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Influence of gypsum share on selected properties of high-density wet-formed fiberboard

ADA GOLIASZEWSKA, GRZEGORZ KOWALUK
Department of Technology and Entrepreneurship in Wood Industry, Faculty of Wood Technology, Warsaw University of Life Sciences – SGGW

Abstract: *Influence of gypsum share on selected properties of high-density wet-formed fiberboard.* The purpose of the study was characterize the properties of high-density wet-formed fibreboards produced in laboratory conditions, with a different proportion of gypsum binder. The scope of the research included the examination of the manufactured boards in terms of their selected physical and mechanical properties, in order to determine the influence of gypsum share on the properties of the boards. Studies have shown that the non-zero gypsum share (without correlation between the proportion of gypsum and the tested feature) increased the contact angle of the tested panels and increased thickness swelling, water absorbability and surface absorption.

Keywords: hardboard; fibreboard; wet-formed fibreboard; gypsum; density profile; contact angle; modulus of elasticity in bending; bending strength; surface water absorption

INTRODUCTION

Gypsum consists of calcium sulphate dihydrate with the chemical formula ($CaSO_4 \cdot 2H_2O$), and forms a tangled network of interconnected crystals (Chen et al. 2010). The gypsum binder is widely used in the construction industry. Binding and hardening of the gypsum adhesive occurs due to reaction with water. The characteristic feature of gypsum is the short binding time.

The gypsum binder can be used for the production of boards such as gypsum panels, plasterboards (also known as a drywall), gypsum particleboards (GPB) and other. In the early 1980s, numerous studies were carried out to modify the structure of the gypsum board with cellulose fibres or wood shavings (Kossatz and Lempfer 1982). The experiments were aimed at reducing the amount of water used to cure the gypsum binder. According to the book of Dobrowolska (2002), the mechanical properties of gypsum particleboards made in semi-dry technology are significantly higher than in the case of plasterboard panels. These boards have better sound-absorbing properties as well as lower flammability. Due to better mechanical properties and high susceptibility of gypsum particleboards to machining (Kossatz and Lempfer 1982), they can be used more widely in construction than drywalls.

Boards containing calcium sulphate dihydrate (gypsum) are valued as a building material, mainly due to lack of formaldehyde emission, high fire resistance and lower heat losses (Feng et al. 2007). However, according to literature, gypsum particleboards have a low water resistance, and what is related to this: high thickness swelling and high water absorption. Deng and Furuno (2001) conducted a study that tested whether the addition of fibrous materials would improve the properties of GBP. Studies have shown that the correct use of polypropylene fibres has improved the properties of gypsum particleboards. A year later, the same scientists (Deng and Furuno 2002) carried out further research, this time on the impact of the addition of jute fibers on the physical and mechanical properties of gypsum particleboards. The addition of fibers did not affect the water absorption and thickness swelling, however the optimal amount of fibers influenced the improvement of the mechanical properties of the board.

Due to the fact that the research carried out so far mainly concerned the properties and modifications of gypsum particleboards and plasterboards, the object of this research was the study of using a gypsum binder in the production of wet formed fibreboard panels.

After the formation of high density wet-formed fibreboards with different proportions of gypsum binder, the key task was to determine how the share of binder affected their properties.

MATERIALS AND METHODS

Six different types of fibreboards with assumed density of about 900 kg/m^3 in wet technology have been produced in laboratory conditions. Each of them had a different mass share (in relation to totally dry fibers) of the added gypsum binder: 0%; 0.5%; 1%; 2%; 5%; 10%.

An industrial fibrous mass of softwood fibres with a relative moisture content of 60% was used to obtain the fibreboard. Test specimens with appropriate dimensions were obtained from the prepared fibreboard panels of dimensions 320x320 mm^2 and assumed thickness of 2 mm. The panels have been pressed under manometric pressure of 5.5 MPa and temperature 200°C within 420 s.

All the samples were prepared for every test mentioned below by air conditioning in the following conditions: 20°C and 65% relative humidity to weight stabilization.

Bending strength and modulus of elasticity

As many as 48 samples with dimensions 130x50x thickness, mm^3, were selected for bending strength tests and modulus of elasticity, 8 samples for each variant.

The modulus of elasticity test in static bending and bending strength was carried out on the basis of PN-EN 310 standard. The span between supports was 100 mm.

Contact angle

18 samples with dimensions 130x50x thickness, mm^3, were used to the contact angle test, 3 samples from each variant of the fibreboard panels with different share of gypsum binder. The contact angle was measured after the first second and after 60th second of drop deposition on the surface of the panel. There were 3 drops measured on every sample. The tests were performed on the contact angle analyser PHOENIX 300 (SEO).

Water absorption and thickness swelling test

The test of water absorbability and thickness swelling was carried out on 60 samples with nominal dimensions 50x50x thickness, mm^3, from each variant were used 10 samples.

The swelling test was performed based on the PN-EN 317 standard. The absorbability test was accomplished in parallel on the same samples which used for the swelling test. The samples were soaked in water for 24 hours. Absorbability and swelling tests were carried out after 2 and 24 hours of soaking.

Surface water absorption

On the basis of the methodology presented in PN-EN 382-2 standard, surface absorption tests were carried out.

Six samples with dimensions 120x120x panel thickness, mm^3, were taken from fibreboards with different shares of gypsum binder. The impact of water on the surface of fibreboards took two hours.

Density profile

The density profile test was based on six samples from each type of panels produced. The samples had nominal dimensions: 50x50x thickness, mm^3.

The device for measuring the density profile was a X-Ray density profile analyser DA-X from GreCon. The sampling step was 0.02 mm.

Statistical analysis

The obtained results were examined by means of the analysis of variance (ANOVA) and the Student's test was carried out ($\alpha = 0.05$) to determine the significance of differences between the factors. The results presented in the graphs show mean values and standard deviations.

RESULTS

Bending strength

The graph (Figure 1) presents the effect of the proportion of gypsum binder on the bending strength of high density fibreboards. The bending strength of the obtained boards reaches values from 20 to 28 N/mm^2. The addition of 0.5% gypsum binder lowered the strength of the fibreboard compared to the board without the additive. However, the results do not differ statistically. A variant with a one-percent addition of gypsum binder reached the highest result (28 N/mm^2) among all tested panels. The share of gypsum binder higher than 1% significantly reduced the values of static bending strength. The lowest value of strength (20 N/mm^2) was achieved by the fibreboard with 10% gypsum content. There is no clear dependence between the gypsum mass share and bending strength of tested panels, what means, there is no impact of the gypsum share in the range of 0 – 10% (w/w) on the bending strength of panels with gypsum content. According to initial statistical analysis, a difference between the highest and the lowest value of bending strength is the only statistically significant.

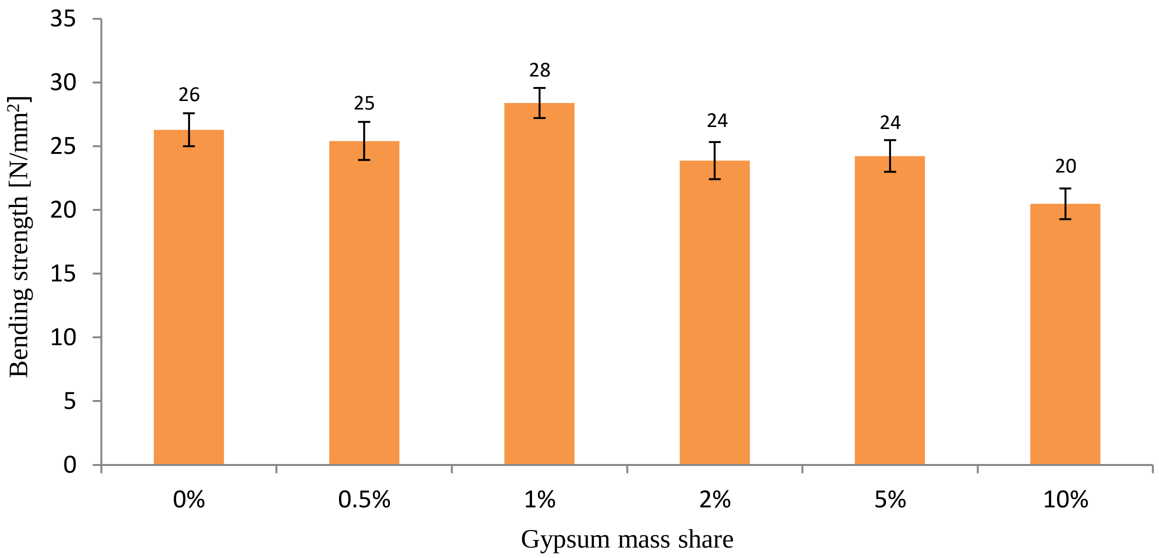

Figure 1. Influence of the mass gypsum share on the bending strength of tested panels.

Modulus of elasticity

The plot (Figure 2) shows the relationship between the addition of gypsum to tested fibrous panels and the modulus of elasticity. The highest value of the modulus of elasticity was demonstrated by the board with a one-percent addition of gypsum binder (3791 N/mm^2). The modulus of elasticity of this variant is about 800 N/mm^2 higher than the smallest obtained value of the module, which was achieved by the board with a 10% addition of gypsum (2983 N/mm^2). Fibreboard with a one-percent share of gypsum binder demonstrated even a higher result than the reference fibreboard, by about 200 N/mm^2. Results of these variants showed statistically significant differences. The high modulus of elasticity was also obtained by a fibreboard with a five percent gypsum content. It reached the value of 3605 N/mm^2 and was comparable to the control fibreboard. However, it is hard to conclude that there is significant influence of the mass gypsum share in the panels on their modulus of elasticity. Referring to the results of research on the properties of cement-modified gypsum particleboards, it should be concluded that fibreboards with the addition of gypsum achieve a greater values of modulus of elasticity than gypsum particleboards, tested by Deng et al. (1998).

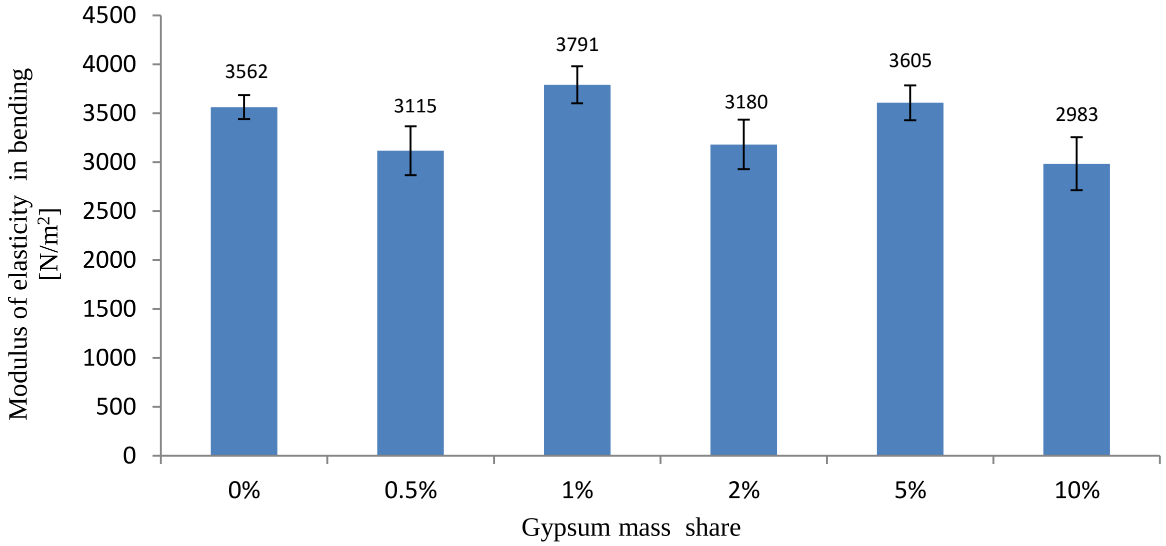

Figure 2. Influence of the mass gypsum binder share on the modulus of elasticity of the tested panels.

Contact angle

The influence of the share of gypsum binder in wet-formed fibreboards on the contact angle is shown in the graph (Figure 3). The contact angle after 1 second from placing the drop takes values equal to or higher than 90 degrees in the case of fibreboards with a gypsum share: 0.5%, 2% and 10%. It means that the wettability of the surface of tested panels is low. Other variations of panels immediately gained a contact angle values lower than 90 degrees. After 60 seconds of study most variants reached a contact angle of less than 90°. The highest values of the contact angle both after 1 second and after sixty seconds showed panels with a two-percentage and ten-percentage share of gypsum binder. However, the smallest values of the contact angle were shown by a fibreboard with one percent of gypsum (about 80°). These values are also lower (by a few degrees) than the contact angle values of the reference fibreboard (0% of gypsum). This indicates the higher wettability of this variant of board.

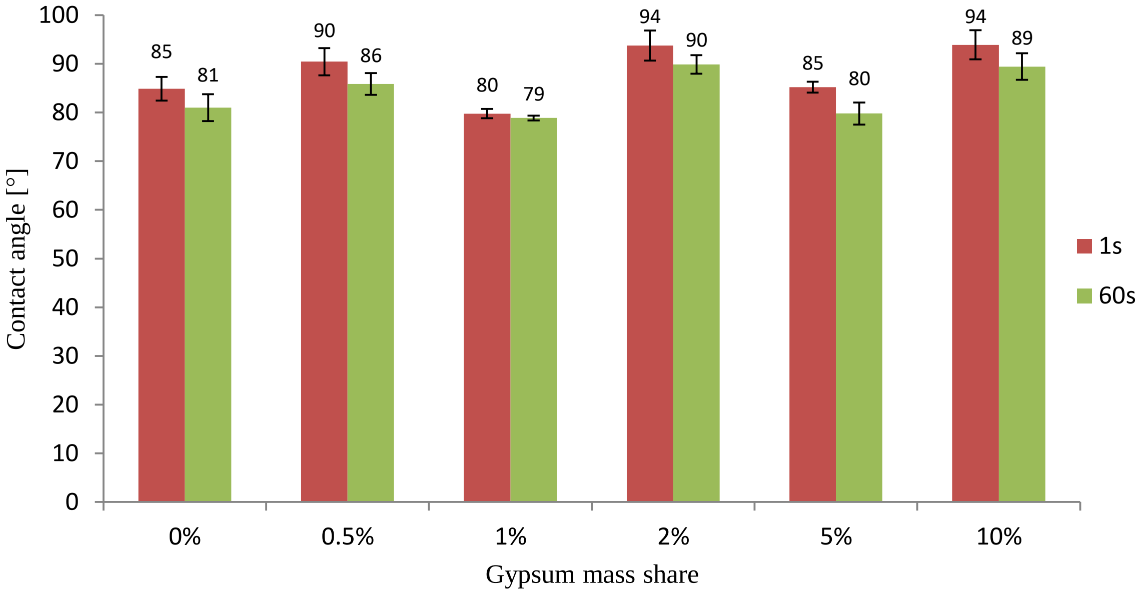

Figure 3. Influence of the mass gypsum binder share on the contact angle of the tested panels.

Water absorbability test

The Figure 4. shows how the amount of gypsum binder added to fibreboards influenced their water absorbability. The control board achieved the lowest absorbability compared to the boards with the addition of a gypsum binder. After two hours of soaking in water, the absorbency was about 40%, and after 24 hours it was almost twice as high. Regarding the boards with the addition of gypsum, the lowest absorption value was obtained by the board with the addition of one percent of the gypsum binder. After two hours of soaking, the absorbability was as much as the value of the absorbability after 24 hours of soaking the reference board. The highest increase in absorbability in fibreboard panels with gypsum was observed in the first two hours, after which the absorbability increases to a lesser extent. Variants of fibreboards with the participation of gypsum 0.5%, 2%, 5% and 10% showed absorbability values of about 100% and more after just 2 hours of soaking. After the statistical analysis of achieved results it should be concluded, after 2 h of soaking there were statistically significant differences of mean values of water absorption between the following panel types: 0 and remaining, 1% and 0.5, 5 and 10%. The same analysis gave the information that after 24 h of soaking, the only statistically significant differences have been found in case of 0 and remaining panels. It can be observed that the water absorbability of boards with a non-zero gypsum binder is higher than medium density fibreboards, which is at a level of 65% (Zheng et al. 2006).

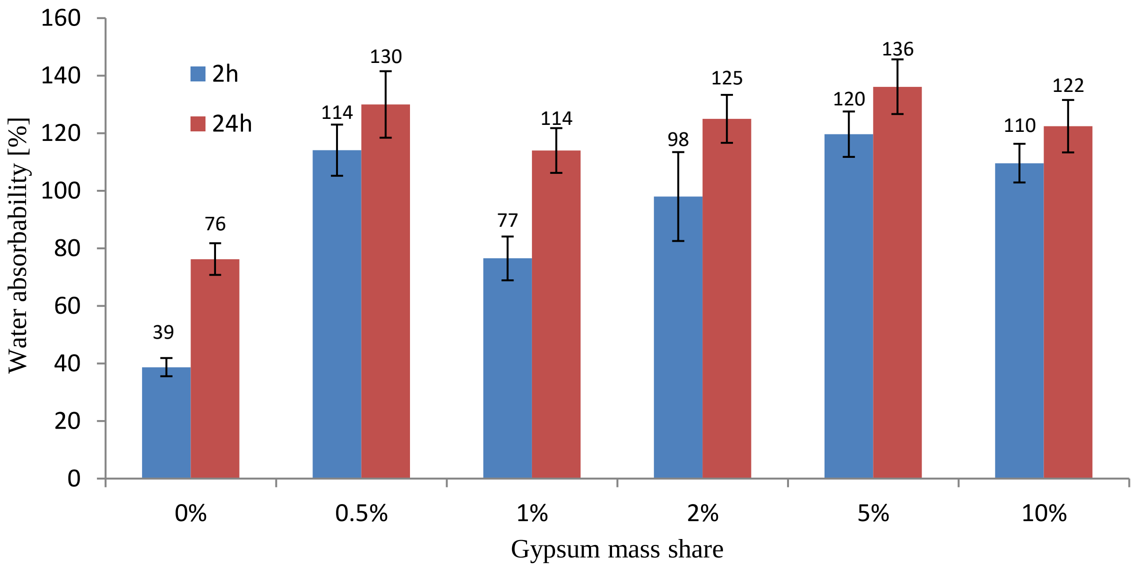

Figure 4. Influence of the mass gypsum binder share on water absorbability of the tested panels after 2 and 24 h of soaking in water.

Thickness swelling test

The relationship between the thickness swelling and the amount of gypsum added to the wet-formed fibreboard is shown in Figure 5. Panels without the addition of gypsum showed the smallest swelling. After two hours of soaking, the swelling was 30% and after 24 hours it increased to 50%. The swelling values of boards with the addition of gypsum binder are much higher after just 2 hours of soaking compared to the tested control board after 24 hours of soaking, what means that the water-related reaction of the panel thickness is more intensive in case of the panels of non-zero gypsum share. A boards with a one-percent addition of gypsum binder shows the smallest swelling values compared to other fibreboards with gypsum. This panels obtained values after two hours of the study, about 50%, and after 24 hours about 70%. The statistically significant differences of average thickness swelling after 2 h of soaking in water have been observed for the reference and remaining, as well as for 1% and remaining panels with gypsum content. The similar relations have been found in case of statistically significant differences of the average values of tested panels thickness swelling after 24 h of soaking in water. There is no clear relation between the gypsum content and swelling in thickness of tested panels with the gypsum share ranged from 0 to 10% w/w.

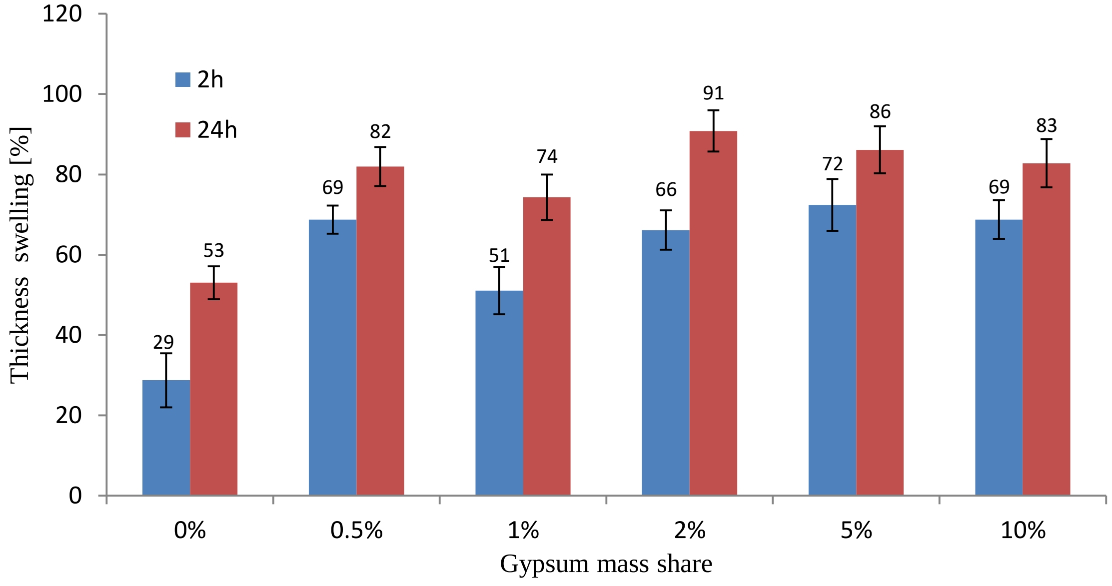

Figure 5. Influence of the mass gypsum binder share on swelling in thickness of the tested panels after 2 and 24 h of soaking in water.

Surface water absorption

The graph (Figure 6) shows the surface water absorption values of fibreboards with different proportions of gypsum binder. It can be noticed that the addition of gypsum caused a significant increase in surface absorption (at least by 150 g/m^2, what means over 250% higher than for control panel) in comparison to a control panel whose absorption value was below 100 g/m^2. The highest surface water absorption values are visible in fibreboards with a gypsum content above 1%. These boards obtain values greater than 300 g/m^2. What should be underlined, even the smallest (0.5%) addition of gypsum causes over 300% raise of surface water absorption of tested panels. It should be concluded that generally higher thickness swelling and water absorption of the panels of non-zero content of gypsum is similar remark to conclusion of Espinoza-Herrera and Cloutier (2011).

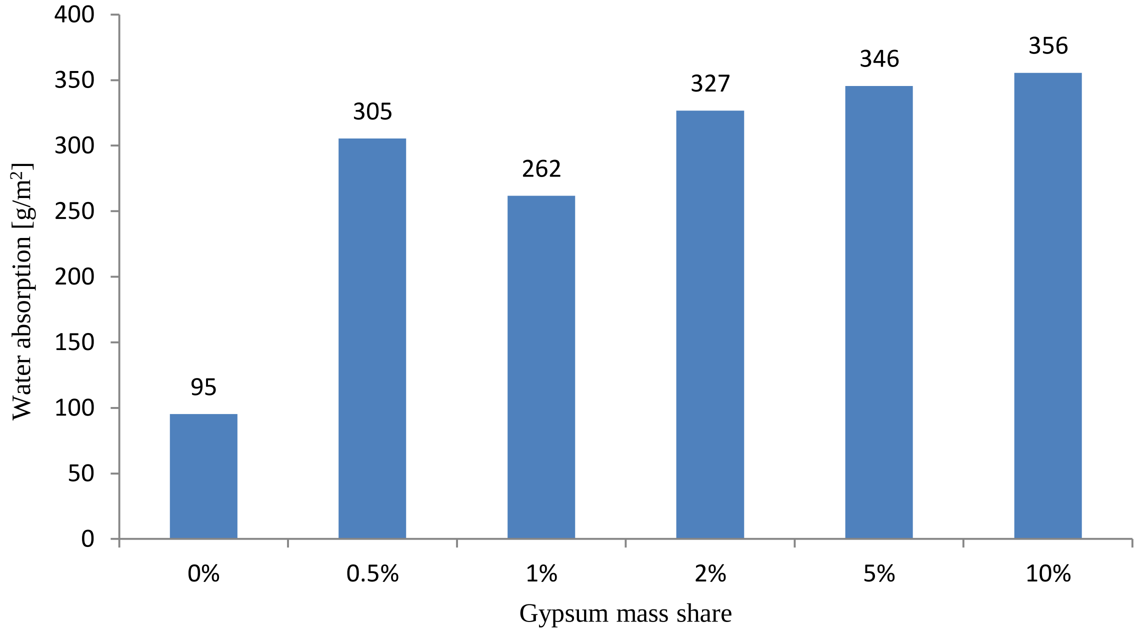

Figure 6. Influence of the mass gypsum binder share on the water absorption.

Density profile

Figure 7. presents the density profiles of high density wet-formed fibreboards with different gypsum binder shares. All variants of the tested panels reach the maximum density (within the range of 1000-1100 kg/m^3) at a thickness of 0.2 - 0.4 mm. After reaching the highest values, the density of the boards starts to decrease slightly in the entire inner zone. In the outer zone where the mesh imprint is located, at a thickness of 1.7-1.8 mm, the density of panels decreases gently to 0. Panels with the addition of a half percent and one percent of gypsum binder achieve slightly higher density values than other variants. It should be concluded that there is no special differences in the density profiles among the tested panels.

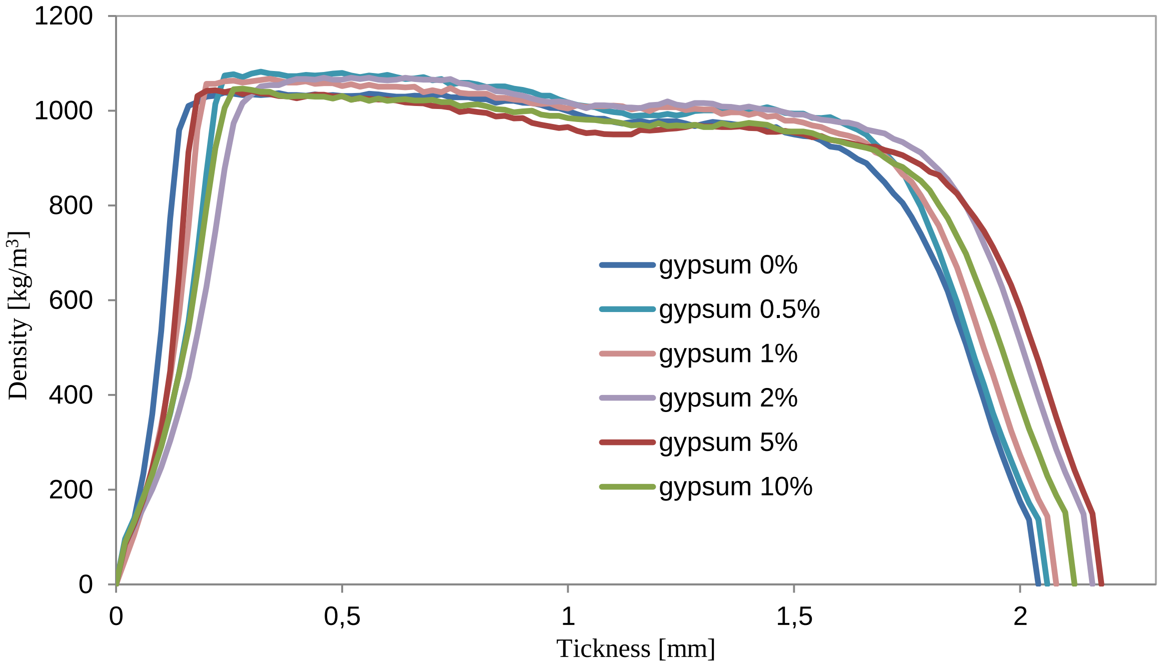

Figure 7. Density profiles of samples of panels with different mass gypsum binder share.

CONCLUSIONS

On the basis of the conducted research and analysis of their results of the properties of the wet formed fiberboards of different gypsum content, the following conclusions can be drawn:

1. The addition of gypsum binder to fibreboards reduces their hydrophobic properties.
2. The modulus of elasticity and bending strength of fibreboards with a one-percent proportion of a gypsum binder reaches the highest values. However, there is no significant influence of the gypsum content on the bending strength and modulus of elasticity of the tested panels.
3. The water absorption and thickness swelling of the panels of different gypsum share is significantly higher than for the reference panel.
4. The share of gypsum binder above 1% significantly raises the selected properties of the wet-formed fibreboard panels, like surface water absorption and contact angle.
5. There is no significant influence of the gypsum share on the density profile of the panels.

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Streszczenie: *Wpływ udziału gipsu na wybrane właściwości płyt pilśniowych mokroformowanych wysokiej gęstości.* Celem pracy było zbadanie wybranych właściwości mechanicznych i fizycznych płyt pilśniowych mokroformowanych o dużej gęstości wytworzonych w warunkach laboratoryjnych, z różnym udziałem spoiwa gipsowego w zakresie od 0 do 10% udziału masowego. Zakres badań obejmował zbadanie wytworzonych płyt pod kątem wybranych właściwości fizycznych oraz mechanicznych, w celu ustalenia wpływu udziału gipsu na właściwości płyt. Badania wykazały, że niezerowy udział gipsu (bez korelacji pomiędzy udziałem gipsu i badaną cechą) podwyższał kąt zwilżania badanych płyt oraz powodował wzrost spęcznienia, nasiąkliwości i absorpcji powierzchniowej.

Corresponding author:

Grzegorz Kowaluk
Nowoursynowska Str. 159
02-787 Warszawa, Poland
email: grzegorz_kowaluk@sggw.pl

ORCID ID:

Kowaluk Grzegorz 0000-0003-1463-0540