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Properties of Particle Boards Laminated with Different Grammage Decor Papers

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In order for the decorative papers to be used in the surface lamination process of particle boards to meet the expected performance characteristics, they must be impregnated with specially prepared synthetic resins, especially against surface abrasion and moisture. Depending on the effects that laminated process, the bulk strength and surface physical resistance against wear are important to determine the quality of the products.

A positive relationship was found between laminated decor paper grammage and bending strengths (MOR) of samples. The control sample has a bending strength value of $\bar{X}0$: 9.47 followed by $\bar{X}80$: 10.92, $\bar{X}90$: 11.01 and $\bar{X}110$: 13.14 for 80 gr/m2-, 90 gr/m2-, and 110 gr/m2 decor paper laminated samples, respectively. It could be suggested that the lamination of decorative papers improve bending strength of boards regardless of conditions. However, only marginally different internal bond (IB) strength properties were measured for those three grammage paper laminated samples

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(X̄0: 0.38 N/mm^2, X̄80: 0.37 N/mm^2, X̄90: 0.38 N/mm^2 and X̄110: 0.36 N/mm^2). Moreover, more complicated results were found for surface strengths, with a decreasing trend for samples that laminated both 90 gr/m2 and 110 gr/m2 decor papers, while an increasing trend was found with 80 gr/m^2 laminated samples. In contrast to surface strength and IB properties, an increasing surface abrasion resistance found with decor paper grammage while the highest initial surface abrasion resistance was found with 110 gr/m^2 grammage decor paper laminated samples (X̄110: 373). It is also important to note that all samples were found to be Class 4 in terms of surface scratch resistance, regardless of lamination process or type of laminated decor paper grammage.

Keywords: Decor paper; particle board; lamination; resing impregnation; surface properties.

1. INTRODUCTION

In recent years, rapid population growth and increasing urbanization have led to an increased interest in wooded materials. Due to the intensive use, increasing pressure has been placed on natural forests to meet wood demand. It has reported by many researchers that if the wood demand continues to increase at this rate, it will be difficult to meet the need for wood as raw material from natural forest resources in the future [1-4]. Regarding this issue, numerous type and kinds of bio-based engineering products have been developed and put into market [5-7]. However, wood-composites have gain increasing interest which is considered to be on high-value-added engineered materials from once unusable or considered low value wooden materials. Those engineering design wood-composites have began to be produced in different forms, sizes and usage purposes depending on customer needs over time [5,8].

As a result of technological developments and costumer preferences, wood-composites have begun to be covered with different types of surface coating materials (foil, plastic, paper, etc.), in order to meet expected properties such as; aesthetic appearance, heat resistance, sound acoustics, moisture resistance and fire resistance [9,8]. Those are produced not only for interior applications, but also outdoor atmospheric conditions. However, type of surface treatments (i.e., painting, lamination, plastic coating, etc.) on wood composites impact on performance properties [10].

Due to the numerous advantages and positive situations briefly mentioned here, the need for wood-based composite materials is constantly increasing. In parallel with this situation, more aesthetically pleasing but highly durable surface decorative products have been in high demand [9,11,8]. However, the use of decorative α-cellulose papers impregnated with synthetic resin by gluing them to wood-based board surfaces (lamination process) has become a very widely applied method [8].

Nemli et al. [11] investigated the effects of material type on board properties by covering particle board surfaces with different materials. They explained that statistically, there were differences in the mechanical properties of the boards which laminated with decorative papers according to the continuous pressing technique, but there was no statistical effect on the Internal bond strength. İstek and Özsoylu [12] concluded that as the hot-press used during decorative paper lamination on the surfaces of fibreboard, the Internal Bond Strength (IB) was not correlated with press time while Bending Strength (MOR) and Modulus of Elasticity (MOE) were generally increase with increasing temperature. Nazerian [13] explains the effect of coating the surfaces of particle boards produced from agricultural sources with the lamination technique on the mechanical resistance and physical properties of the board using three variable parameters: the rice straw/poplar wood ratio, the type of wood used in the coating, and the amount of urea-formaldehyde glue used, which were investigated with the Response Surface Methodology (RSM) method. The selected variables provide a close correlation with the properties of the boards, the use of up to 30% rice straw in the board structure does not cause a significant decrease in bending strength (MOR), the internal bond strength (IB), thickness swelling (TS), They stated that the boards to which beech wood veneers were glued using wood provided the highest MOR and lowest TS properties.

The impregnation technique and prepared formulations directly impact on the preformance of the laminated products [14,15] studied on particle board surfaces with laminated decorative papers. However, during laminations, applied pressing parameters such as; temperature and time were negative effect on the internal bond strength, cause a decrease in the general strength properties. It was explained that after lamination of particle board surfaces with decor paper, the mechanical strength properties of the boards increase while the thickness swelling, electrical conductivity and formaldehyde emission properties decrease [11].

There have been numerous studies in the literature regarding decorative paper on wood composites. However, there is limited information on decor papers which is same kind (α-cellulose) but in different grammages, impact on particle board properties. In our study, the decorative papers prepared standard impregnation technique to produce three different grammage (80 g/mm^2, 90 g/mm^2, and 110 g/mm^2), and applied on same type particle boards to determine selected mechanical strength and surface resistance properties.

2. MATERIALS AND METHODS

The decorative papers were supplied from a commercially operated paper company, located in Germany. The decor papers were used as received. Those papers were undergo standard synthetic resin impregnation process, raw papers immersed first in 55% urea-formaldhyde resin bath, followed second in 50-53% melamine-formaldehyde resin bath, then dried at 140-160 ºC to established a total 110 gr/m^2 resin weight applied on decor papers which is ready to glued to standard raw particle boards.

These three different grammage prepared and impregnated decorative papers were glued to standard medium density particle boards, were obtained from a particle board plant, Turkiye. The decorative paper laminated panels obtained at the end of these processes were tested according to TS EN 14323 and related standards, which are surface quality features such as surface abrasion, surface scratch tests [16,17].

A total of 600 samples (ten samples for each condition in each decor paper grammage) were prepared. After reaching full strength at ambient temperature, the samples were conditioned at 20ºC and 25% relative humidity and samples were cut to determine the IB (Internal bond), MOR (Modulus of Rupture), in accordance with TS EN 310 (1999) and TS EN 319 (1999), respectively [18-20,21-22].

3. RESULTS AND DISCUSSION

In Table 1, the bending strengths (MOR) values of samples laminated with three different grammage decor papers are shown in comparison with the control (uncoated samples). As expected, the bending strength properties of the samples whose surfaces were laminated with decor papers were generally found to be higher than the control samples ($\bar{X}_0$: 9.47 N/mm^2). It was found to be in ranged from 8.15 N/mm^2 to 10.56 N/mm^2 for 80 gr/m^2 ($\bar{X}_{80}$: 10.92 N/mm^2), ranged from 9.19 N/mm^2 to 13.86 N/mm^2 for 90 gr/m^2 ($\bar{X}_{90}$: 11.01 N/mm^2), and ranged from 9.09 N/mm^2 to 14.90 N/mm^2 for 110 g/m^2 ($\bar{X}_{110}$: 13.14 N/mm^2), decor paper laminated samples, respectively. It is important to note that the higher grammage decor papers laminated samples show wider ranges of bending resistance values than the lower grammage decor paper laminated samples. However, three different homogeneous groups (a,b,c) were found for the bending strength properties of laminated samples.

However, the average bending strengths are calculated to be 15.31% for 80 gr/m^2, 16.26% for 90 gr/m^2 and 38.75% for 110 gr/m^2 higher bending strength properties than control sample. It is a predictable situation for the lamination process that additional surface layer on raw boards in same properties (density and size) with decor papers increases the bending strength property of the boards. In addition, it is expected that the increase in the grammage of the decor paper will have a further positive effect on the bending resistance properties of the speciemens.

Fig. 1 shows the Internal Bond (IB) strength properties of samples. The average IB strength value were found to be $\bar{X}_0$: 0.38 N/mm^2, $\bar{X}_{80}$: 0.37 N/mm^2, $\bar{X}_{90}$: 0.38 N/mm^2 and $\bar{X}_{110}$: 0.36 N/mm^2, respectively. In contrast to bending strength, there is no statistically different group was found for IB strength properties of samples. When the IB data is carefully analyzed, it could be suggested that there is no relationship between the grammage of laminated decor paper and IB properties of samples, regardless of treatment conditions.

In general, in wood-based composite materials, such as particle boards, the IB strength properties of the matrix structure are evaluated differently than the surface properties while various results can be obtained. It was suggested that the hot press temperature could be impact on strength properties of fiberboards (MDF) [12]. Since the decor paper lamination on particle boards is a surface process with using high temperature (> 100 ^{0}C), those could be impact on internal adhesion in matrix. However, decor paper lamination is a surface modification technique which is not expect to support IB bond rather than bending strength. The data given in Table 1 and Fig. 1 support those suggestions.

In order to be evaluated bending and IB strength properties together at the similar treatment conditions, the calculated MOR and IB values were plotted and given in Fig. 2. It could be seen that bending strength appeared to positively correlated with decor paper grammage while it properties appeared to be more smooth shape with decor paper grammage which indicates poor or no correlation.

Table 1. The bending strength (MOR) (N/mm^2) properties of samples

		Different Grammage Decor Paper Laminated Samples		
Samples	**Control**	**80 gr/m^2**	**90 gr/m^2**	**110 gr/m^2**
1	9.09^a	10.43^b	10.22^b	13.86^c
2	10.55^a	10.27^b	9.06^b	13.16^c
3	10.11^a	10.59^b	9.59^b	13.10^c
4	9.23^a	12.94^b	9.40^b	10.83^c
5	9.14^a	11.05^b	14.46^b	16.83^c
6	10.55^a	9.72^b	12.90^b	14.06^c
7	9.83^a	10.67^b	10.89^b	13.64^c
8	10.86^a	11.36^b	10.49^b	14.53^c
9	9.18^a	9.94^b	11.27^b	11.47^c
10	8.81^a	9.62^b	11.70^b	11.70^c
11	9.62^a	11.32^b	10.22^b	13.86^c
12	8.92^a	11.03^b	9.06^b	13.16^c
13	8.15^a	12.43^b	9.59^b	13.10^c
14	9.27^a	10.03^b	9.40^b	10.83^c
15	10.44^a	9.19^b	14.46^b	16.83^c
16	8.29^a	9.94^b	14.90^b	14.06^c
17	9.38^a	11.62^b	10.39^b	10.17^c
18	9.57^a	11.31^b	10.53^b	13.70^c
19	9.33^a	13.86^b	10.73^b	12.30^c
20	9.02^a	10.99^b	10.98^b	11.70^c
$\bar{X}$	**9.47 (0.73)**	**10.92 (1.16)**	**11.01 (1.81)**	**13.14 (1.77)**

**Symbols with superscript (a,b,c) indicate whether there is a statistical difference between samples at the P≤0.05 confidence level*

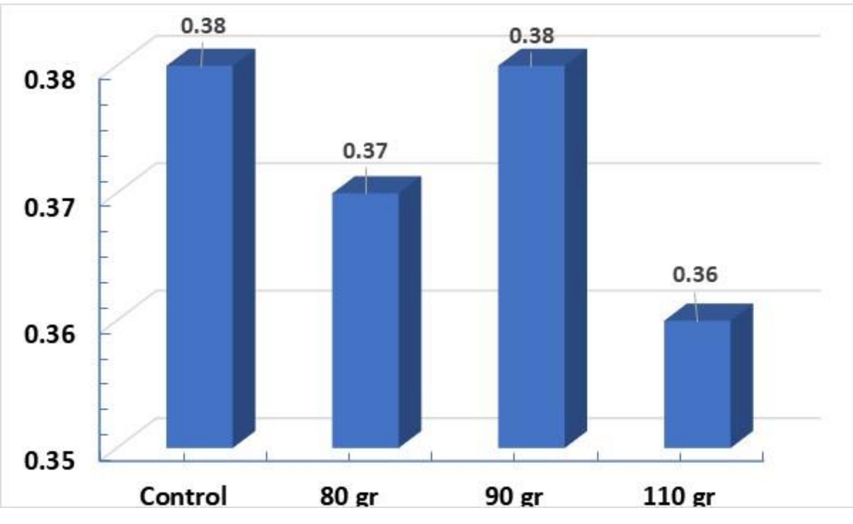

Fig. 1. The Internal Bond (IB) (N/mm^2) properties of samples

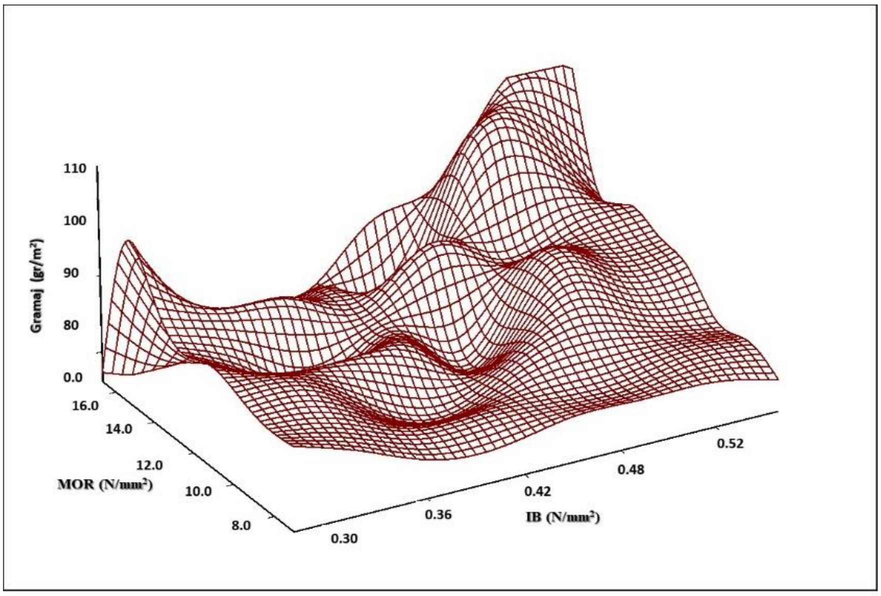

Fig. 2. Bending and IB strength properties of the samples depending on the decor paper grammage

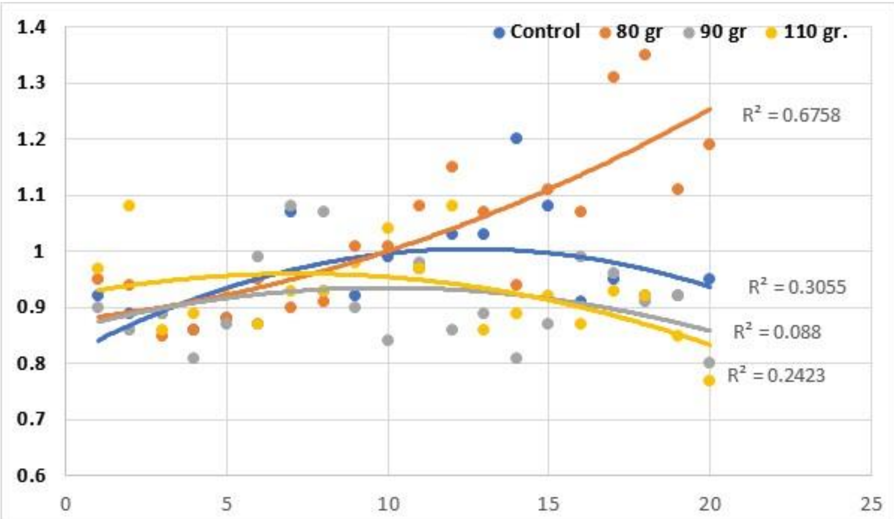

Fig. 3. Surface strength (N/mm²) properties of the samples

The surface strength properties of the samples are given comparatively in Fig. 3. Compare to the bending (MOR) and internal bond (IB) strength properties, quite different results were obtained for the surface strengths. It was found to be in range of 0.86 N/mm² and 1.20 N/mm² for control ($\bar{X}_0$: 0.96 N/mm²), in range of 0.85 N/mm² to 1.35 N/mm² for 80 gr/m² laminated samples, ($\bar{X}_{80}$: 1.03 N/mm²), in range of 0.80 N/mm² to 1.08 N/mm² for 90 gr/m² laminated samples ($\bar{X}_{90}$: 0.91 N/mm²), and in range of 0.77 N/mm² to 1.09 N/mm² for 110 gr/m² laminated samples ($\bar{X}_{110}$: 0.93 N/mm²), respectively. Here, the highest surface average strength was observed in the boards laminated with 80 gr/m² decor paper while the lowest average surface strentgh was observed in the samples laminated with 90 gr/m² decor paper.

It is appeared to a decrease trend for samples which laminated both 90 gr/m² and 110 gr/m² decor papers while increasing trend found with 80 gr/m² samples. Those could be explained that chip sizes in the structure of particle boards and the usage rates of chips of different sizes on the outer and inner parts are important parameters that affect the properties of the boards [13]. Particularly, chip sizes used in surface layers are closely related to surface strength. However, the delicate sanding process applied immediately after boards manufacturing and the subsequent decor paper lamination process (application of additional heat for adhesion) may have a negative effect on the surface durability. The data found in this study partially support those assumptions.

It is also important to note that the surface strength values of 80 gr/m^2 decor paper laminated samples statistically difference at P ≤0.05 confidence level (one homogen group) while the control, 90 gr/m^2 and 110 gr/m^2 laminated samples have in another homogen group.

Fig. 4 shows the effect of different grammage of decor papers on the surface strength and internal bond (IB) properties of the samples. When the shape of the graph is examined, a trend/relationship between decor paper grammage with surface strength resistance and IB strength cannot be clearly observed. In general, it has been understood that increasing the grammage of the overlay paper has a negative effect on the surface strength value to a certain degree under the same conditions while there is no considerable change in the IB of the samples. From this point of view, it is important that the decor paper grammage has a limited effect on both surface strength and IB strength but independent from bending strength.

The surface abrasion/wear resistance of samples are shown in Table 2. It can be seen that 80 gr/m^2 decor paper laminated samples showed initial abrasion resistance (IP) between 250 and 350 revaluations ($\bar{x}_{80}$: 304) and were mostly in the 3B class in terms of surface quality. However, it has been observed that the boards laminated with 90 gr/m^2 decor papers have resistance properties in range of 250 to 450 revaluations initial wear ($\bar{x}_{90}$: 310), and are mostly in the 3B class, similar to the 80 gr/m^2 conditions. It is appeared to 110 gr/m^2 laminated samples shows an initial abrasion resistance in range of 300 to 450 revaluations ($\bar{x}_{110}$: 373), which is the highest initial surface abrasion resistance than others, are mostly in class 4. There is also statistically significant differences were found in the initial abrasion of the samples at the P ≤0.05 confidence level. The 80 gr/m^2 and 90 gr/m^2 decor paper laminated samples were statistically in the same group (a) while 110 gr/m^2 laminated samples in another groups (b).

The surface scratch resistance properties of three different grammage decor paper laminated samples were determined according to TS EN 14323 standard [17]. The measured average values are presented in Fig. 5. Although the sctratch resistance values were calculated to be between 3.5 N and 5.0 N for all samples while the average values were found to be only marginally different ($\bar{X}_{80}$: 4.3 N; $\bar{X}_{90}$: 4.1 N; $\bar{X}_{110}$: 4.3 N). Hence, there is no statistically difference were found for three different grammage decor paper laminated samples. However, all samples were found to be classs 4, regardless of lamination process or type of laminated decorative paper grammage.

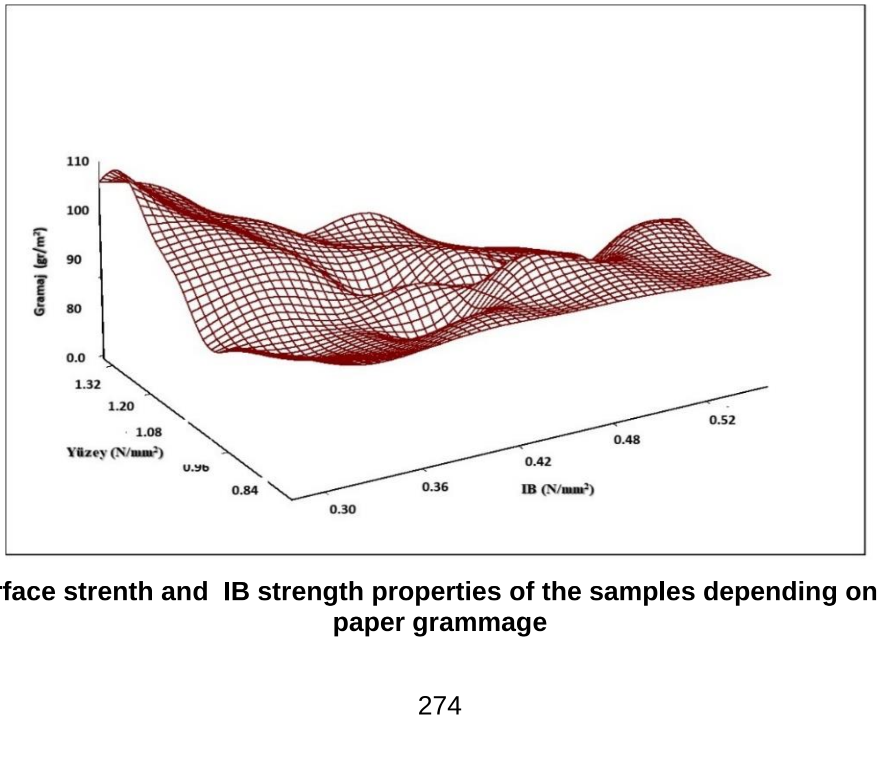

Fig. 4. Surface strenth and IB strength properties of the samples depending on the decor paper grammage

Table 2. Surface initial (IP) abrasion resistance and quality classes

Samples	80 gr/m^2		90 gr/m^2		110 gr/m^2	
	Initial Abrasion Resistance (IP)	Class	Initial Abrasion Resistance (IP)	Class	Initial Abrasion Resistance (IP))	Class
1	275[a]	3B	300[a]	3B	350[b]	4
2	350[a]	4	300[a]	3B	325[b]	3B
3	250[a]	3B	450[a]	4	375[b]	4
4	250[a]	3B	300[a]	3B	450[b]	4
5	325[a]	3B	325[a]	3B	300[b]	3B
6	300[a]	3B	300[a]	3B	400[b]	4
7	300[a]	3B	275[a]	3B	350[b]	4
8	300[a]	3B	350[a]	4	325[b]	3B
9	325[a]	3B	450[a]	4	350[b]	4
10	300[a]	3B	300[a]	3B	350[b]	4
11	300[a]	3B	250[a]	3B	350[b]	4
12	250[a]	3B	300[a]	3B	325[b]	3B
13	325[a]	3B	250[a]	3B	375[b]	4
14	300[a]	3B	300[a]	3B	400[b]	4
15	325[a]	3B	350[a]	4	375[b]	4
16	325[a]	3B	250[a]	3B	400[b]	4
17	350[a]	4	250[a]	3B	450[b]	4
18	300[a]	3B	300[a]	3B	400[b]	4
19	275[a]	3B	300[a]	3B	350[b]	4
20	350[a]	4	300[a]	3B	450[b]	4
$\bar{X}$	304 (31.7)	3B	310 (55.8)	3B	373 (43.6)	4
TS EN 14323 Standard			Class 1: IP<50 Class 2: IP≥50 Class 3A: IP≥150 Class 3B: IP≥250 Class 4: IP≥350			

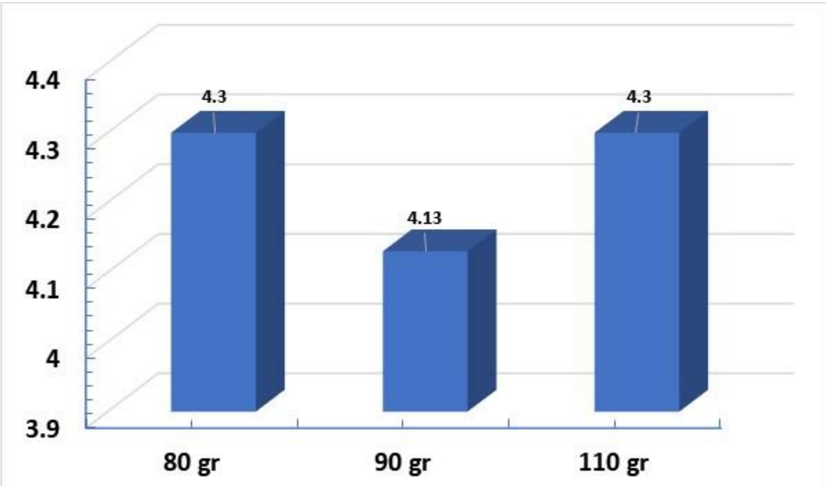

Fig. 5. Surface sctratch resistance (N) properties of the samples

4. CONCLUSIONS

Wood-based boards laminated with decorative papers must be subjected to a series of tests in order to ensure the expected performance properties from their first production to final use. These tests include many subtest groups, such as raw decor paper tests, impregnated decor paper tests, tests of chemicals formulated for the impregnation process, and surface quality and performance tests.

This study investigated the effects of the decor paper grammage on the physical properties of the laminated particleboard panels. It appears that not all of the properties of the decor papers laminated particleboards are affected by decor paper grammage. Increasing the decor paper grammage improved the bending strength and surface abrasion resistance some level while statsitically not any difference were observed for IB, surface strength and scratch resistance of the samples.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rials GT, Wolcott MP. Physical and mechanical properties of agro-based fibers, In: Paper and composites from agro based resources, Rowell RM, Young RA, Rowell JK. (Eds), CRC Press Inc, Boca Raton, Florida. 1997;63-81.
2. Youngquist JA, Krzysik AM, Chow P, Meimban R. Properties of composite panels. In: Paper and composites from Agro-based resources, R.M. Rowell, R.A. Young JK. Rowell, (Eds), CRC Press Inc, Boca Raton, Florida; 1997.
3. Carll C. Wood particleboard and flakeboard: Types, grades, and uses. US Department of Agriculture, Forest Service, Forest Products Laboratory.Madison, WI. 1986;53.
4. Ndazi B, Tesha JV, Bisanda ETN Some opportunities and challenges of producing bio-composites from non-wood residues, J. Mater Sci. 2006;41:6984–6990.
5. Maloney TM. The family of wood composite materials, Forest Products Journal. 1996;46(2):19-26.
6. McKeever DB. Engineered wood products: A response to the changing timber resource. Pacific Rim Wood Market Report. 1997;123(5):
7. Ross RJ. Forest products laboratory. Wood Handbook-Wood as an engineering material, General Technical Report FPLGTR-190, Madison, WI. 2010;508.
8. Akbulut T, Ayrılmış N. Yonga Levha Endüstrisi (Particleboard Industry), (Turkish, Abstract in English), İstanbul Universites-Cerrahpaşa (İÜC) yayınevi. Istanbul. 2024;136.
9. Nemli G, Çolakoglu G. The influence of lamination technique on the properties of particleboard. Building and Environment. 2005;40(1):83-87.
10. Muğla K. The effect of different finishing materials on the surface properties of mdf, Bartın Üniversity, (MSc thesis), (Turkish, Abstrcat in English), Graduate School of Natural and Applied Sciences, Department of Forest Products Engineering, Bartın-Turkiye. 2010;107.
11. Nemli G, Örs Y, Kalaycıoğlu H. The choosing of suitable decorative surface coating material types for interior end use applications of particleboard. Construction and building materials. 2005;19(4):307-312.
12. İstek A, Özsoylu İ. The effect of temperature and duration changes on mdf properties in lamination process. Bartın Orman Fakültesi Dergisi. 2021;23(3):899-905
13. Nazerian M. The lamination influence on properties of agro-based particleboard. Wood Material Science & Engineering. 2013;8(2):129-138.
14. Aksu S. Fact of decor paper and resin type to physical mechanic and surface quality of particleboard, (MSc thesis), Graduate School of Natural and Applied Sciences, Department of Forest Products Engineering, Bartın-Turkiye. 2019;107.

15. İstek A, Gözalan M, Özsoylu İ. The effects of surface coating and painting process on particleboard properties (Turkish, ABstrcat in English), Kastamonu University Journal of Forestry Faculty. 2017;17(4):619-629.
16. Nemli G. Sentetik Laminant Endüstrisi. (Turkish language), KTÜ Orman Fakültesi Yayınları. Ders Teksirleri Serisi No: 71, Trabzon. 2013;110 s.
17. TS EN 14323. Wood-based panels-Melamine faced boards for interior uses-Test methods, Turkish Standard Institute, Ankara, Turkiye.
18. TS EN 309. Wood particleboards-Definition and classification, Turkish Standard Institute, Ankara, Turkiye.
19. TS EN 310. Wood- Based panels-Determination of modulus of elasticity in bending and of bending strength, Turkish Standard Institute, Ankara, Turkiye.
20. TS EN 319. Particleboards and fibreboards- Determination of tensile strength perpendicular to the plane of the board, Turkish Standard Institute, Ankara, Turkiye.
21. Thébault M, Kandelbauer A, Müller U, Zikulnig-Rusch E, Lammer H. Factors influencing the processing and technological properties of laminates based on phenolic resin impregnated papers. European Journal of Wood and Wood Products. 2017;75:785-806.
22. Kawalerczyk J, Dziurka D, Majlingová A, Lieskovský M, Walkiewicz J, Mirski R. The effect of impregnation with fire retardant on the properties of particleboard bonded with PF/pMDI adhesive. Wood Material Science & Engineering. 2024;19 (2):530-40.

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