that the failure occurs in 300±120 seconds.

The following values were recorded: F_1 - the load at about 10% of the maximum load and F_4, at about 40% of the maximum load, respectively the corresponding deflections a_1 and a_4 and F_{max} - the maximum load at failure.

2.1.2. Concentrated static load

The bending stiffness and the maximum load of the assembly were determined by application of a static concentrated load at the most vulnerable point of the assembly. Figure 3 shows, schematically, the static diagram of the parquet assembly.

The concentrated static load was applied using a steel cylindrical head with a diameter of 25 ± 0.1 mm and a radius of 2 mm, with rounded edges on the contact with the surface. The steel barrel axis was perpendicular on the loaded assembly.

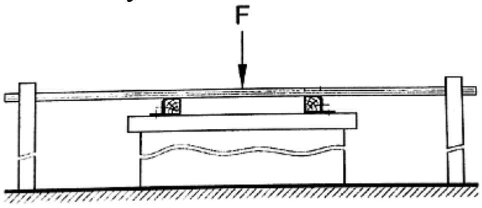

Figure 3. Schematic representation of concentrated static load [21]

The most vulnerable point of the assembly was determined experimentally, using a speed of 10 ± 5 mm/min for the load application point.

To determine the estimated average maximum load $F_{max,est}$, and the time at which this is obtained, an increasing load was applied, with uniform speed, up to failure. The speed was chosen so that the failure occurs in 300 ± 120 seconds.

For the determination of bending stiffness under concentrated static load, the load application procedure was as follows (Fig. 4 a):

– increase the value of F ($F_{max.est}$), to 0.1 (point 01) of the load / time chart and load / deflection, then to 0.4 (point 04), and keep the load constant.
– decrease from 0.4 to 0.1.
– maintain the load
– increase again to 0.1 (point 21) to 0.4 (point 24)
- decrease from 0.4 to 0.

The deflection from support was measured at times 01, 04, 21, 24, being plotted on the diagram in Figure 4 b.

The deflection, at the weakest point of the loaded assembly at 0.4 $F_{max,est}$ was the average of the two loads applied and previously defined:

$$W_m = \frac{4}{3} x \frac{(w_{04} - w_{01}) + (w_{24} - w_{21})}{2} \qquad (1)$$

where: w_{01}, w_{04}, w_{21} and w_{24} are the deflections, expressed in mm, measured at the 01, 04, 21, 24 time moments.

The bending stiffness of the weakest point of each loaded assembly was obtained by a second application of the load.

$$R = \frac{F_{24} - F_{21}}{w_{24} - w_{21}} \quad (2)$$

where: F_{21} and F_{24} are the loads applied at the 21 and 24 moments, expressed in N.

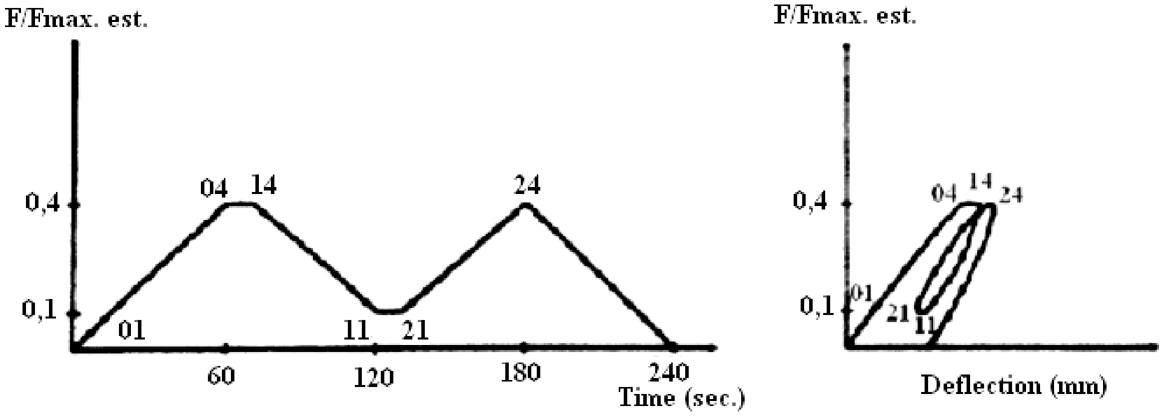

Figure 4. Schematic representation of the way the load was applied [22]

2.2. Thermal Conductivity

It was determined the heat transfer property of the samples with a thermofluxmetric method for an average temperature between plates, of 10°C. The sample, dried in an oven up to a constant mass, was placed in the apparatus for determining the thermal conductivity. The sample thickness was measured automatically by the apparatus. The thermal conductivity of the specimen was recorded. Then, for each type of parquet, the thermal resistance was calculated, using Equation 3:

$$R = \frac{t}{\lambda}(m^2K/W) \quad (3)$$

where: t = thickness of the product (m) and λ = thermal conductivity (W/mK).

2.3. Slip Resistance

The tests were carried out to assess the resistance to slip, using the friction pendulum.

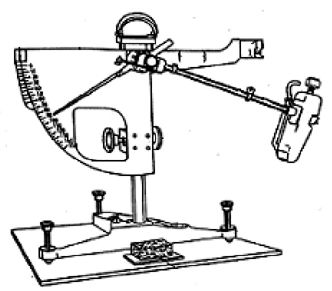

Figure 5. Equipment for friction pendulum test [23]

The equipment for friction pendulum (Fig. 5) incorporates a cursor placed on a rubber resort, attached to the end of the pendulum. At the balance of the pendulum, the friction force between the slider and the test surface is evaluated by reducing the length of the balance on a scale (USRV units).

The friction value of each specimen was calculated as the average of the two mean values measured in opposite directions.

3. RESULTS

3.1. Determination of flexural properties

3.1.1. Linear static load

It can be observed, in Figure 6, that the highest bending stiffness was obtained for the solid oak flooring assembly, while the lowest, for the laminated baking oak, the decrease being of approximately 70% in comparison with the maximum value.

Overall, the reduction of the bending stiffness can be put, on one side, on the differences in material (wood or laminated wood), on the treatment of wood and, on the other hand, on the thickness of the parquet elements.

Given that tests were carried out on commercially available parquet elements, tests could not be performed on the same floor thickness for better analysis. The thickness of solid wood is 25% higher than the thickness of baking oak parquet and laminated oak, respectively.

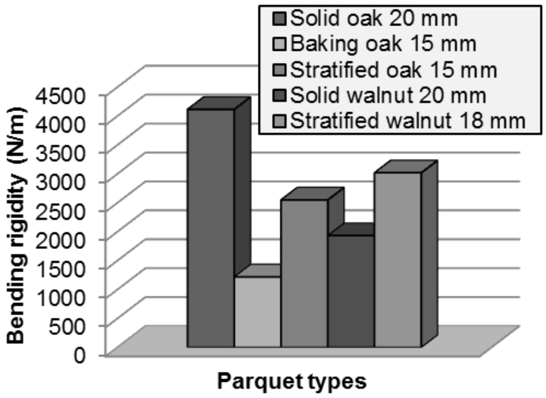

Figure 6. Variation of the bending rigidity for linear load test, as a function of wood type and thickness

By analyzing the laminated walnut flooring samples, it can be noticed that the bending stiffness increases through the process of stratification by approximately 56%, as compared to the corresponding value of walnut flooring, even if the thickness of the laminated element is 10% smaller.

On the other hand, the stiffness of the assembly of solid oak is with about 113% higher than of the corresponding solid walnut assembly, in both cases the thickness of the elements being the same.

From Figure 7 it can be observed that the highest bending capacity was obtained for the oak parquet assembly; this was with about 69% higher than the flexural capacity of the walnut parquet assembly, for the same thickness of the elements.

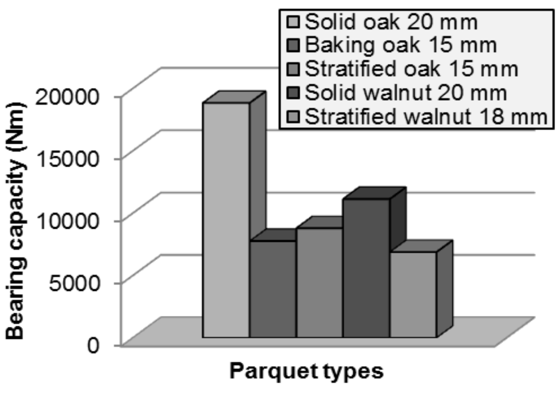

Figure 7. Variation of bearing capacity in linear load test, as a function of wood type and thickness

Due to the reduction of element thicknesses, either in oak or in walnut, there was a decrease of flexural capacity of about 53% for laminated oak, of 59% for baking oak and of about 38% for laminated walnut, as compared to the maximum value.

3.1.2. Concentrated static load

By analyzing the behavior of the assemblies of the five types of flooring, at concentrated load in the weakest point (Figures 8 and 9), it can be noticed that:

- for the same thickness of the flooring elements (20 mm), the deflection for the solid oak assembly is approximately 61% higher than that of the walnut elements. In addition, it was observed that the deflection of the baking oak is approximately equal to that of the laminated oak assembly (with a difference of about 5%);

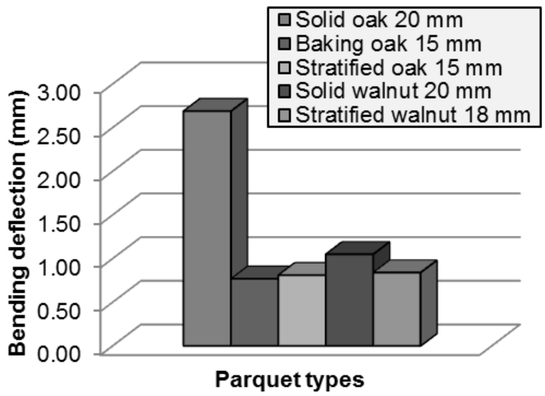

Figure 8. Variation of bending deflection at the weakest point of the loaded assembly depending on the type of wood used

- by wood treatment and for the layering material, the deflection decreases with about 71% for baking oak flooring and with about 70% for the stratified oak flooring, as compared with the solid oak flooring. For walnut flooring, the layered material determines a 20 % decrease in the bending deflection for laminated parquet, in comparison with the walnut hardwood flooring;
- in terms of bending stiffness under concentrated static load, as expected given the previous results, the assembly of laminated oak parquet showed the highest value, which

was approximately 104% higher than that for the assembly of mature hardwood, at the same thickness (15 mm);
- in the case of solid wood elements, for equal thicknesses it can be observed that the bending stiffness under concentrated static load is approximately 50% less in the case of the oak assembly, in comparison with the walnut flooring.

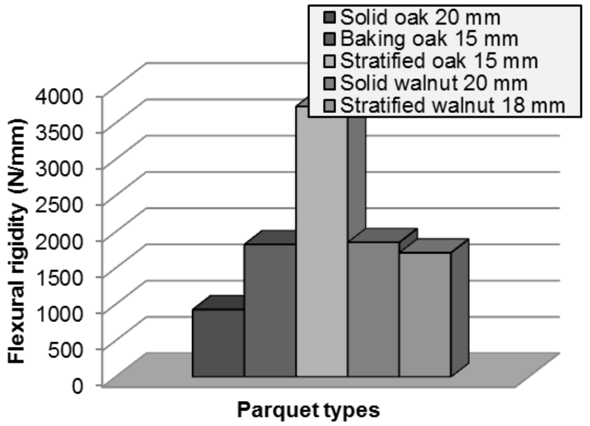

Figure 9. Variation of flexural rigidity in the weakest point of the tried assembly, as a function of wood type, for the concentrated static load test

3.2. Thermal conductivity

Regarding the thermal conductivity (Fig. 10), it was found that wood treatment and stratification reduced the coefficient of thermal conductivity, thus contributing to the efficiency level of thermal insulation. It can be seen that the stratified oak flooring shows the lowest thermal conductivity value. The thermal conductivity of baking oak and of layered oak are relatively equal, which determines, for equal element thicknesses, a relatively equal thermal resistance (Fig. 11).

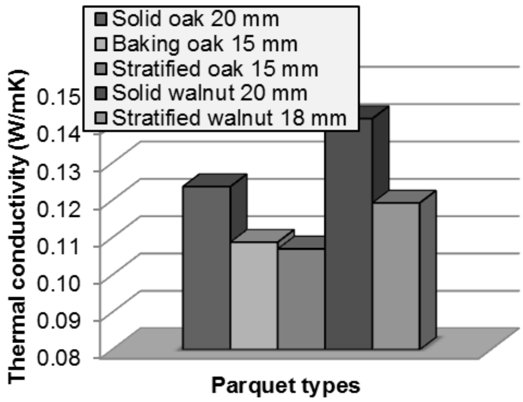

Figure 10. Variation of thermal conductivity floors depending on the type of used wood

Based on the analysis results (Figs. 10 and 11) it was found that the solid oak flooring provide a better resistance than the solid walnut and the stratified oak parquet is more effective, in terms of thermal insulation from the solid oak.

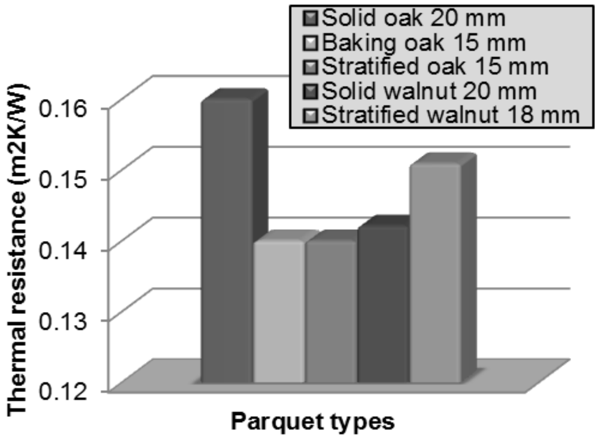

Figure 11. Variation of thermal resistance of flooring depending on the type of used wood and the thickness of the element

3.3. Slip resistance

It can be observed (Fig. 12) that the slip resistance is strongly influenced by the surface treatment method. Thus, in the case of laminated or solid oak flooring, varnishing caused an increase of slip with of about 31%, while oiling caused an increase of slip of approximately 13%, as compared to the untreated oak parquet surface. Walnut parquet varnishing caused an increase of about 38% and oiling an increase of about 26% of slip, toward the surface of untreated walnut flooring.

Oiled oak flooring has a lower level of slip toward the walnut hardwood flooring, similarly treated. In the case of untreated surface, it showed that the oak surface has a higher sliding than walnut wood.

Table 2 shows how to interpret the slip resistance determined with the friction pendulum according to AS/NZS 4663:2004. It can be concluded that: the painted floor belongs to class Y, that shows a high risk of slipping, the oiled flooring belongs to class X, that shows a moderate risk of slipping and the unfinished flooring belongs to the class W, that shows a low risk of slipping. None of these types of flooring, on which the tests were made, were classified as Class V, which means very low risk of slipping, and neither in class Z corresponding to a high risk of slipping.

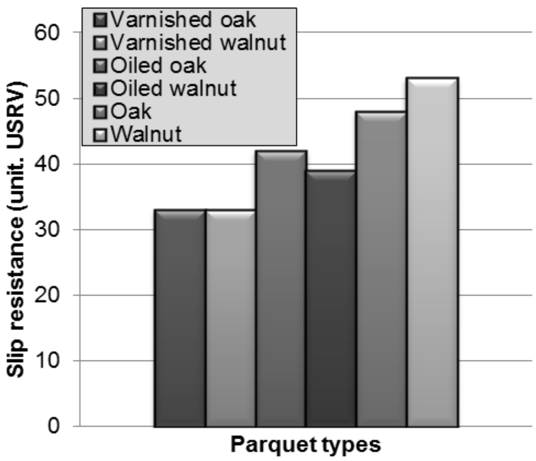

Figure 12. Variation of slip resistance of parquet as a function of wood type

Table 2. *The interpretation of sliding resistance determined with friction pendulum according to AS / NZS 4663:2004 [24]*

Class	URSV	Risk of slipping
V	>54	Very low
W	45-54	Low
X	35-44	Moderate
Y	25-33	High
Z	<25	Very high

4. CONCLUSIONS

Based on the studied literature and on the experimental results, it was concluded that:

- Warm wood floors are a convenient alternative in terms of durability, thermal efficiency, aesthetics, elegance and price/quality ratio;
- Currently, there is a growing trend to use these materials instead of using other low cost coating materials such as vinyl tiles etc.;
- The behavior of parquet element assemblies to linear or concentrated loads is influenced by wood type, material type (solid or subjected to technological processing stratification), lamellar flooring element thickness and finishing method (varnishing, oiling);
- The reduction of the heat transfer through the floor is also influenced by the characteristics of the chosen material. It was found that the solid oak flooring provides a better resistance than the solid walnut and that the stratified oak parquet is more efficient in terms of thermal insulation, as compared to the solid oak;
- The slip resistance is influenced by the material used for the manufacturing of lamellar flooring elements, by the finishing method and by product finishing. The selection should be done according to the location and environmental conditions, where the product will be used (temperature, humidity) as well as according to the intensity of traffic to which it will be submitted.

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