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Selected physical and mechanical properties of high-density wet formed fibreboards produced with different cement content

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Abstract: *Selected physical and mechanical properties of high-density wet formed fibreboards produced with different cement content.* The aim of this work was to produce, in laboratory conditions, high-density wet formed fibreboards with a different cement binder content: 0%; 0.5%; 1%; 2%; 5%; 10%. The panels were tested for their physical and mechanical properties in order to determine the effect of added cement on the properties of the boards. The results show that the mechanical parameters of the tested panels grow compare to the reference panel when the mass share of cement is 0.5%, and decreases with the cement share increase to 10%. The remaining physical parameters of the tested panels get worse with the cement content increase.

Keywords: hardboard; cement; water absorption; density profile; contact angle; wet formed fibreboard

INTRODUCTION

Cement, according to the standard PN-EN 197-1: 2012, is a hydraulic binder and a finely ground inorganic material that - when mixed with water - gives a mixture that is binding and hardening as a result of hydration reactions and processes. It remains firm and durable, also under water. Cement is produced by grinding Portland clinker, a setting time regulator and depending on the type of cement, optional non-clinker components. Clinker is made from firing the mineral raw materials such as limestone, marl or clay at 1450°C in a rotary furnace.

The binder has found a wide application in construction. It is used for mortars, concrete or cement production, but also for the production the cement boards with various additions, among others, wood fibers. Cement-fibreboards are perfect for house facades. Studies have also been carried out to check how the addition of bamboo and sugar cane fibers will affect the properties of the cement panels (Mendes et al. 2017). Chady et al. (2018) conducted research on the methods of panel evaluation and crack detection. Also, shavings was added to the cement boards. This mixture forms cement – particleboards. The addition of shavings has a positive effect on the properties of the boards. Atoyebi et al. (2018) tested the effect of adding of azobe wood shavings and palm seed shell coatings on the physical and mechanical properties of cement panels. Cement is also added to drywall to improve their mechanical properties and increase resistance to moisture (Espinoza-Herrera and Cloutier 2010). Brasileiro et al. (2013) conducted a study in which coconut fiber particles have been added to cement composites, these composites can be used for light, unstructured building materials. Wet formed fibreboards according to the standard PN-EN 316 are boards made of lignocellulosic fibers, produced under pressure and heat. Wet formed fibreboards can be divided into hard (HB) and porous/soft (SB). The carrier medium of fibers in the production process is water. The fibers used for the production of wet-buffered boards have a moisture content above 20%. In the production of wet panels, it is possible to add various hydrophobic substances, which reduces the absorbability of the boards or strengthening e.g.: glue resins.

However, on the basis of the above mentioned state-of-the-art research, it should be concluded, that there is no information about cement utilization as an additive to wet formed fibreboards, and about the properties of the panels produced. The aim of this work was to test the selected mechanical and physical properties of the wet formed fiberboards produced with use various share of cement added to fibrous mass when panels producing in laboratory conditions.

MATERIALS AND METHODS

The tested samples have been produced in the laboratory conditions from wet formed fibreboards with a assumed density of 900 kg/m^3. The panels were made of fibers with a relative moisture content of 60% obtained from pine and spruce wood. Each of the 6 panels made had a different proportion (relative to totally dry fibers) of cement (0%; 0.5%; 1%, 2%, 5%, 10%). The fibreboards have been pressed for 420 s at 200ºC and at a pressure of 5.5 MPa. All samples before the tests were conditioned at approx. 20°C and 65% air relative humidity to weight stabilization.

Modulus of elasticity and bending strength

For the static bending strength and modulus of elasticity, 8 samples with dimensions 130x50xthickness mm^3 were used for each variant with share of cement. The modulus of elasticity and bending strength test was carried out according to the formula contained in the standard PN-EN 310.

Thickness swelling and water absorption

As many as 60 samples of nominal size 50x50xthickness, mm^3, were used for the thickness swelling and water absorption test. Each 10 samples were obtained from boards with a different proportion of cement.

The thickness swelling test was carried out in accordance with the norm PN-EN 317. The tests were performed after 2 and 24 hours of soaking.

The absorbability test was conducted parallel to the thickness swelling test on the same samples.

Surface water absorption

The surface absorption test was performed on 6 samples with nominal size 120x120xthickness, mm^3. Each of the used samples had a different percentage of cement. The time in which the surface of the samples was in contact with water was 2 hours

The test was accomplished in accordance with the standard PN-EN 382-2.

Contact angle

For the contact angle test, 18 samples of HB fiberboard were used. Three samples from each variant of the panels were used for the test. Samples had a nominal size of 130x50xthickness, mm^3. Three drops of distilled water have been measured on each sample and mean and standard deviation values have been calculated for each panel variant.

The contact angle was tested at 1 and 60 seconds after dropping. Contact angle analyzer PHOENIX 300 (SEO) was used to carry out the test.

Density profile

Six samples of each panel variant with nominal dimensions 50x50xthickness, mm^3, were used to test the density profile. A density profile study was carried out using a DA-X, X-ray density profile analyzer (GreCon). The measurement was carried out at a rate of 0.10 mm/s and the sampling step was 0.02 mm.

The obtained results from the conducted tests were examined by means of analysis of variance (ANOVA) and subjected to the Student's test ($\alpha = 0.05$), in order to determine the significance of differences between the factors. The results shown in the graphs show mean values and standard deviations.

RESULTS

Modulus of elasticity

The graph (Figure 1) shows how the elastic modulus has changed depending on the amount of cement addition to the panel. The values of modulus of elasticity ranged from 2457 to 4278 N/m^2.

Fibreboard with 0.5% cement addition reached the highest modulus of elasticity of 4278 N/m^2, it is higher by 600 N/m^2 than the modulus of elasticity of the control board. The addition of 1% cement binder reduced the module values by approximately 300 N/m^2 compared to the reference board. The boards with 1%; 2%; and 5% addition of cement achieved very similar results and they were not statistically different. The smallest modulus of elasticity was obtained for boards with 10% addition of cement binder and it amounted to 2457 N/m^2, it is almost twice less than at the board with a 0.5% addition of cement. It can be concluded that the modulus of elasticity of fibreboards with the addition of cement showed lower values than the modulus of elasticity in cement-particle boards (Okino et al. 2004). Generally, the increase the content of the cement in the range of 0.5 – 10% w/w causes reduction of modulus of elasticity values of the panels produced with use of cement.

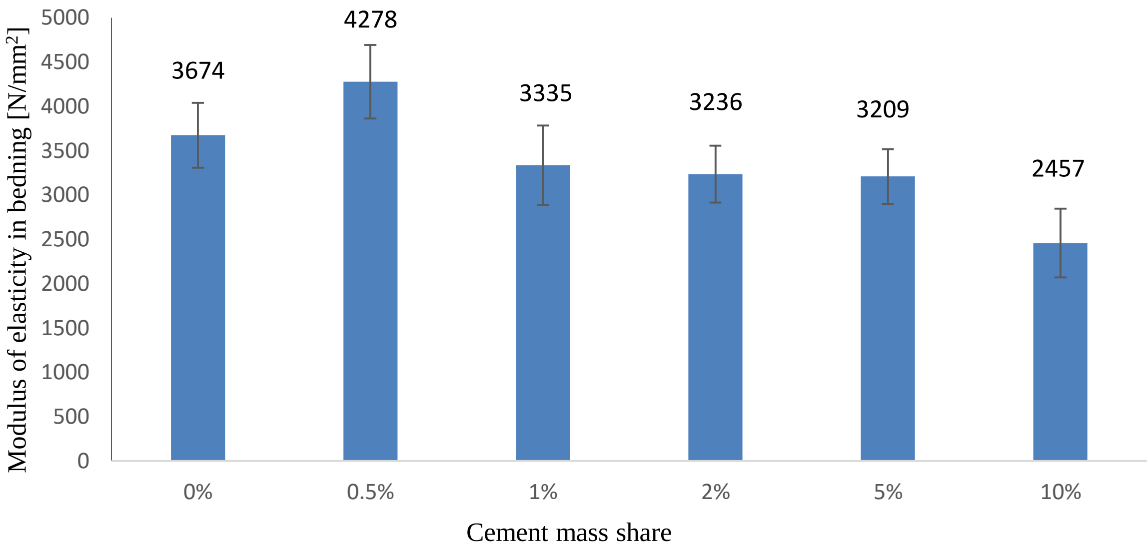

Figure 1. Influence of the mass cement binder share on the modulus of elasticity.

Bending strength

The diagram (Figure 2) shows the effect of a different amount of cement binder additive on bending strength. Strength values ranged from 16 to 32 N/mm^2.

The highest value was shown by the board with 0.5% cement binder, it was 32 N/mm^2 and the board without added cement, which value was 30 N/mm^2. The lowest strength was achieved by the panel in which the cement addition constitutes 10% of the fiber mass and it was 16 N/mm^2. The bending strength of boards with 1%, 2%, 5% does not differ statistically from one another and ranges from 23 to 26 N/mm^2. It can be observed that boards with cement addition have lower values of bending strength than medium density fibreboards (Jiang and Kamdem 2004). It also can be concluded that with the increase of the cement content in the range of 0.5 – 10% w/w the bending strength of the tested panels decreases.

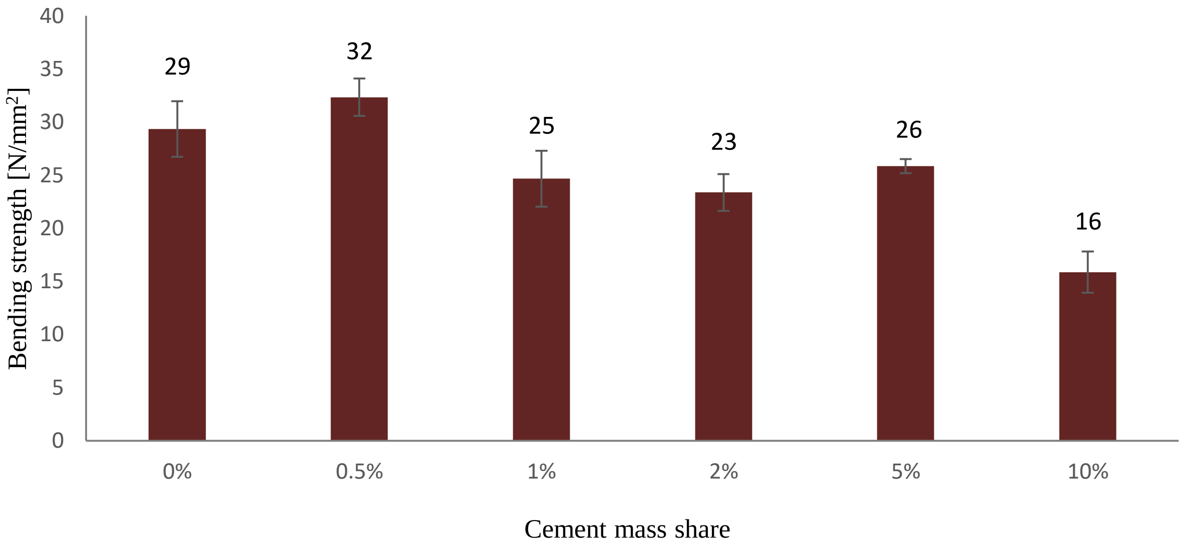

Figure 2. Influence of the mass cement binder share on the bending strength.

Thickness swelling test

The plot (Figure 3) shows how the effect on the thickness swelling of the panel after 2 and 24 hours has a different addition of cement.

All variants achieved lower thickness swelling values after two hours compared to values after 24 hours. The lowest swelling value, both after 2 and 24 hours, was achieved for a control panel (0%) without cement addition. The swelling values of the reference board were, respectively, 29 and 52%. The highest gain in thickness was achieved by boards with a 5% addition of cement binder. The increase in thickness after 2 hours was 85% and after 24 hours 101%. It can be concluded that with the cement content increase from 0 do 5% w/w the thickness swelling of the tested panels raises.

Panels with 0.5; 1; 2; 10% addition of cement reached similar swelling values after 2 and 24 hours of soaking in water. According to a statistical analysis based on a standard deviation, it can be concluded that the average swelling values analyzed for variants with 0.5, 1, 2, 5, 10% share of the cement binder does not significantly different.

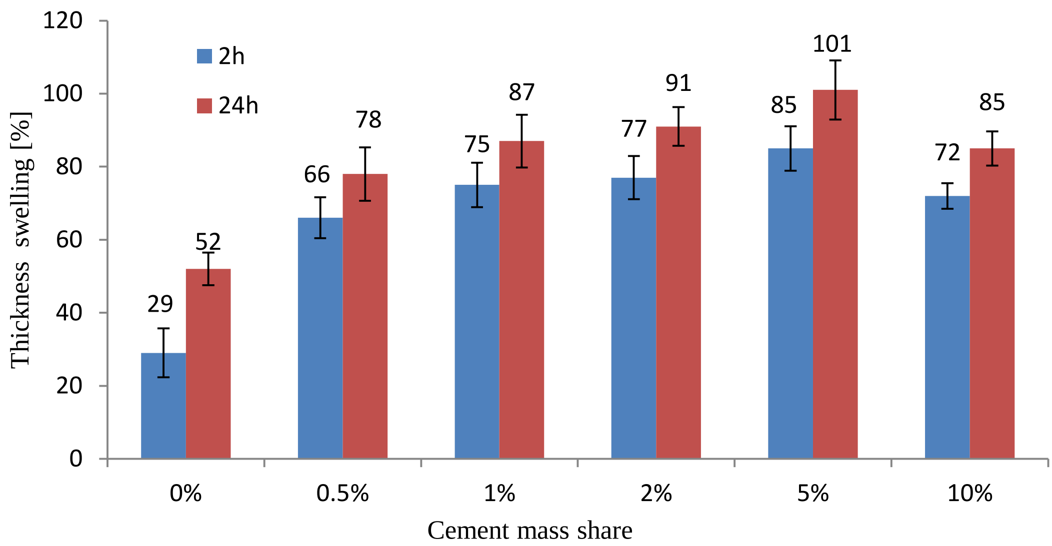

Figure 3. Influence of the mass cement binder share on swelling after different times of soaking.

Water absorption

The graph (Figure 4) shows how the water absorbability changes depending on the amount of cement binder added in wet formed fibreboards panels.

The diagram shows that in all variants the absorbability of the panels after 2 hours of soaking in water is less than the absorbability after 24 hours of soaking. The lowest absorbability achieved the reference panel and the board with 0.5% addition of cement. The highest absorbability was achieved by the board with 5% cement addition. However, it does not statistically different from the other panels to which the cement binder was added in amounts of 1%; 2%; 10%. It can be concluded that panels with cement mass share achieve higher water absorption values than MDF panels, where the water absorption was 65% (Arevalo and Peijs 2016). Similar to swelling in thickness, it can be concluded, that with the cement content increase from 0 do 5% w/w the water absorption of the tested panels raises.

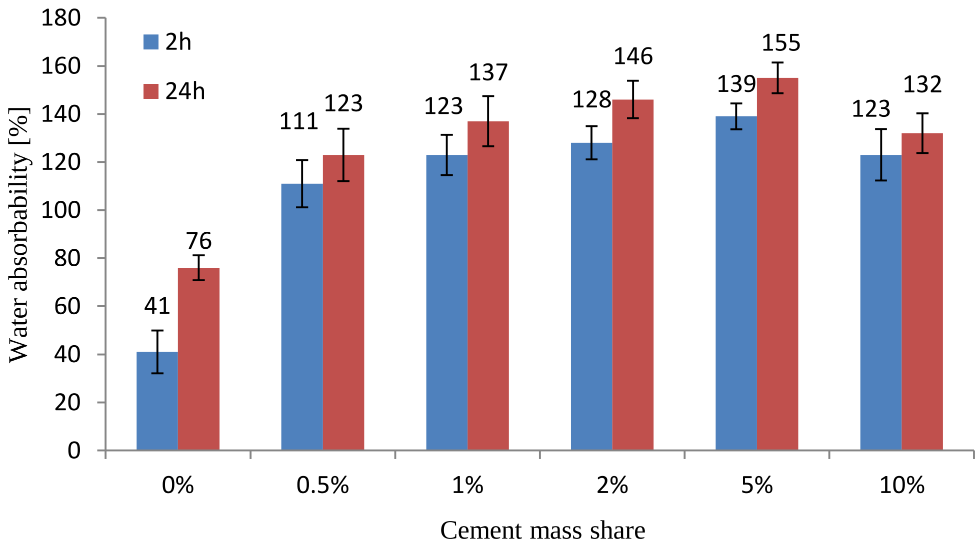

Figure 4. Influence of the mass cement binder share on absorbability after different times of soaking.

Surface water absorption

The graph (Figure 5) shows how the surface absorption varies depending on the share of cement addition. The surface absorption values, depending on the amount of cement addition to the board, range from 114 g/m^2 to 435 g/m^2.

The lowest value was achieved by the panel without the addition of cement binder and it amounted to 114 g/m^2. The highest value was reached by the board with a 10% addition of cement and it amounted to 435 g/m^2. The fibreboard with 0.5% cement content reached a value of about 140 g/m^2 higher than the control board. Boards with 1%; 2%; 5% added binder subsequently achieved surface absorption values: 399 g/m^2, 413 g/m^2, 435 g/m^2.

The graph shows that with the increase in the cement additive the surface absorption of the tested panels increases.

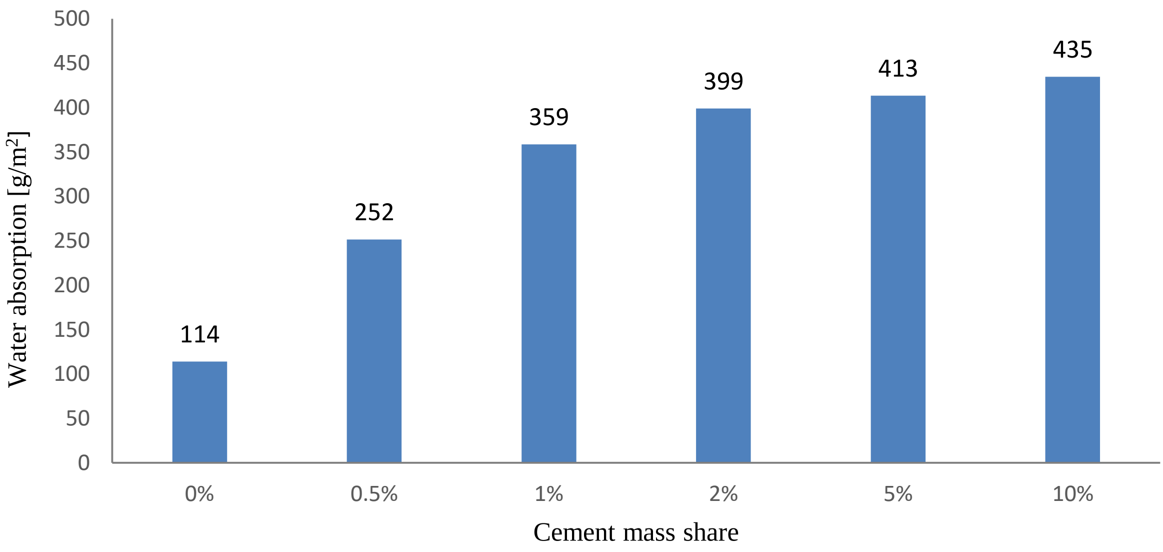

Figure 5. Influence of the mass cement binder share on the surface water absorption.

The contact angle

The relationship between the contact angle and the different proportion of cement addition is shown in Figure 6.

The contact angle after 1 second from the drop setting in each case is greater than the contact angle measured after 60 seconds. The highest contact angle was achieved with a sample with 0.5% cement content. Both after 1 and 60 seconds it has reached values greater than 90º, which means that the wettability is low. Low wettability was also achieved by boards with 1% and 2% added cement, after 1 second from dropping. The remaining panels after 1 second and 60 seconds of testing have achieved high wettability. In the case of panels with 5% and 10% cement content, the drop was absorbed after 50 seconds and 20 seconds, respectively. This indicates very high wettability of the fibreboards.

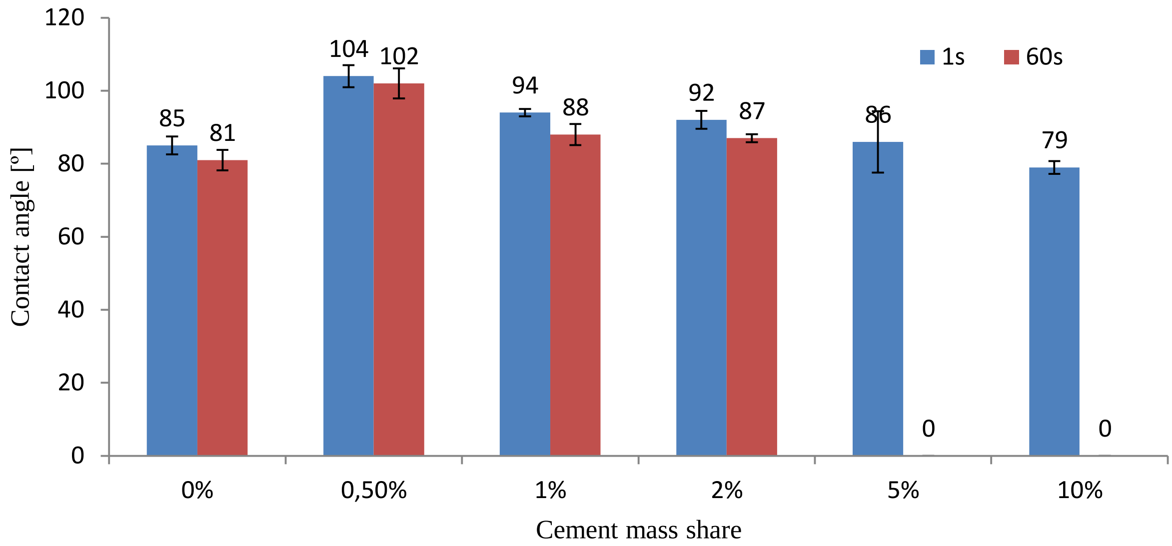

Figure 6. Influence of the mass cement binder share on the contact angle of the tested panels.

Density profile

Diagram (Figure 7) shows the density profile of 6 samples obtained from boards with different cement content. All the tested panels had the highest density from 0.2 mm to 0.5 mm thickness and it was about 1000 kg/m^3. The density of the panels slowly dropped to a density of about 900 kg/m^3 at a thickness above 2 mm. From a thickness of about 2 mm, the density of the panels drastically decreases. The boards with 5% addition of cement showed the highest density. There is no special differences of the density profiles among tested panels of various mass share of cement.

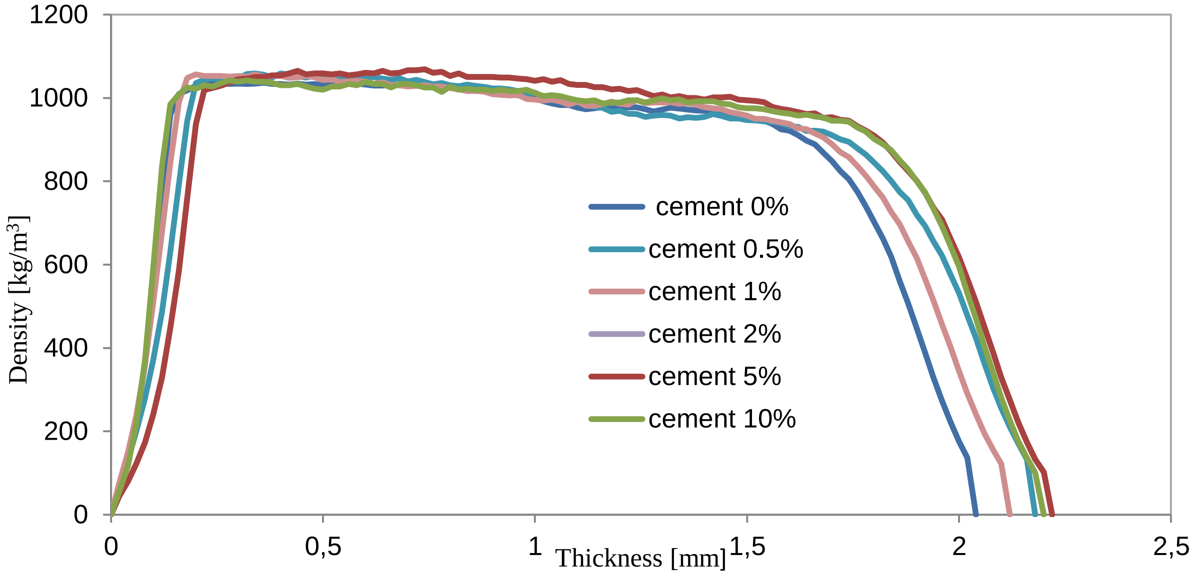

Figure 7. Density profile of samples with different share of cement binder.

CONCLUSIONS

From the research and analysis obtained results, the following conclusions can be drawn:

1. The addition of 0.5% cement binder positively affects the modulus of elasticity and bending strength. On the other hand, higher proportions of cement from 0.5 to 10% w/w worsen the mentioned mechanical properties of the tested panels.
2. In the wet formed fibreboards, together with the addition of cement from 0 to 5%, the thickness swelling and water absorption increases.
3. The raise of the cement content in wet formed fiberboards from 0 to 10% w/w causes significant raise of the surface water absorption.
4. The addition of cement in the range of 0.5 – 10% w/w lead to decrease of water contact angle.
5. There is no significant differences between density profiles of the wet formed high density panels produced with use different cement content in the range of 0 – 10% w/w.

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Streszczenie: *Wybrane właściwości fizyczne i mechaniczne płyt pilśniowych mokroformowanych wysokiej gęstości wytworzonych z różnym udziałem cementu.* Celem pracy było wytworzenie w warunkach laboratoryjnych płyt pilśniowych mokroformowanych o wysokiej gęstości, z różnym udziałem spoiwa cementowego: 0%; 0.5%; 1%; 2%; 5%; 10%. Wytworzone płyty zostały zbadane pod kątem ich wybranych właściwości fizycznych oraz mechanicznych, w celu ustalenia wpływu dodatku cementu na właściwości płyt. Badania wykazały, że parametry mechaniczne płyt w stosunku do płyt referencyjnych, gdy udział cementu wynosi 0,5%, a spadają wraz ze wzrostem udziału cementu do 10%. Pozostałe parametry fizyczne badanych płyt pogarszają się wraz ze wzrostem udziału cementu.

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