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Influence of the amount and type of anti-adhesive agent on selected properties of fibreboards

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Abstract: *Influence of the amount and type of anti-adhesive agent on selected properties od fibreboards*. The aim of the research was to determine the effect of the type and amount of release agent used in the manufacture of high-density fiberboards (HDF) on selected mechanical and physical properties of the produced boards. The scope of work included producing boards under laboratory conditions with 10 g/m^2, 25 g/m^2 and 50 g/m^2 applied to the surface of the board and subjecting them to selected physical and mechanical importance. The results obtained show that the properties of the manufactured boards are related to the amount of formulation applied and that by using the right amount of formulation we can obtain values that meet the requirements of the relevant European standards.

Keywords: fiberboard, HDF, release agent, coat

INTRODUCTION

HDF is a board for indoor use in dry conditions due to its low mechanical strength and moisture resistance. Spraying the surface of the board before it is pressed is a procedure to prevent HDF from sticking to the surface of the pressing board (Badin et al. 2018). Release agents make the materials to which they are added reduce their adhesion (clinging) to various bodies. The study aimed to investigate whether, in addition to reducing the adhesion of the panel, the release agent also affects the mechanical and physical properties of these products. The main property that was looked at during the study was the absorption of water through the made boards.

In an article by Flores-Yepes et al. (2012), we can learn about the development of a particleboard that is based on a common reed. One of the main properties that was obtained in the board was water resistance. They achieved this resistance thanks to the hydrophobic properties of common reed, without the need for melamine or any other water-repellent additive. In the course of the tests, it was found that under certain conditions, that is, at high pressure and with the right proportion of resin (pressure of more than 3 MPa and more than 15% liquid resin), the particleboard showed full regeneration after the swelling test. This property provides an interesting property for use in high-humidity environments without the need for a special resin or impregnation process.

Thanks to the research of Du et al. (2014) involving modification of water absorption properties of bamboo fibre (BF) and high-density polyethylene (HDPE) composites. The heat processing of the BFs was carried out before combining them with HDPE to form the composites. In the study, the moisture sorptive properties of the composites were gauged and their diffusion coefficients (Dm) were assessed using a one-dimensional diffusion model. The moisture diffusion coefficient values for all the materials in the composites were in the range of 0.115×10^{-8} to 1.267×10^{-8} cm^2/s. Dm values declined with an increase in BF heat treatment temperature and rose with an increase in BF loading level. The Dm values for 40 wt% bamboo fiber/HDPE composites of BF processed at 100°C were the highest (i.e., 1.267×10^{-8} cm^2/s). Plastic composites reinforced with natural fibers are gaining popularity mainly due to their strength properties and sustainability. Among these natural fabrics, bamboo has a high strength-to-weight ratio due to its elongated fibers (Abdul Khalil et al. 2012).

A variety of modification approaches have been used to alter the water absorption of composites. For instance, aluminium as a nano-filler has been used in both wood flour and polypropylene (PP) composites, and the water absorption of the materials by the composites is reduced as the clay content increases (Ghasemi and Kord 2009). Extraction of hemicelluloses from wood/natural fibers under high pressure and regularly hot water extracting and adding coupling agents to the composite has been shown to help improve the water repellency of the composites, as these processes reduce the hydrophilic properties of the fibers and enhance the bond of the matrix to the fibers (Hosseinaei et al. 2012; Karmaker et al. 1997).

In a publication of Abenghal et al. (2023), we learn that the release agent is used in the production of release coatings whose production has been increasing in recent years due to their use in various fields. However, commercially available release coatings are considered non-recyclable, making them an important source of pollution. Looking for solutions to this problem, new coating materials have been used. Release liners are substrates made of paper or plastic film that is coated on one or both sides with a release agent. We currently use them for a variety of self-adhesive applications such as labels, tapes, fiber composites or medical and hygiene products (von Gradowski 2019; Vasilev et al. 2020).

This research aimed to investigate the influence of two different release agents added in different amounts on the surface of the pressed HDF mat, on the selected mechanical and physical properties of the produced panels.

MATERIALS AND METHODS

Materials

The panels were produced under laboratory conditions from industrial softwood fiber pulp of 95% pine (*Pinus sylvestris* L.) and spruce (*Picea abies* (L.) H.Karst) with a moisture content (MC) of about 3%.

An industrial urea-formaldehyde (UF) resin with a dry matter content of 65% was used for the panels.

The curing time of the resin mixed with ammonium nitrate-based hardener at 100°C was 82 seconds. Two different industrially-developed and tested release agents were applied to the surface of the panels. Due to the developing stage, it was impossible to characterize in-deep the agents, thus, these are called “A” and “B”.

No hydrophobic agent was used in the production of the panels.

Production of the panels

HDF fiberboard with a nominal thickness of 3 mm and a nominal density of 900 kg/m^3 manufactured under laboratory conditions with two sheets per variant tested. The resination of the boards was 12%. The application of release agent was 0 g/m^2, for the reference variant and successively 10 g/m^2, 25 g/m^2 and 50 g/m^2 for subsequent variants. The pressing parameters were as follows: hydraulic press (AKE, Mariannelund, Sweden), temperature: 200°C, pressing time factor of 20 s/mm of nominal panel thickness and unit pressure of 2.5 MPa. The produced boards were air-conditioned at 20°C ±1°C and 65%±2% relative humidity for 7 days for weight stabilization before testing.

Characterization of the panels

The following physical characteristics of the boards were tested: determination of modulus of elasticity (MOE) and modulus of rupture (MOR) (bending strength) were tested according to EN 310 (1993), determination of swelling of thickness (TS) and water absorption (WA) after soaking in water according to EN 317 (1993), surface water absorption (SWA) according to EN 382-2 (1993). The water contact angle was tested on a PHOENIX 300 (SEO Co. Ltd, South Korea) using distilled water, the measurement of the angle was made 1 s and 60 s after the deposition of the droplet on the tested surface. The density profile was measured using a density profiler (Laboratory Density Profile Measuring System) from GreCon (Fagus-GreCon Greten GmbH and Co. KG, Alfeld/Hannover, Germany). For all tests of mechanical and physical characteristics, except for density profile, as many as 10 repetitions have been completed per every tested type of sample. For density profile measurement, 3 samples per every tested variant have been used, and one representative profile has been chosen per every sample type to final evaluation of the profiles. The results shown in the graphs, where applicable, show mean values and standard deviations as error bars.

The statistically significant differences between the achieved average values, wherever applicable, have been distinguished based on ANOVA analysis.

RESULTS AND DISCUSSION

Modulus of elasticity

The modulus of elasticity data for the panels with different applications and types of release agents are shown in figure 1. Analysis of the results showed that with agent “A”, we see that the modulus of elasticity increases with increasing application of the agent to the mat. The highest result was obtained by the panel with the highest application (50 g/m^2) 3516 N/mm^2 and this is also higher than for the reference sample (REF) 3334 N/mm^2. The lowest result was achieved by the sample with the lowest application rate (10 g/m^2) 2963 N/mm^2.

On the other hand, analysing the results for agent “B”, we can see that the highest result was obtained for the board with the intermediate application (25 g/m^2) 3720 N/mm^2, this result is higher than that of the reference sample (REF) 3334 N/mm^2, but interestingly it is also higher than that of the sample with the highest application (50 g/m^2) 3635 N/mm^2. The lowest result was for the sample with the lowest application rate (10 g/m^2) 3145 N/mm^2.

We can read similar results from Wronka et al. (2020), who tested fibreboard with a potato starch binder, and when testing citric acid-modified maize starch used as a binder for wood composites (Hazim et al. 2020). In these studies, MOE values increased with increasing filler addition.

The only statistically significant differences among MOE average values have been found for the “B” agent with 25 g/m^2 release when referred to the “A” agent with 10 g/m^2 release.

The results achieved values that met the minimum requirements set by EN 622-5 (2009).

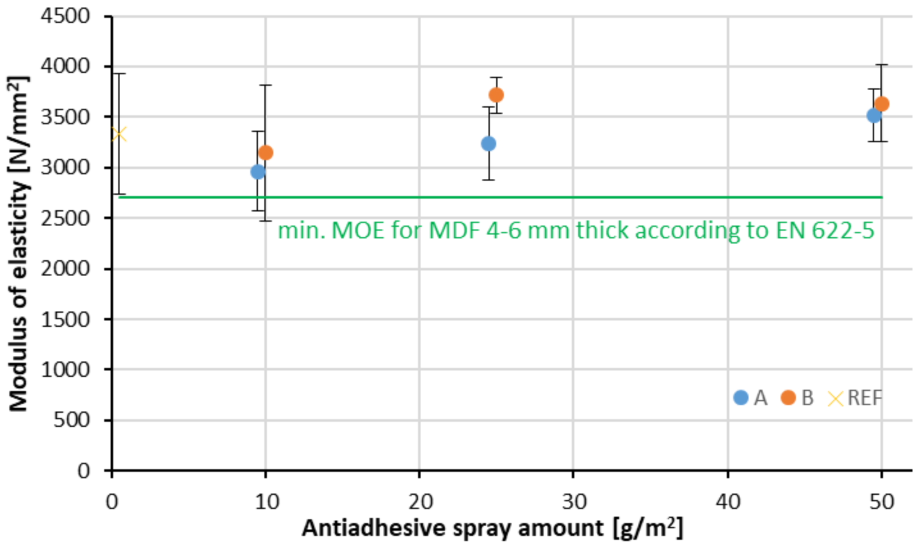

Figure 1. Modulus of elasticity of panels with different applications and types of release agent

Modulus of rupture

The results of measuring the bending strength of the fibreboard with different applications and types of release agents are shown in figure 2. The results show that, when agent “A” was used, the sample with the highest agent application (50 g/m^2) obtained the highest result of 46.3 N/mm^2, but this is lower than the reference sample (REF) result of 47.2 N/mm^2. The lowest result was achieved by the agent-applied sample (25 g/m^2) of 42.5 N/mm^2.

When analysing the results with agent “B”, it is apparent that the highest result was achieved by the sample with the intermediate application (25 g/m^2) of 47.8 N/mm^2. This is a higher result than the reference sample (REF) of 47.2 N/mm^2. The lowest result was achieved by the sample with the lowest application rate (10 g/m^2) of 44.3 N/mm^2. It appears that for agent “B” the distribution of the results came out similar to the MOE.

Interestingly, the values of the results with the smallest and largest application are very close to each other, as for the 10 g/m^2 application the bending strength value is 44.3 N/mm^2 but for the 50 g/m^2 application the value is 44.4 N/mm^2.

Similar results regarding the increase in MOR were obtained when studying fibreboards glued with rice starch (Dasiewicz and Kowaluk 2023), (Wronka et al. 2020) in which the boards were glued with potato starch. In these studies, the MOR value increased with increasing binder addition.

No statistically significant differences among MOR average values have been found.

As in the MOE study, the results achieved values that met the minimum requirements set by EN 622-5 (2009).

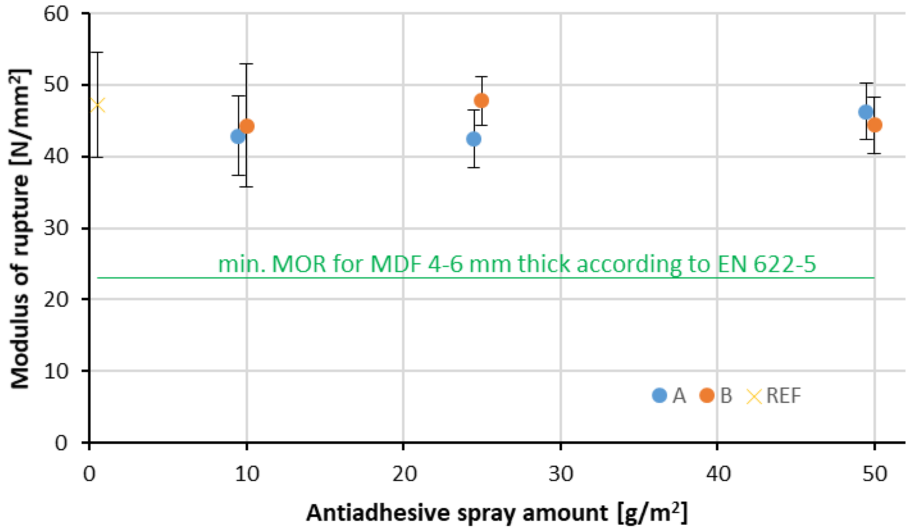

Figure 2. Modulus of rupture of panels with different applications and types of release agent

Water absorption

The results of water absorption of the panels according to application and type of release agent are shown in figure 3. From the graphical data, it is possible to read that water absorption decreased with increasing agent application. For agent "A", water absorption during a 2-hour soaking at the lowest application (10 g/m^2) was 119.6% and at the highest application (50 g/m^2) 88.1%. After soaking the samples for 24 hours, water absorption for agent "A" was 119.8% at the lowest application rate (10 g/m^2) and 92.5% at the highest application rate (50 g/m^2).

Analysing the results of agent "B", we see that absorption was 107.0% for the smallest application (10 g/m^2) and 87.1% for the largest application (50 g/m^2). When the samples were soaked for 24 hours, the absorption was 111.8% for the smallest application (10 g/m^2) and 89.8% for the largest application (50 g/m^2).

It is worth noting that the water uptake for both agents with the smallest application (10 g/m^2) was lower than the reference sample (REF) uptake of 121.1% (after a 2-hour soak) and 126.6% (after a 24-hour soak).

For both agents "A" and "B", the differences in absorption in relation to the soaking time of the samples are very small.

Analysing the results with agent "B", we see that the swelling of the material after a 2-hour soak is 32.0 % for the smallest application (10 g/m^2) and 15.3 % for the largest application (50 g/m^2). Results after a 24-hour soak show that swelling at the lowest application rate (10 g/m^2) is 34.1 % and at the highest application rate (50 g/m^2) is 15.7 %.

It is worth noting that, for agent "A", the swelling of the samples with the smallest application (10 g/m^2) is lower than that of the reference sample (REF) of 31.3% after a 2-hour soak and 32.1% after a 24-hour soak. In contrast, for agent "B", the swelling of the reference sample (REF) is lower than that of the samples with the lowest application rate (10 g/m^2) of 32.0% after a 2-hour soak and 34.1% after a 24-hour soak.

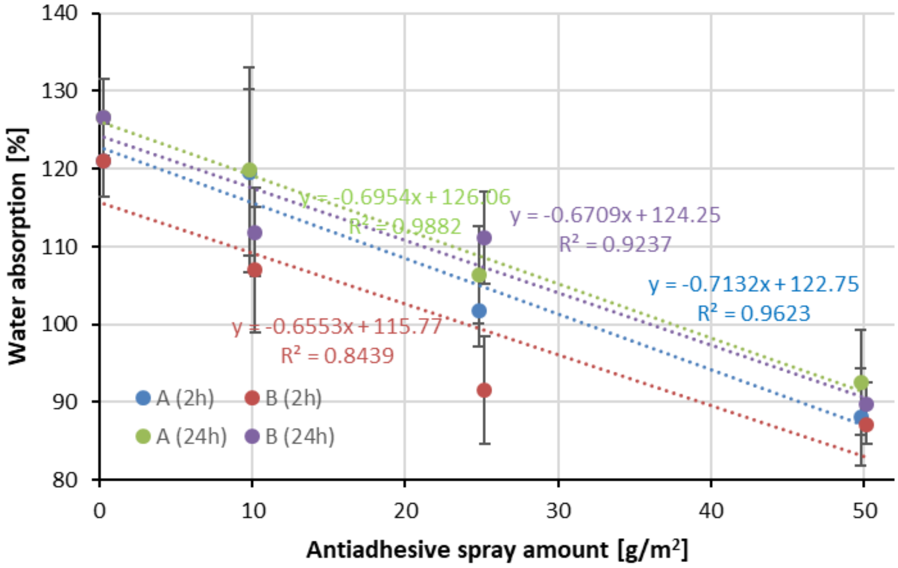

Figure 3. Water absorption by application and type of release agent

All the results obtained reach values meeting the requirements set by EN 622-5 (2009).

Similar swelling values were reported in a study by Bartoszuk and Wronka (2023) in which the effect of recycled artificial leather particle content in particleboard on its selected properties was investigated. The study showed that swelling decreased as the leather content of the boards increased.

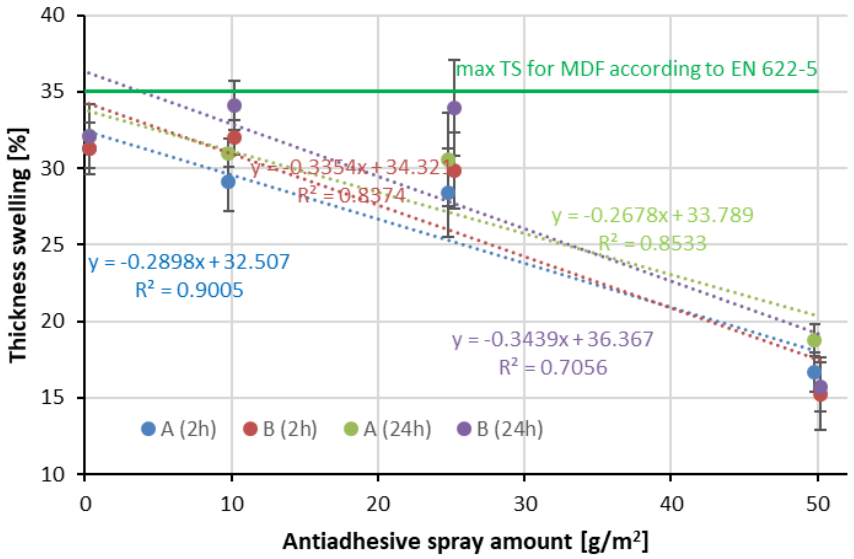

Figure 4. Thickness swelling by application and type of release agent

Surface water absorption

The results of the surface water absorption of panels with different application rates and agent types are shown in figure 5. As can be seen, SWA gradually decreases with increasing application rates. From 2889 g/m^2 for the lowest application (10 g/m^2) to 2674 g/m^2 for the highest application (50 g/m^2) with agent "A" and from 2905 g/m^2 for the lowest application (10 g/m^2) to 2633 g/m^2 for the highest application (50 g/m^2) with agent "B".

At the lowest application rate (10 g/m^2), agent "A" (2889 g/m^2) records a lower SWA than agent "B" (2905 g/m^2). At intermediate application (25 g/m^2), agent "A" 2758 g/m^2, records a larger SWA than agent "B" (2689 g/m^2). On the other hand, at the highest application rate (50 g/m^2), both agents enter at similar values (A – 2674 g/m^2, B – 2633 g/m^2). The highest SWA, 4134 g/m^2 has been found for reference panels.

The only statistically significant differences in average SWA have been found for both agents released at 10 g/m^2 when referred to remaining average values.

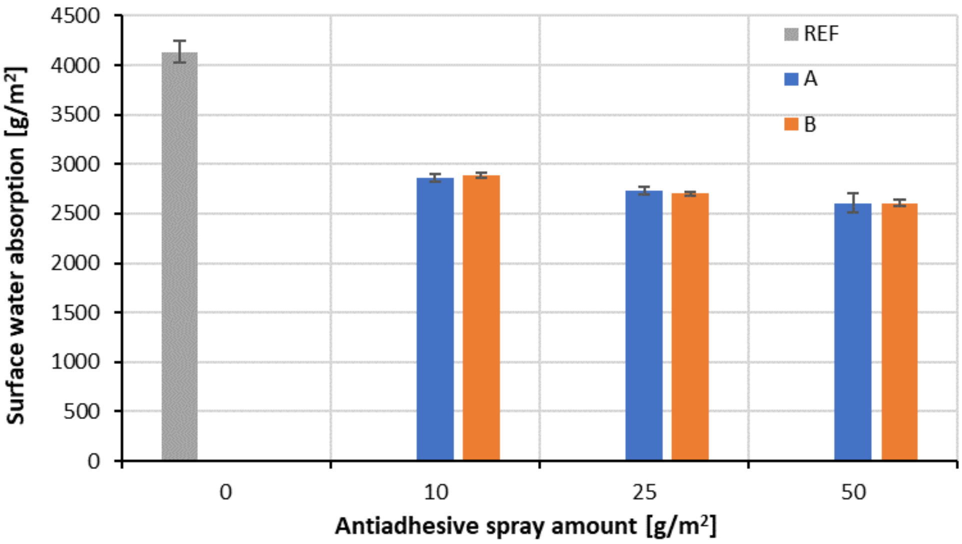

Figure 5. Surface water absorption by application rate and type of release agent

The contact angle

The results of the wetting angle test are shown in Figure 6. The graph shows that the wetting angle decreased with increasing time from droplet placement. It is also possible to read from the graph data that as the amount of agent applied increased, the water droplet soaked into the panel more slowly.

The highest wetting angle for agent "A" was obtained for the sample with the highest formulation application (50 g/m^2) after 0 s was 107°, while the lowest wetting angle for this formulation recorded with the lowest application (10 g/m^2) after 60 s was 26°.

When analysing the wetting angle for formulation "B", the highest angle was recorded for the sample with the highest formulation application (50 g/m^2) after 0 s (103°), while the lowest angle was recorded for the sample with the lowest application (10 g/m^2) after 60 s (24°).

The highest wetting angle after 0 s as well as after 60 s came out with the highest agent application (50 g/m^2).

Similar results were obtained in a study by Dasiewicz and Kowaluk (2023) in which fibreboards bonded with rice starch were tested. It was noted that the wetting angle decreases with time after drop placement. We can also read interesting results from this study in a publication by Dasiewicz and Kowaluk (2022) in which cellulose-based binder plywood was studied. It was noted there that all samples showed good hydrophobic properties. The wetting angles after 1 s as well as after 60 s were very similar to each other in each of the samples bonded with biodegradable glue.

There are statistically significant differences between the contact angle measured 0 s and 60 s after deposition. When comparing the different amount of agent release, there is no statistically significant differences between 10 and 50 g/m^2 release.

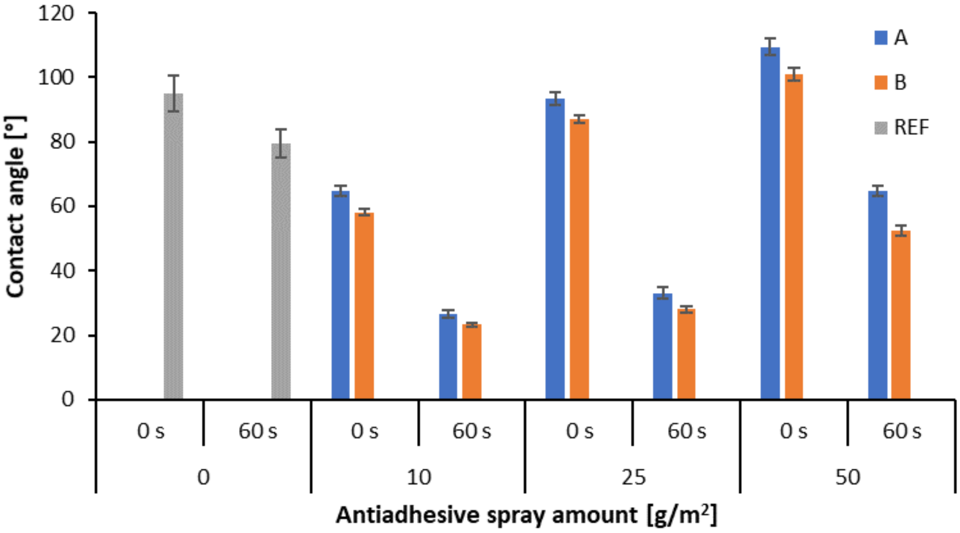

Figure 6. The contact angle dependence on the application rate and type of release agent

Density profile

The results of the density profile are shown in figure 7. Reading the results of the density of the panels when agent "A" was used, the highest density values were recorded at the highest application (50 g/m^2) where, at a panel thickness of 0.12 mm, the density was 989 kg/m^3, while the lowest density was recorded at the lowest application (10 g/m^2) where, at a thickness of 0.02 mm, the density was 9 kg/m^3.

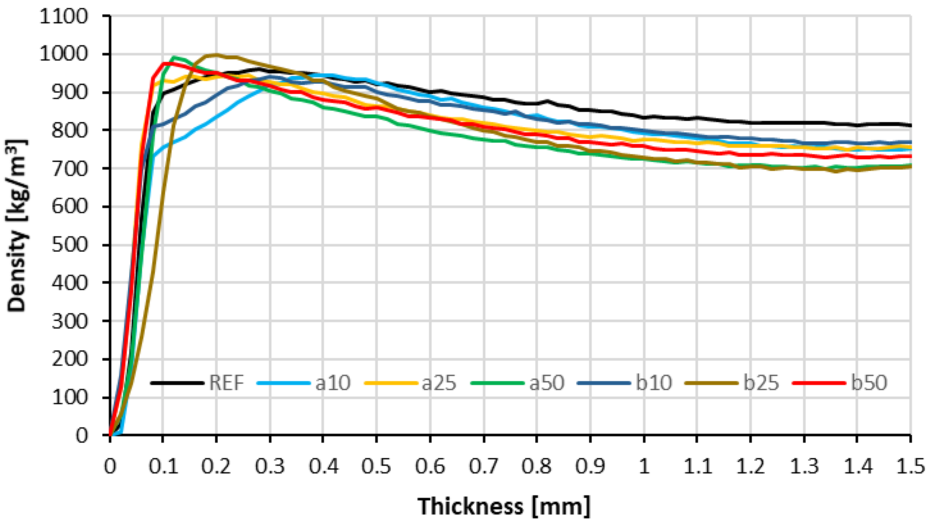

Figure 7. The density profiles of the panels depend on the application and type of release agent

When the samples were analysed with Agent "B", the highest density values were recorded on the intermediate application (25 g/m^2) where, at a thickness of 0.24 mm, the density was 990 kg/m^3. The lowest density was also recorded for the intermediate application (25 g/m^2) where, at a thickness of 0.02 mm, the density was 57 kg/m^3.

Interesting results were reported during a study by Borysiewicz and Kowaluk (2023) in which selected properties of panels bonded with different fractions of recycled HDPE particles were investigated. After analysing the results, the density profile was shown to be uneven and random. During the mixing of the polymer with the fibres, the distribution of the polymer particles was random, so a single, larger HDPE particle could form agglomerates, which may result in a higher local panel thickness.

CONCLUSIONS

On the basis of the tests carried out and the analysis of the results obtained, the following conclusions can be drawn.

- Both modulus of elasticity and bending strength increase slightly with increasing release agent application, reaching values that meet the minimum requirements of European standards. No significant differences among both investigated agents have been found for MOR and MOE.
- Water absorption, swelling thickness and surface water absorption decrease with the release agent increasing application rates. No significant differences among both investigated agents have been found for mentioned features.
- As the amount of release agent application increased, the water droplet soaked into the panel surface more slowly causing the wetting angle to increase. The "B" agent was in this case less hydrophobic than the "A" agent.
- The density profile changed by the growing densification of face layers with increasing agent application. No significant differences among both investigated agents have been found for density profiles.

In summary, it can be concluded, that with the proper amount of release agent application, it is possible to achieve the panels of the desired mechanical and physical properties.

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Streszczenie: *Wpływ ilości i rodzaju środka antyadhezyjnego na wybrane właściwości płyt pilśniowych.* Celem badań było określenie wpływu rodzaju i ilości środka antyadhezyjnego stosowanego w produkcji płyt HDF na wybrane właściwości mechaniczne i fizyczne wytworzonych płyt. Zakres prac obejmował wytworzenie w warunkach laboratoryjnych płyt o naniesieniu środka antyadhezyjnego w ilości 10 g/m^2, 25 g/m^2 i 50 g/m^2 naniesionych na powierzchnię kobierca płyty przed prasowaniem oraz poddanie ich wybranym oddziaływaniom fizycznym i mechanicznym. Uzyskane wyniki pokazują, że właściwości wytworzonych płyt są związane z ilością zastosowanego preparatu, a stosując odpowiednią ilość preparatu można uzyskać wartości spełniające wymagania odpowiednich norm europejskich.

Słowa kluczowe: płyta pilśniowa, HDF, środek antyadhezyjny, powłoka

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