

# Properties of Particle Boards Laminated with Different Grammage Decor Papers

## 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.

An 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/m<sup>2</sup>-, 90 gr/m<sup>2</sup>-, and 110 gr/m<sup>2</sup> decor paper laminated samples, respectively. However, only marginally different internal bond (IB) strength properties were measured for those three grammage paper laminated samples ( $\bar{X}_0$ : 0.38 N/mm<sup>2</sup>,  $\bar{X}_{80}$ : 0.37 N/mm<sup>2</sup>,  $\bar{X}_{90}$ : 0.38 N/mm<sup>2</sup> and  $\bar{X}_{110}$ : 0.36 N/mm<sup>2</sup>). Moreover, more complicated results were found for surface strengths, with a decreasing trend for samples that laminated both 90 gr/m<sup>2</sup> and 110 gr/m<sup>2</sup> decor papers, while an increasing trend was found with 80 gr/m<sup>2</sup> 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<sup>2</sup> grammage decor paper laminated samples ( $\bar{X}_{110}$ : 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

## Introduction

In recent years, rapid population growth and increasing urbanization have led to an increased interest in wooded materials. Due to the intensive **utilization**, 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 **[Rials and Wolcott 1997; Youngquist et al., 1997; Call, 1986; Ndazi et al., 2006]**. Regarding this issue, numerous type and kinds of bio-based engineering products have been developed and put into market **[Maloney, 1996; McKeever 1997; Ross, 2010]**. 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 **(Maloney, 1996; Akbulut and Ayirmis 2024)**.

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 **[Nemli and Colakoglu 2005; Akbulut and Ayirmis 2024]**. 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 [**Muğla, 2010**].

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 [**Nemli, 2003; Nemli et al., 2005, Akbulut and Ayrilmis 2024**]. However, the use of decorative  $\alpha$ -cellulose papers impregnated with synthetic resin by gluing them to wood-based board surfaces (lamination process) has become a very widely applied method [**Akbulut and Ayrilmis 2024**].

Many researchers have explained that the application of **decorative paper** on wood-based composite materials has many advantages [**Aksu, 2009; Muğla, 2010**]. They even explained that, with the modern techniques developed, these products cannot be easily distinguished from solid wood veneers, that they can be produced more economically than solid wood veneers with the desired color, pattern and abrasion resistance, and that they are easy to apply to board surfaces [**Nemli, 2003; Nemli et al., 2005, Aksu, 2009; Muğla, 2010; Akbulut and Ayrilmis 2024**].

The impregnation technique and prepared formulations directly impact on the performance of the laminated products [**Aksu, 2009**]. **Istek et al. (2017)** studied on particle board surfaces with laminated decorative papers. They found that density, bending strength and modulus of elasticity increased. 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. **Nemli and Çolakoğlu (2005)** 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. **Nazerian (2013)** explains the effect of surface lamination impact on particle board properties which was prepared from mixture of rice straw/poplar wood.

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 ( $\alpha$ -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<sup>2</sup>, 90 g/mm<sup>2</sup>, and 110 g/mm<sup>2</sup>), and applied on same type particle boards to determine selected mechanical strength and surface resistance properties.

## **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-formaldehyde resin pool, followed second in 50-53% melamine-formaldehyde resin bath, then dried at 140-160 °C to established a total 110 gr/m<sup>2</sup> resin weight applied on overlay 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 overlay 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.

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 20 °C 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].

## Results and Discussions

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 always found to be higher than the control samples ( $\bar{X}_0$ : 9.47). It was found to be in ranged from 8.15 N/mm<sup>2</sup> to 10.56 N/mm<sup>2</sup> for 80 gr/m<sup>2</sup> ( $\bar{X}_{80}$ : 10.92), ranged from 9.19 N/mm<sup>2</sup> to 13.86 N/mm<sup>2</sup> for 90 gr/m<sup>2</sup> ( $\bar{X}_{90}$ : 11.01), and ranged from 9.09 N/mm<sup>2</sup> to 14.90 N/mm<sup>2</sup> for 110 g/m<sup>2</sup> ( $\bar{X}_{110}$ : 13.14), 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.

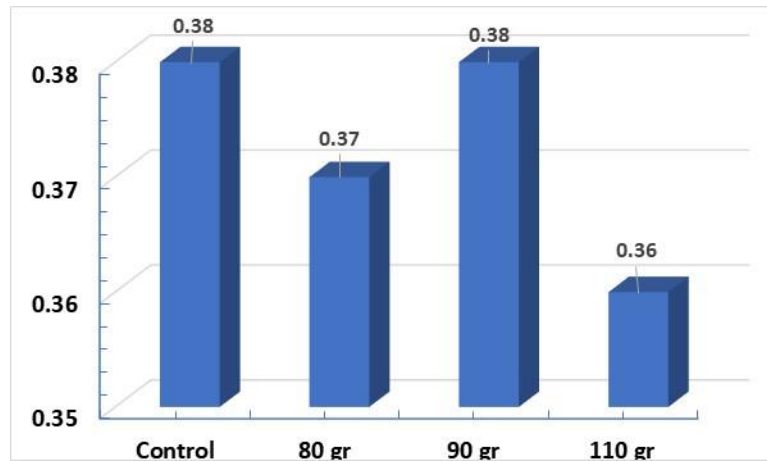
**Table 1.** The bending strength (MOR) (N/mm<sup>2</sup>) properties of samples.

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

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

However, the average bending strengths are calculated to be 15.31% for 80 gr/m<sup>2</sup>, 16.26% for 90 gr/m<sup>2</sup> and 38.75% for 110 gr/m<sup>2</sup> 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 specimens.

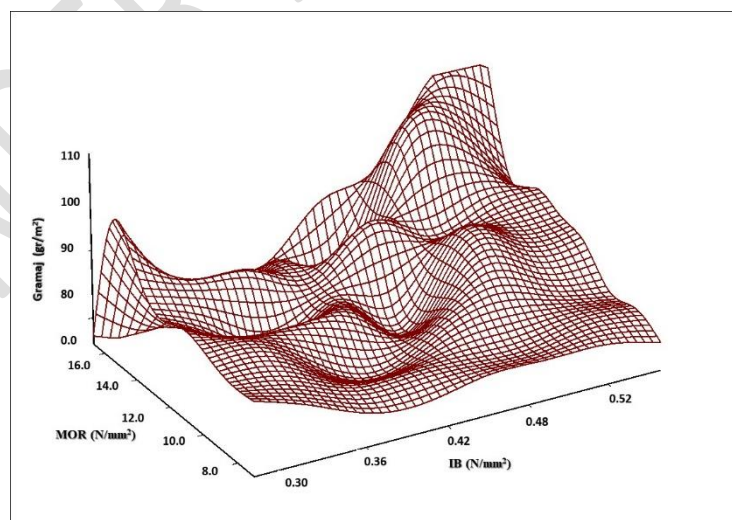
**Figure 1** shows the Internal Bond (IB) strength properties of samples. The average IB strength value were found to be  $\bar{X}_0$ : 0.38 N/mm<sup>2</sup>,  $\bar{X}_{80}$ : 0.37 N/mm<sup>2</sup>,  $\bar{X}_{90}$ : 0.38 N/mm<sup>2</sup> and  $\bar{X}_{110}$ : 0.36 N/mm<sup>2</sup>, respectively. In contrast to bending strength, there is no statistically different group was found for IB strengt properties of samples. It is important to note that 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.



**Figure 1.** The Internal Bond (IB) (N/mm<sup>2</sup>) properties of samples.

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) [İstek and Özsoylu 2021]. Since the decor paper lamination on particle boards is a surface process with using high temperature (> 100 °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 Figure 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 **Figure 2**. It could be seen that bending strength appeared to positively correlated with decor paper grammage while **IB** properties appeared to be more smooth shape with decor paper **grammagess** which indictaes poor or no correlation.

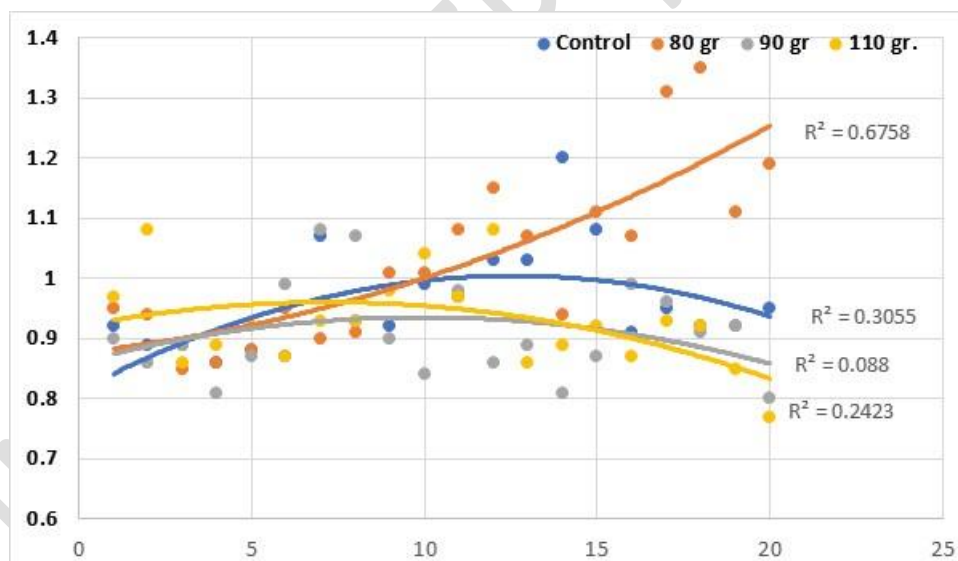


**Figure 2.** Bending and IB strength properties of the samples depending on the decor paper grammage.

The surface strength properties of the samples are given comparatively in **Figure 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/mm<sup>2</sup> and 1.20 N/mm<sup>2</sup> for control ( $\bar{X}_0$ : 0.96), in range of 0.85 N/mm<sup>2</sup> to 1.35 N/mm<sup>2</sup> for 80 gr/m<sup>2</sup> laminated samples, ( $\bar{X}_{80}$ : 1.03), in range of 0.80 N/mm<sup>2</sup> to 1.08 N/mm<sup>2</sup> for 90 gr/m<sup>2</sup> laminated samples ( $\bar{X}_{90}$ : 0.91), and in range of 0.77 N/mm<sup>2</sup> to 1.09 N/mm<sup>2</sup> for 110 gr/m<sup>2</sup> laminated samples ( $\bar{X}_{110}$ : 0.93), respectively. Here, the highest surface average strength was observed in the boards laminated with 80 gr/m<sup>2</sup> decor paper while the lowest average surface strength was observed in the samples laminated with 90 gr/m<sup>2</sup> decor paper.

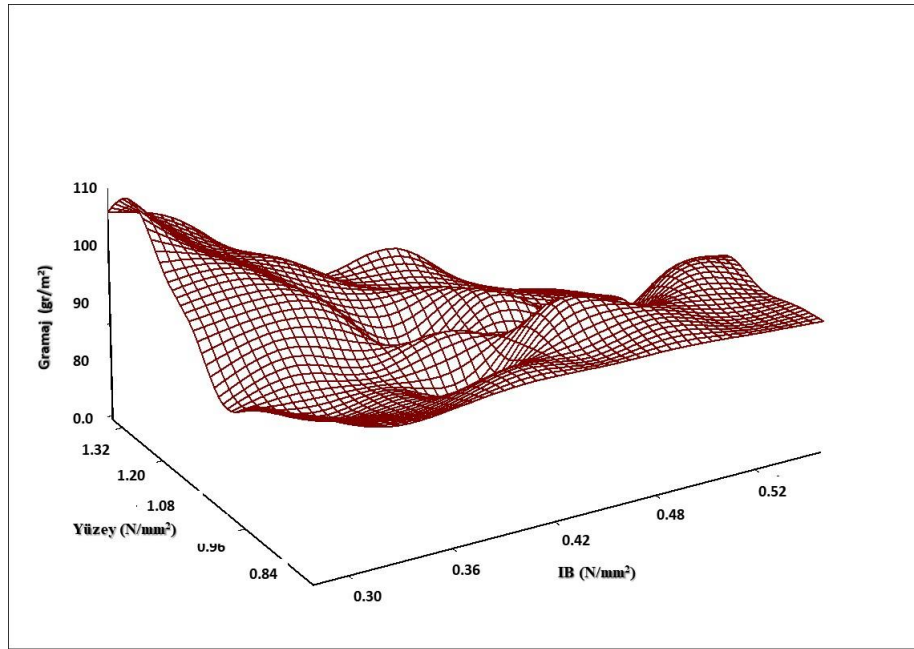
It is appeared to **an decreasing** trend for samples which laminated both 90 gr/m<sup>2</sup> and 110 gr/m<sup>2</sup> decor papers while increasing trend found with 80 gr/m<sup>2</sup> laminated samples. Those could be explained that chip sizes in the structure of particle boards and the usage rates of chips of different sizes on the outer and inner parts are important parameters that affect the properties of the boards. 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<sup>2</sup> decor paper laminated samples statistically **diffence** at  $P \leq 0.05$  confidence level (one **homojen** group) while the control, 90 gr/m<sup>2</sup> and 110 gr/m<sup>2</sup> laminated samples have in another **homojen** group.



**Figure 3.** Surface strength (N/mm<sup>2</sup>) properties of the samples.

**Figure 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 overlay paper grammage has a limited effect on both surface strength and IB strength but independent from bending strength.



**Figure 4.** Surface strength and IB strength properties of the samples depending on the overlay paper grammage.

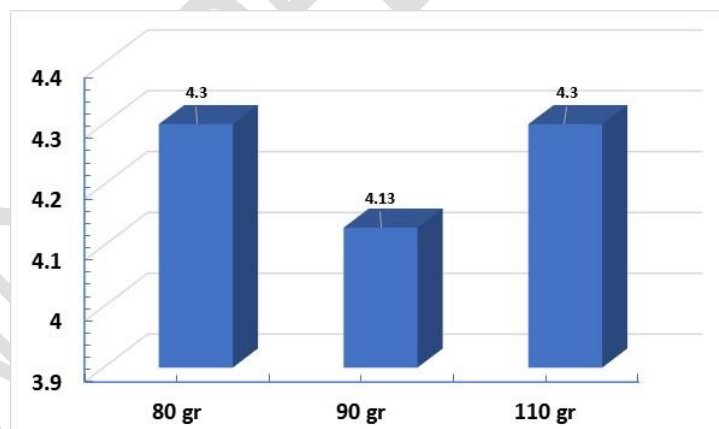
The surface abrasion/wear resistance of samples are shown in **Table 2**. It can be seen that 80 gr/m<sup>2</sup> decor paper laminated samples showed initial abrasion resistance (IP) between 250 and 350 ( $\bar{x}_{80}$ : 304) and were mostly in the 3B class in terms of surface quality. However, it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

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

Samples	80 gr/m <sup>2</sup>		90 gr/m <sup>2</sup>		110 gr/m <sup>2</sup>	
	Initial abrasion resistance (IP)	Class	Initial abrasion resistance (IP)	Class	Initial abrasion resistance (IP)	Class
1	275 <sup>a</sup>	3B	300 <sup>a</sup>	3B	350 <sup>b</sup>	4
2	350 <sup>a</sup>	4	300 <sup>a</sup>	3B	325 <sup>b</sup>	3B
3	250 <sup>a</sup>	3B	450 <sup>a</sup>	4	375 <sup>b</sup>	4
4	250 <sup>a</sup>	3B	300 <sup>a</sup>	3B	450 <sup>b</sup>	4
5	325 <sup>a</sup>	3B	325 <sup>a</sup>	3B	300 <sup>b</sup>	3B
6	300 <sup>a</sup>	3B	300 <sup>a</sup>	3B	400 <sup>b</sup>	4
7	300 <sup>a</sup>	3B	275 <sup>a</sup>	3B	350 <sup>b</sup>	4
8	300 <sup>a</sup>	3B	350 <sup>a</sup>	4	325 <sup>b</sup>	3B
9	325 <sup>a</sup>	3B	450 <sup>a</sup>	4	350 <sup>b</sup>	4
10	300 <sup>a</sup>	3B	300 <sup>a</sup>	3B	350 <sup>b</sup>	4
11	300 <sup>a</sup>	3B	250 <sup>a</sup>	3B	350 <sup>b</sup>	4

<b>12</b>	250 <sup>a</sup>	3B	300 <sup>a</sup>	3B	325 <sup>b</sup>	3B
<b>13</b>	325 <sup>a</sup>	3B	250 <sup>a</sup>	3B	375 <sup>b</sup>	4
<b>14</b>	300 <sup>a</sup>	3B	300 <sup>a</sup>	3B	400 <sup>b</sup>	4
<b>15</b>	325 <sup>a</sup>	3B	350 <sup>a</sup>	4	375 <sup>b</sup>	4
<b>16</b>	325 <sup>a</sup>	3B	250 <sup>a</sup>	3B	400 <sup>b</sup>	4
<b>17</b>	350 <sup>a</sup>	4	250 <sup>a</sup>	3B	450 <sup>b</sup>	4
<b>18</b>	300 <sup>a</sup>	3B	300 <sup>a</sup>	3B	400 <sup>b</sup>	4
<b>19</b>	275 <sup>a</sup>	3B	300 <sup>a</sup>	3B	350 <sup>b</sup>	4
<b>20</b>	350 <sup>a</sup>	4	300 <sup>a</sup>	3B	450 <sup>b</sup>	4
$\bar{X}$	304 (31.7)	3B	310 (55.8)	3B	373 (43.6)	4
<b>TS EN 14323 Standard</b>			Class 1: IP<50 Class 2: IP≥50 Class 3A: IP≥150 Class 3B: IP≥250 Class 4: IP≥350			

The surface scratch resistance properties of three different grammage decor paper laminated samples were determined according to TS EN 14323 standard. The measured average values are presented in **Figure 5**. Although the scratch 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 any** statistically difference were found for **all** three different grammage decor paper laminated samples. However, all samples were found to be class 4, regardless of lamination process or type of laminated decorative paper grammage.



**Figure 5.** Surface **sctractch** resistance (N) properties of the samples.

## 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 overlay paper grammage on the physical properties of the laminated particleboard panels. It appears that **the** not all of the properties of the decor papers laminated particleboards are affected by grammage. Increasing the raw paperweight grammage improved the bending strength and surface abrasion resistance some level while statistically not any difference were observed for IB, **surface** strength and **sctractch** resistance of the samples.

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