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GYPSUM COMPOSITES WITH WOODCHIP AND SAWDUST FILLERS*

Aleksandra Repelewicz, Katarzyna Regulska**

Czestochowa University of Technology, Department of Civil Engineering

Abstract

Gypsum composites have been gaining increasing interest during last years. The focus on increasing their production in Poland results from the rich, countrywide natural gypsum sources and the growing amounts of synthetic gypsum derived from flue gas desulfurization in domestic power plants. Nowadays, the environment-supporting options are in game. Comparison of results of tests concerning the physical and mechanical properties of gypsum composites with organic fillers: wood sawdust and chips is described in the paper.

Keywords: Gypsum composites, organic fillers, woodchip fillers, sawdust fillers

1. Introduction

The paper presents a comparison of results of tests concerning the physical and mechanical properties of gypsum composites with organic fillers in the form of wood sawdust and chips. The detailed research results are presented in papers (Regulska et al., 2019a, 2019b). The aim of the research was to determine the influence of the composition and preparation of the fillers on the quality of gypsum composites, with particular emphasis on their strength and thermal properties. The physical and mechanical properties of gypsum composites are strongly influenced by the mineralization process of organic fillers. The research has yielded favorable results in terms of the possibility to use composites with fillers from both sawdust and wood chips in the construction industry. These materials are waste materials from the woodworking process and are easily available in Poland. Production of building materials from gypsum composites with these fillers is an environmentally friendly activity.

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** Corresponding author: e-mail: aleksandra.repelewicz@pcz.pl

2. Research methodology

In the research, the poured gypsum technology was used, which provides the most extensive ability to determine the relationship between the properties of composites and the composition and physical properties of gypsum mixes. This method also guaranteed an even distribution of the composite filler particles. Both sawdust and chips were delivered from the same carpentry workshop. This waste came from processing of coniferous wood (without bark). Due to the size of the samples (4 x 4 x 16 cm), the material was sifted through 6- and 1-mm mesh screens to eliminate the thickest and finest fractions. The bulk density of the filler in the air-dry condition was: wood sawdust: 44 kg/m^3 while loose - 60 kg/m^3 while compacted; chips: 130 - 140 kg/m^3. The binder was hemihydrate gypsum produced by the Zakłady Gipsowe "Dolina Nidy" plant.

A number of technological recipes was designed. The components of the gypsum mixes were determined in percentage by weight. The water-gypsum ratio (W/G) was variable in the range of 0.7 to 1.0, which was also intended to show the effect of the quantity of water on the consistency of the mixtures and on the physical and mechanical properties of the materials produced.

The proportion of sawdust in the mixtures was 6, 7, 8, 9, and 10% by weight, which corresponded to 11.5 to 22.2% of the weight of gypsum. Due to their lower bulk density, chips were dosed in the amount of 8, 10, 12, and 14%. This corresponded to 14.8 to 32.5% of the weight of gypsum. Five percent aqueous solutions of calcium chloride, calcium hydroxide, and aluminum sulphate were used for mineralization. The simplest way of mineralization was applied, in which the solutions were used as the batched water.

Samples were prepared for testing as 4 x 4 x 16 cm beams.

The scope of tests included bending strength, compressive strength, and apparent density in the air-dry state and after drying to solid mass. The gypsum samples were formed from mixtures containing sawdust filler and, in separate tests, from chips - without the use of mineralization - as a starting material for further research. Then, for full testing, samples were selected which were made according to those formulas that provided the composites with a compressive strength above 3 MPa in the partial tests. This value is the standard strength limit for sawdust gypsum composites (Chladzynski, 2007; PKN, 1986; PKN, 2008; PKN, 2009). The bending and compressive strength was determined using a strength press. The bending frame was up to 15 kN, the compression frame was up to 250 kN, the press accuracy was up to 0.1 kN.

3. Research results

Compared to the normal consistency of gypsum grout - according to the Southard method, recommended for use by the Polish standard (PKN, 1986), gypsum mixes were mostly dense and plastic. Only in the case of the ratio of water to the dry components (gypsum plus fillers), which was between 0.75 and 0.82, the sample flow corresponded to the normal consistency.

An analysis of the strength test results leads to the conclusion that the amount of sawdust filler can be up to twice as high as the recommendations specified in the standard (PKN, 1955) without the compression strength dropping below 3 MPa. Of note is also the relatively high bending strength and low apparent density of the samples. With an increase in the water-gypsum ratio, the strength of gypsum slightly decreases.

Wood chips can be used as a filler in even larger quantities than sawdust. In general, chips ensure higher strength of gypsum compared to sawdust. Of note is the significant increase in bending strength, often exceeding the increase in compressive strength. This phenomenon can probably be attributed to the action of the elongated fibers of the filler.

As the amount of the filler and the value of the water-gypsum ratio increase, the apparent density of dry samples decreases, in extreme cases (at W/G = 1.0) to as little as approx. 700 kg/m^3, with satisfactory compressive strength and high load bearing capacity.

The results of the research presented in papers (Regulska et al., 2019a, 2019b) provided the basis for a graphical presentation of the basic physical and mechanical characteristics of sawdust and chipboard gypsum composites depending on the composition of the mixtures, i.e. the amount of the filler and the gypsum-water ratio (W/G). These relationships are shown in Figs. 1 - 6. In very general terms, they can be characterized as follows: the relationship between the apparent density of sawdust gypsum composites (Fig. 1) and wood chip gypsum composites (Fig. 2) and the composition of the mixture and the water-gypsum ratio generally indicates a decrease in the value of the apparent density with an increase in the amount of the filler and water. This trend is more pronounced in the case of chip gypsum composites, as evidenced by the shape of the graph's surface.

The bending and compression strengths of sawdust gypsum composites (Figs. 3 and 4) do not show large fluctuations in the whole range of tested variables. A slight decrease in value (slope of the surface) is observed with an increase in the water-gypsum ratio, with the compression strength dropping below 3 MPa starting from W/G = 0.87.

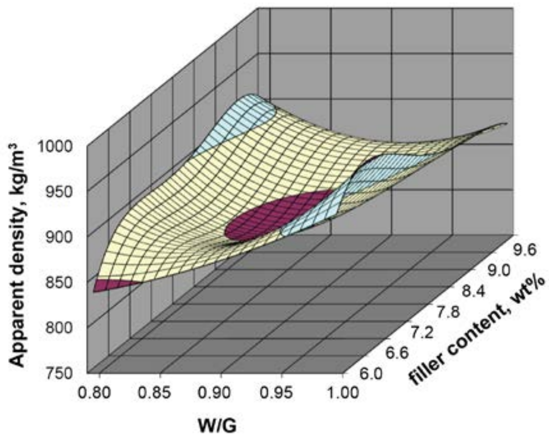

Fig. 1. The relationship between the apparent density of sawdust gypsum composites and the filler content and the water-gypsum ratio

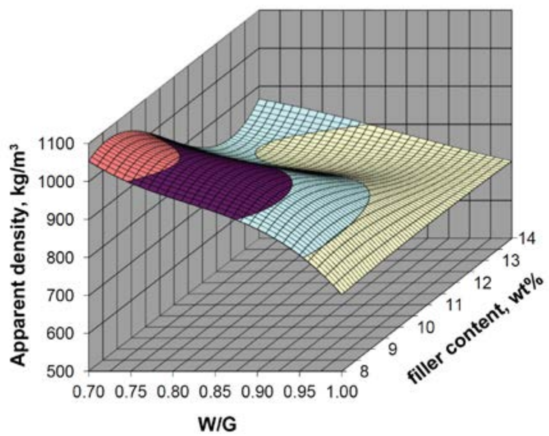

Fig. 2. The relationship between the apparent density of woodchip gypsum composites and the filler content and the water-gypsum ratio

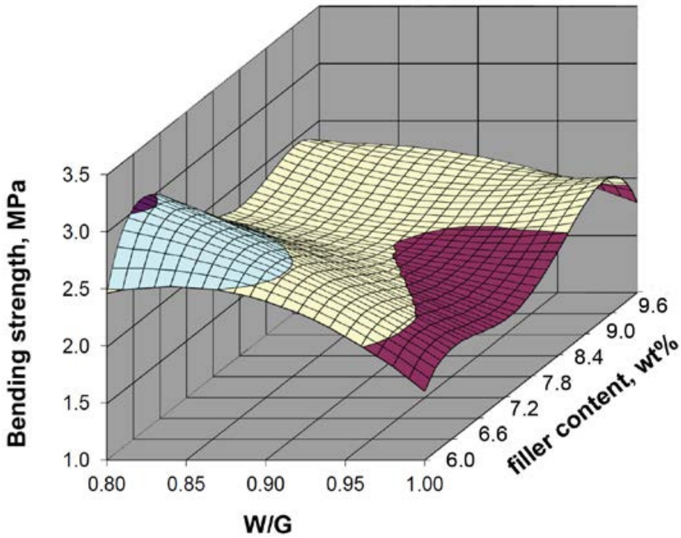

Fig. 3. The relationship between bending strength of sawdust gypsum composites and the filler content and the water-gypsum ratio

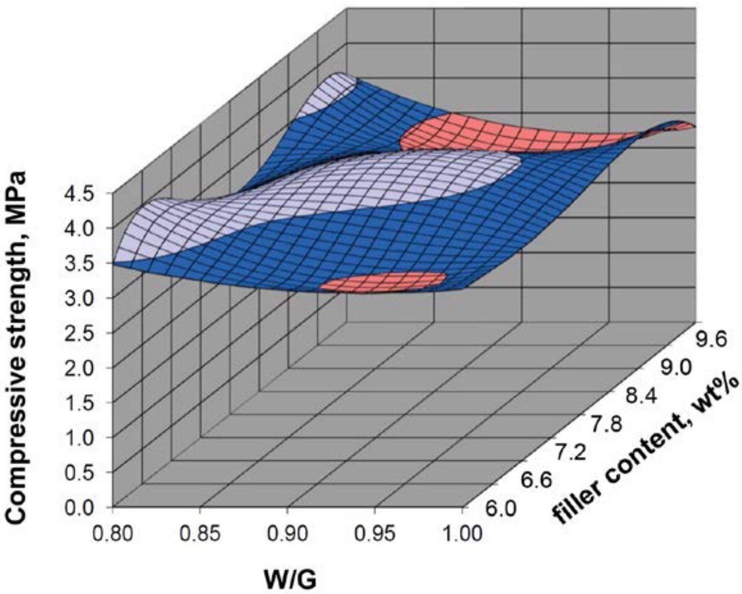

Fig. 4. The relationship between compressive strength of sawdust gypsum composites and the filler content and the water-gypsum ratio

The bending strength of chip gypsum composites (Fig. 5) reaches the maximum values in the W/G range from 0.8 to 0.9 with the filler content of 9 to 12% by weight. Generally, it is higher than the compressive strength, which reaches its maximum values only in the case of a very low water content in the mixture (W/G of about 0.7) and the filler content not exceeding 9% by weight (Fig. 6). It seems that the high bending strength can be explained by the elasticity of the non-mineralized particles of the chip filler, which increase the load bearing capacity of gypsum composites formed from such a mixture.

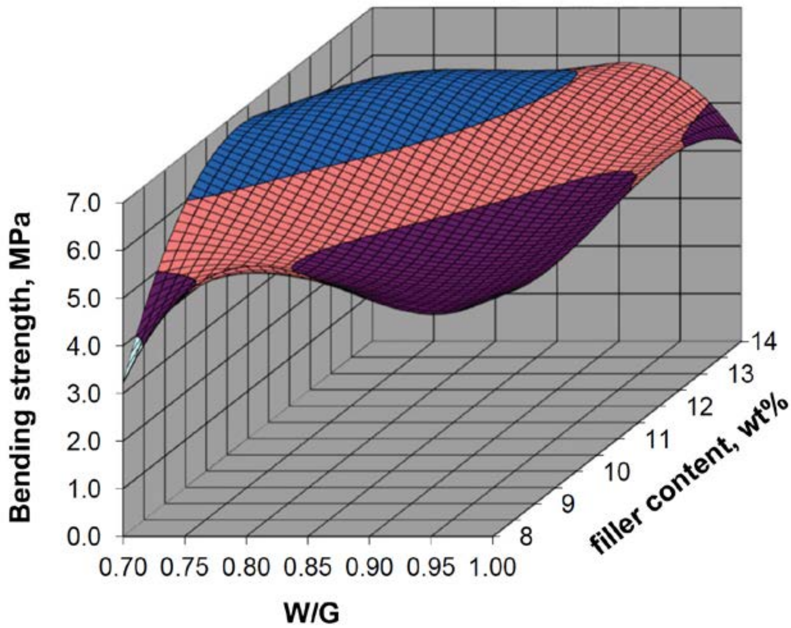

Fig. 5. The relationship between bending strength of woodchip gypsum composites and the filler content and the water-gypsum ratio

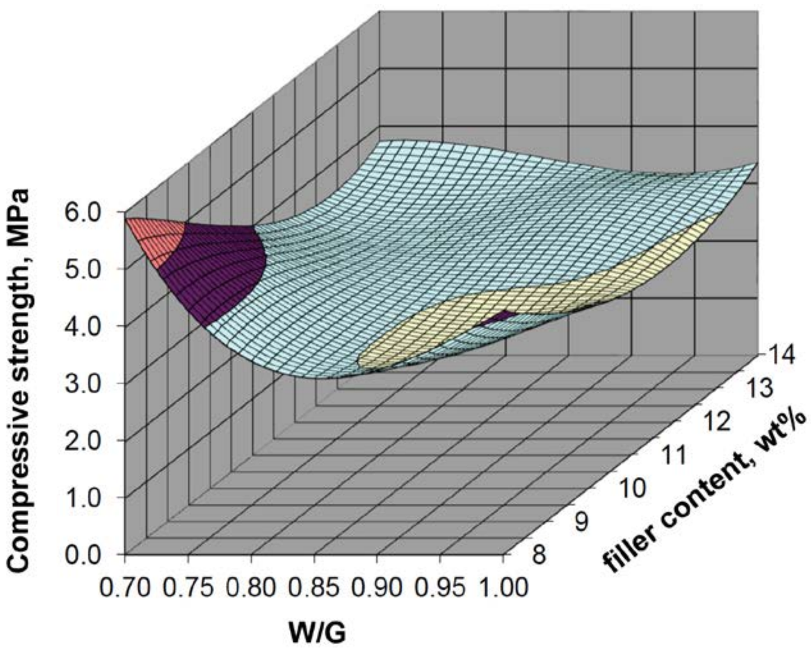

Fig. 6. The relationship between compressive strength of woodchip gypsum composites and the filler content and the water-gypsum ratio

A graphical presentation of the relationship between the aforementioned mechanical properties and the content of mineralized sawdust and chips in the composite is shown in Figs. 7 - 18. They illustrate the relationship between the bending and compressive strengths of composites with fillers mineralized with particular agents and the amount of the filler and the value of the water-gypsum ratio.

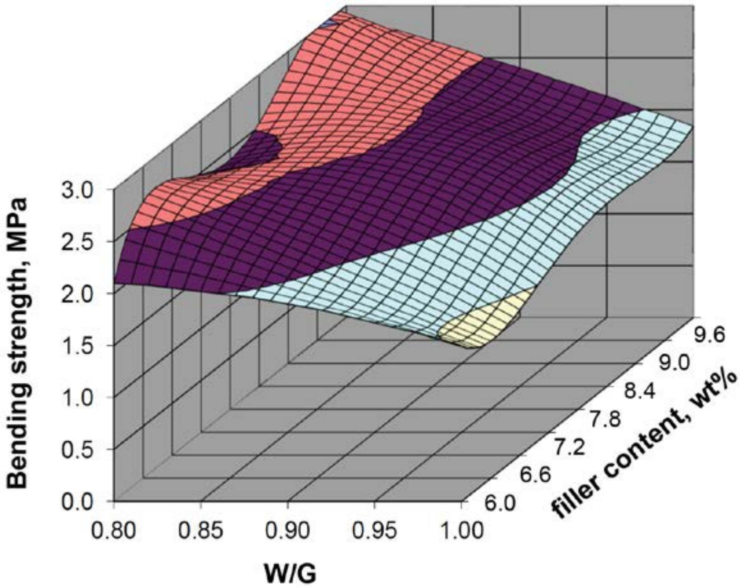

Fig. 7. The relationship between bending strength of sawdust gypsum composites mineralized with a solution of $CaCl_2$ and the filler content and the water-gypsum ratio

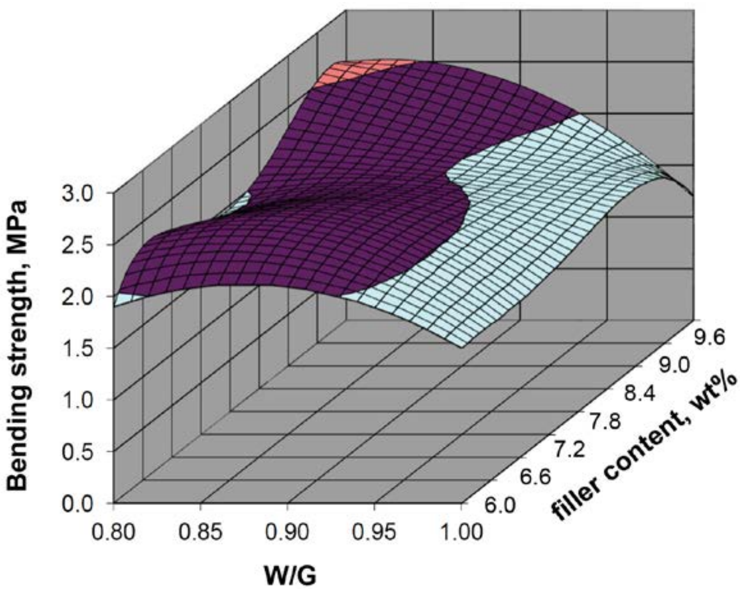

Fig. 8. The relationship between bending strength of sawdust gypsum composites mineralized with a solution of $Ca(OH)_2$ and the filler content and the water-gypsum ratio

After testing of the samples with non-mineralized fillers, the impact of mineralizers on the properties of fresh mixtures and on samples of hardened composites was checked.

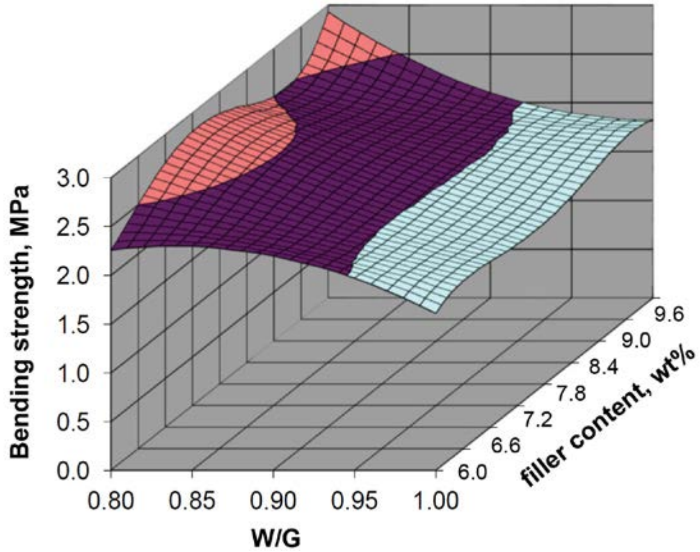

Fig. 9. The relationship between bending strength of sawdust gypsum composites mineralized with a solution of $Al_2(SO_4)_3$ and the filler content and the water-gypsum ratio

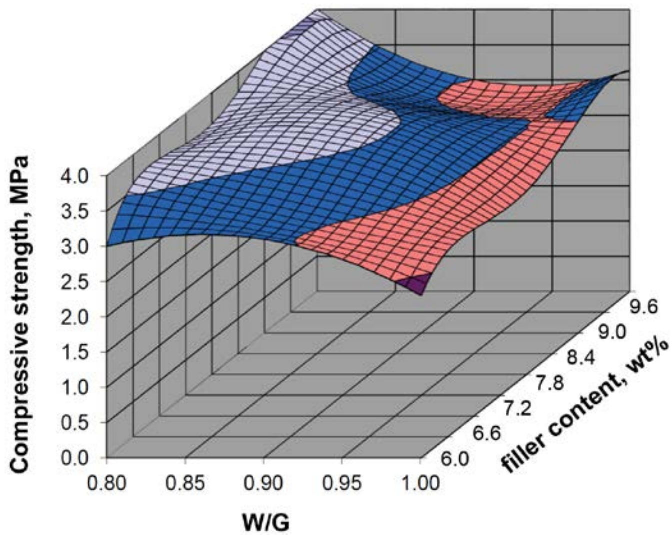

Fig. 10. The relationship between compressive strength of sawdust gypsum composites mineralized with a solution of $CaCl_2$ and the filler content and the water-gypsum ratio

In the case of sawdust mineralized with $CaCl_2$ solution, the bending strength tends to increase with an increase in the amount of the filler and water in the mixture. This regularity was repeated in all series of samples with different water-gypsum ratios. A similar trend was observed with regard to compression strength. Gypsum composites with sawdust mineralized with a solution of $Ca(OH)_2$ showed generally lower bending strength than the composites described above, while their compression strength increased slightly in comparison with samples with non-mineralized filler. This is particularly the case if the value of W/G is equal to 0.8 and 0.9.

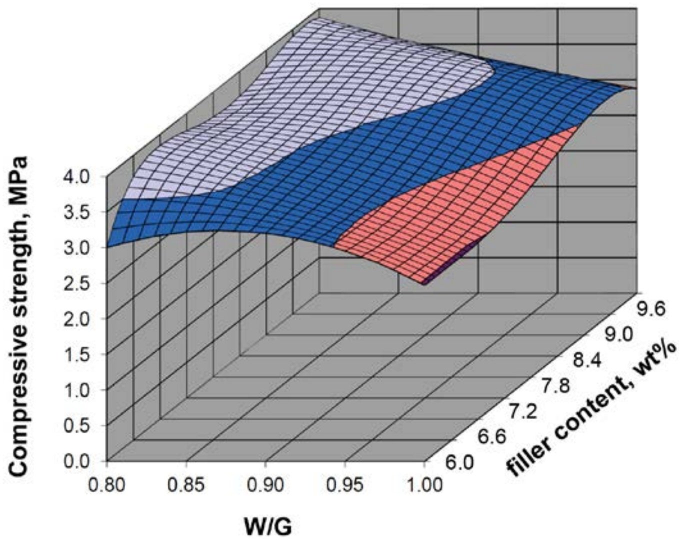

Fig. 11. The relationship between compressive strength of sawdust gypsum composites mineralized with a solution of $Ca(OH)_2$ and the filler content and the water-gypsum ratio

In the case of sawdust mineralization with a solution of $Al_2(SO_4)_3$, no major impact of the mineralizer on the strength of the composites was noted.

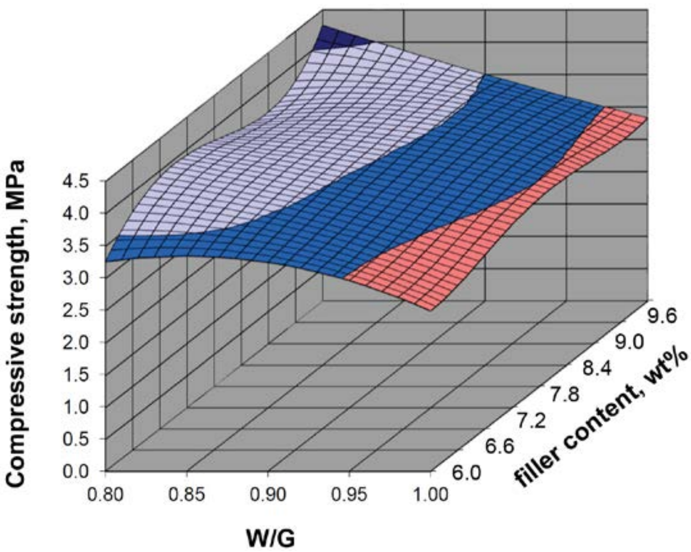

Fig. 12. The relationship between compressive strength of sawdust gypsum composites mineralized with a solution of $Al_2(SO_4)_3$ and the filler content and the water-gypsum ratio

The impact of the mineralizers on the mechanical properties of gypsum composites is even more pronounced when chips are used as the organic filler. Samples with a non-mineralized filler showed the highest bending strength. Mineralization resulted in a clear decrease in bending strength. An inverse relationship was observed for compressive strength. Regardless of the type of mineralizer used, samples of composites with mineralized chips showed higher compressive strength values. This was particularly noticeable in composites made of mixtures with low water-gypsum ratios (0.7 and 0.8).

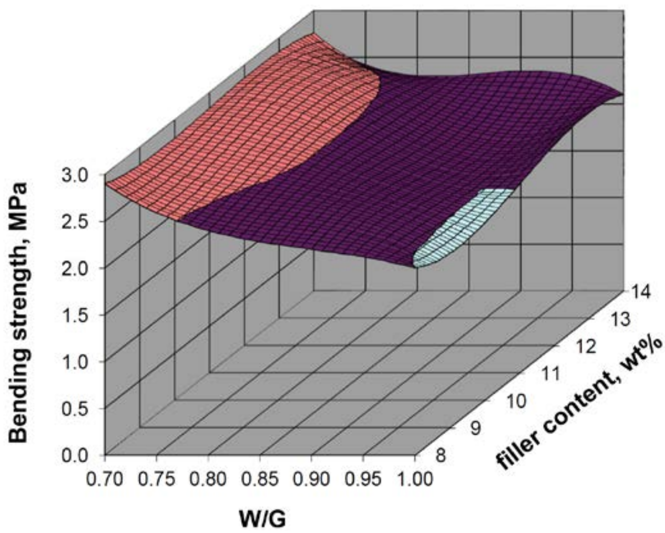

Fig. 13. The relationship between compressive strength of woodchip gypsum composites mineralized with a solution of $CaCl_2$ and the filler content and the water-gypsum ratio

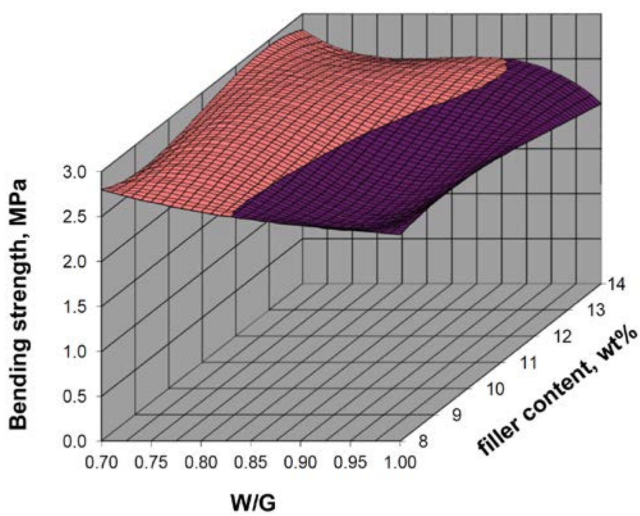

Fig. 14. The relationship between compressive strength of woodchip gypsum composites mineralized with a solution of $Ca(OH)_2$ and the filler content and the water-gypsum ratio

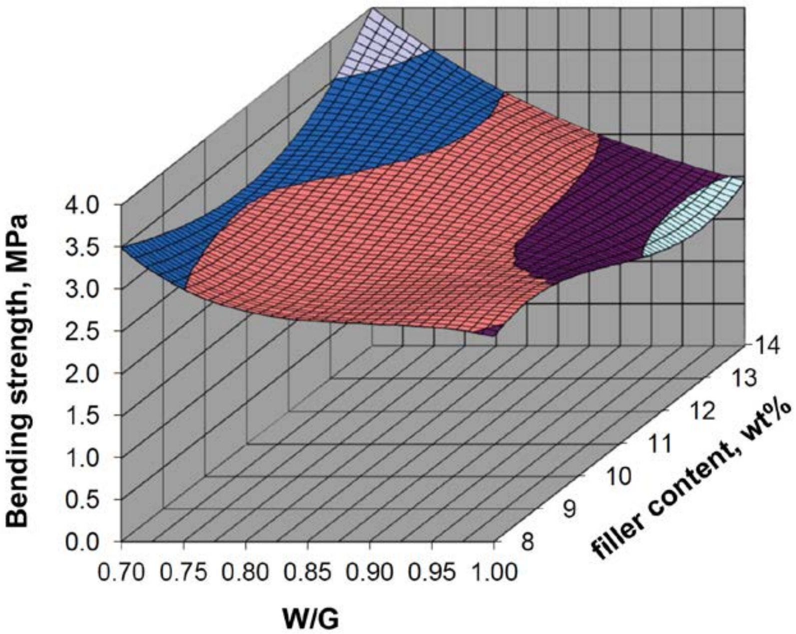

Fig. 15. The relationship between bending strength of woodchip gypsum composites mineralized with a solution of $Al_2(SO_4)_3$ and the filler content and the water-gypsum ratio

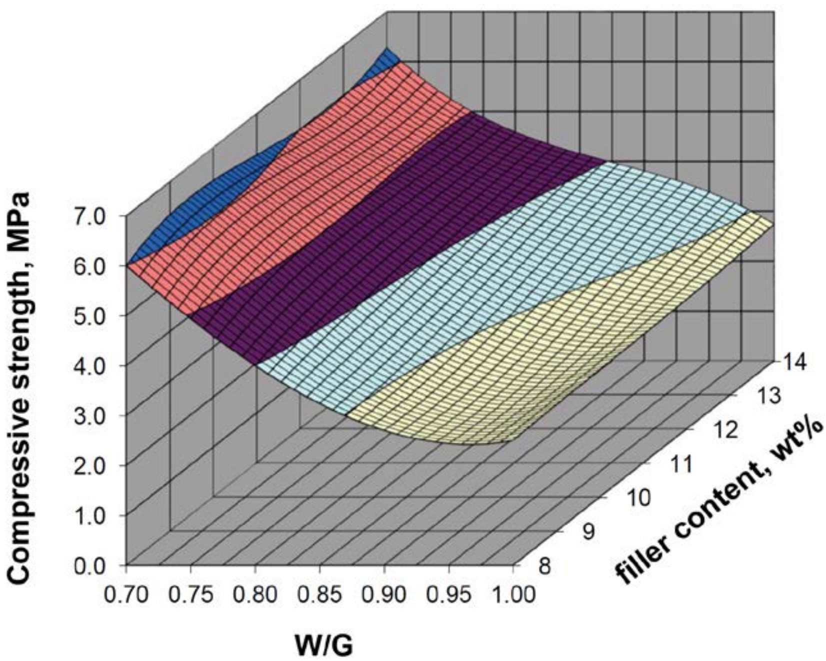

Fig. 16. The relationship between compressive strength of woodchip gypsum composites mineralized with a solution of $CaCl_2$ and the filler content and the water-gypsum ratio

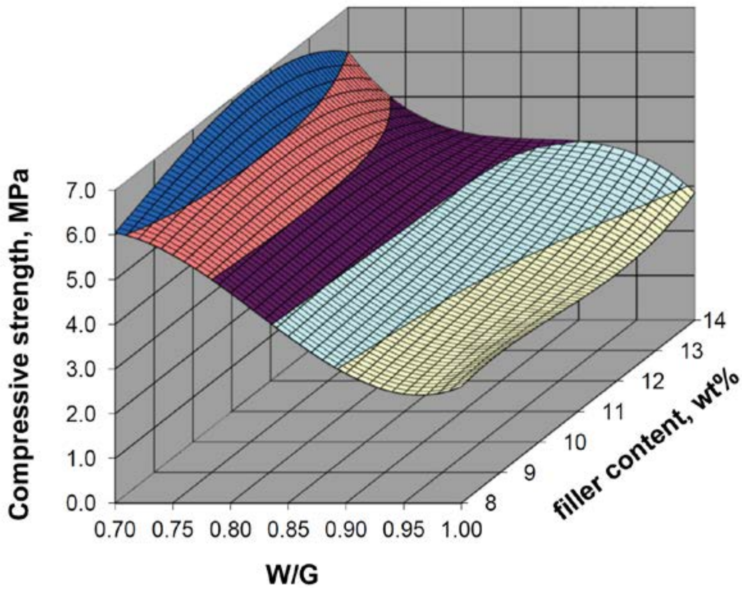

Fig. 17. The relationship between compressive strength of woodchip gypsum composites mineralized with a solution of $Ca(OH)_2$ and the filler content and the water-gypsum ratio

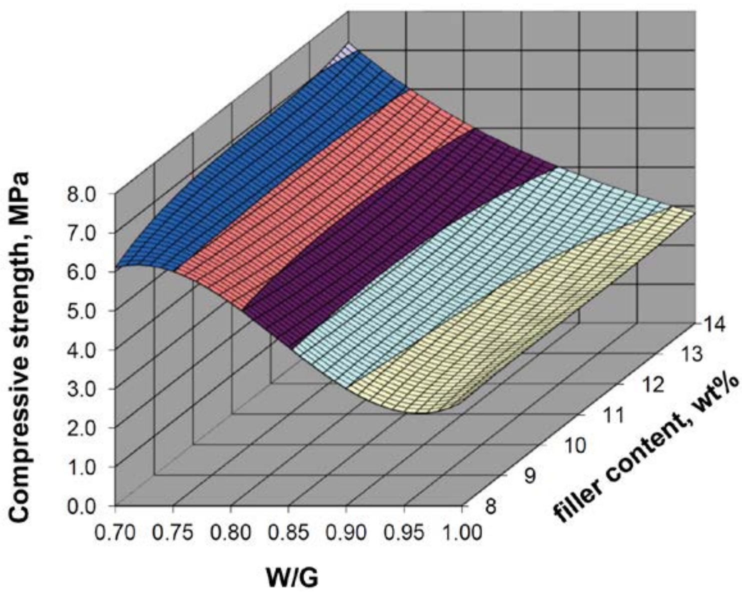

Fig. 18. The relationship between compressive strength of woodchip gypsum composites mineralized with a solution of $Al_2(SO_4)_3$ and the filler content and the water-gypsum ratio

4. Conclusions

To summarize the tests carried out on gypsum samples containing organic fillers in the form of sawdust and non-mineralized chips, the existing relationships between the amount of the filler and the compressive strength of the materials were determined. It was determined, first of all, that these composites can be made from mixtures containing two and three times the amount of filler compared to the recommendations of the standard (PN-B-14550). To specify this data in relation to sawdust, it can be assumed that its proportion in the mixture cannot exceed 9% by weight, which corresponds to 20% of the weight of gypsum. As far as chips are concerned, it is possible to increase the amount of chips in the mixture to 14% by weight, while maintaining the water-gypsum ratio of 0.7 - 0.8, which guarantees compressive strength above 3 MPa. With an increase in the W/G to 0.9 or 1.0, some samples may reach values slightly lower than 3 MPa. The high bending strength of the samples, which generally exceeds the compressive strength, could provide the possibility to design gypsum components for which the load bearing capacity is an important technical parameter. However, this requires further research. An analysis of the impact of the water-gypsum ratio on the properties of gypsum composites discussed herein leads to the conclusion that as the ratio increases, the apparent density decreases, especially if chips are used as the organic filler. However, this decrease is not accompanied by a significant reduction in mechanical strength. It seems that the reason for this may be the absorption of the excess batched water by the organic filler, which absorbs water to a greater extent than mineral fillers. When the ratio of water to the dry components (gypsum + filler) is analyzed, the ratio is between 0.55 and 0.88 for all the tests completed. This may explain the small differences in the strength of the composites despite the high content of weak filler.

The research has shown that it is possible to significantly increase the amount of organic fillers (both chips and sawdust) in gypsum composites without any major impairment to the quality of the composites. This can translate into savings of the gypsum binder and higher utilization of waste from the wood industry, which is a large sector in Poland. Both of these factors are beneficial to the natural environment.

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