

Properties of gypsum composites with sawdust

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Abstract. Gypsum composites have been gaining increasing interest within last decades. Nowadays, the environment-supporting options are regaining more advocates. Thus, organic fillers are back in game. The physical and mechanical properties of gypsum composites with sawdust were tested and are described in the paper. The influence of gypsum mixture composition, the water/gypsum ratio and appropriate mineralization on the composite properties were examined. Present study focuses on the durability, thermal properties, natural radioactivity and susceptibility to biological corrosion of the tested materials.

1. Introduction

Gypsum composites have been gaining increasing interest within last decades. Additionally, 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.

Thermal and sound-proofing properties of those materials are widely known and can be additionally improved by increasing the porosity. This can be achieved by foaming or adding pore-forming organic or non-organic agents. Different fillers can be added to gypsum plaster in order to modify its physical properties.[1] Properly applied additives can improve physical and thermal conductivity (expanded silica gel granules) or reinforce the structure (glass fibers, carbon fibers etc.).

Nowadays, the environment-supporting options are regaining more advocates. Thus, organic fillers, represented by sawdust are back in game. This raw and easy-accessible material can be additionally mineralized to create the desired physical and mechanical properties of the building material. This, apart from protection against biological corrosion, facilitates compacting of gypsum mixtures during the formation of samples for laboratory tests.

There are three different methods of gypsum composites production: pouring, casting and underwater method, where pouring is recognized as the most advantageous method applied in researches. It allows determination of the interrelation between the properties of hardened composites and the composition and physical properties of gypsum mixtures. Moreover, this method ensures more uniform distribution of filler's particles.

Existing studies use different organic and non-organic fiber types, while present study focuses on the gypsum with different mineralized or non-mineralized sawdust content and varying water-gypsum ratio.

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2. Methodology

In the present study, the pouring method was applied with 16 technological recipes. Sawdust was delivered from a carpentry workshop after softwood processing. Prior to the experiments, this raw material was sieved through 6 and 1 mm screens to remove organic material and thick particles.

The bulk density of the filler in the air-dry condition was:

-130 kg / m³ while loose

-140 kg / m³ while compacted.

The gypsum was the semi-water gypsum of the "Nida Valley" Gypsum Factory.

The content of sawdust in the mixtures was respectively 6, 7, 8, 9 and 10%, which, in relation to the weight of gypsum, constituted 11.5 - 22.2%.

Three different water/gypsum ratios (W/G) were applied: 0.8, 0.9 and 1.0.

Both the non-mineralized sawdust and the sawdust after mineralization with CaCl₂, Ca(OH)₂ and Al₂(SO₄)₂, were used.

The test samples of gypsum composites have been prepared according to the following scheme:

- beams 4 x 4 x 16 cm for partial tests;

- cubes 10 x 10 x 10 cm for full tests.

Scope of partial tests:

- bending strength in Michaelis apparatus;
- compression strength on beams' halves on laboratory press, type PLH-12/4-WK-54;
- apparent density in the air-dry condition and after drying to a constant mass.

Only the non-mineralized samples, which proved to present the compressive strength over 3MPa in the partial tests, were utilized further in the full tests.

The full tests included: mass absorbability, softening coefficient and thermal conductivity coefficient.

The conductivity coefficients were determined on the disk-shaped samples with the diameter of 10 cm and thickness of 2 cm, in so-called "lambda meter" (Compact Unit for Lambda Coefficient Measurement).

The samples of gypsum composites were formed of mixtures containing the sawdust fillers without mineralization as an initial material for further comparative tests with a series of samples containing mineralized organic material.

5% water solutions of calcium chloride, calcium hydroxide and aluminium sulphate were used for mineralization. The commonly accepted manner of mineralization was applied, treating these solutions as make-up water.

In addition to that, the microbiological tests of samples have been conducted, due to a potential hazard of biological corrosion of the composites. 10 g of the examined material was prepared and poured with sterile distilled water. After 15 minutes the sample was applied on a sterile substrate. Standard, selective substrates for culturing bacteria, fungi, algae and protozoa, were applied. After appropriate time, the quantities of microbes were assessed.

The natural radioactivity of the samples was also examined. [2-7]

3. Results

The results of conducted physical and mechanical tests are presented in Tables 1, 2 and 3. The results of the microbiological analysis are presented in Table 4.

Table 1. Results of partial tests for the samples of gypsum composites with non-mineralized sawdust filler.

Sample no.	Substance content [%]			Quantity of filler in relation to gypsum mass [%]	W/G	W/ m.	Apparent density [kg/m³]		Strength [MPa]	
	gyp- sum	filler	wate r				in air- dry condi- tion	after drying to constant weight	bendin g	compre- ssion
1	52.0	6	42.0	11.5	0.8	0.72	1406	925	2.47	3.48
2	51.6	7	41.4	13.6	0.8	0.70	1435	952	2.96	3.76
3	51.1	8	40.9	15.6	0.8	0.70	1425	914	2.40	3.12
4	50.5	9	40.5	17.8	0.8	0.68	1346	981	2.36	3.43
5	50.0	10	40.0	20.0	0.8	0.66	1382	873	2.30	3.55
6	49.5	6	44.5	12.0	0.9	0.80	1431	872	2.40	3.11
7	49.0	7	44.0	14.2	0.9	0.78	1415	858	2.37	3.40
8	48.0	8	44.0	16.5	0.9	0.77	1384	839	2.05	3.72
9	48.0	9	43.0	18.8	0.9	0.76	1406	859	2.05	3.02
10	47.0	10	43.0	21.0	0.9	0.74	1399	850	2.19	2.79
11	47.0	6	47.0	12.8	1.0	0.88	1386	839	1.61	3.13
12	46.5	7	46.5	15.0	1.0	0.87	1327	898	1.75	3.05
13	46.0	8	46.0	17.3	1.0	0.85	1367	898	1.73	3.16
14	45.5	9	45.5	19.7	1.0	0.83	1391	917	2.13	3.30
15	45	10	45.0	22.2	1.0	0.82	1365	898	1.79	2.80
16	61	-	39.0	-	0.65	-	1610	1139	4.73	6.75

Table 2. The bending and compression strengths in samples with and without mineralization.

Sample no.	W/ G	Quantity of filler in relation to gypsum mass [%]	Strength of samples depending on the process of mineralization of the filler							
			Bending strength [MPa]				Compression strength [MPa]			
			mineralizer				mineralizer			
			Without minerali- zation	CaCl ₂	Ca(OH) ₂	Al ₂ (SO ₄) ₃	Without minerali- zation	CaCl ₂	Ca(OH) ₂	Al ₂ (SO ₄) ₃
1	0.8	11.5	2.47	2.10	1.90	2.26	3.48	3.00	3.00	3.26
2	0.8	13.6	2.96	2.65	2.20	2.71	3.76	3.65	3.84	3.90
3	0.8	15.6	2.40	2.40	1.96	2.77	3.12	3.55	3.65	3.80
4	0.8	17.8	2.36	2.82	2.30	2.50	3.43	4.00	3.76	3.58
5	0.8	20.0	2.30	2.90	2.50	2.93	3.55	4.00	3.87	4.26
6	0.9	12.0	2.40	1.90	2.09	2.20	3.11	3.10	3.20	3.25
7	0.9	14.2	2.37	2.20	2.29	2.15	3.40	3.34	3.28	3.40
8	0.9	16.5	2.05	2.45	2.11	2.18	3.72	3.60	3.45	3.50
9	0.9	18.8	2.05	2.40	2.00	2.12	3.02	3.20	3.66	3.55
10	0.9	21.0	2.19	2.40	2.27	2.10	2.79	3.00	3.31	3.50
11	1.0	12.8	1.61	1.50	1.50	1.61	3.13	2.30	2.47	2.50
12	1.0	15.0	1.75	1.40	1.51	1.70	3.05	2.65	2.48	2.70
13	1.0	17.3	1.73	1.70	1.62	1.65	3.16	2.60	2.68	2.91
14	1.0	19.7	2.13	1.75	1.72	1.80	3.30	3.00	3.01	2.85
15	1.0	22.2	1.79	1.84	1.62	1.82	2.80	3.13	2.88	2.83

Table 3. Results of full tests for gypsum composite samples with non-mineralized sawdust.

Sam- ple no.	Quantity of filler in relation to gypsum mass %	W/G	Compression strength	Mass absorbability %	Softening coefficient	Thermal conductivity coefficient [W/m x deg]
0*	-	0.65	7.60	35	0.36	0.66

1	11.5	0.8	3.50	45	0.23	0.47
3	13.6	0.8	3.20	47	0.22	0.46
5	20.0	0.8	3.40	48	0.25	0.42
8	16.5	0.9	3.65	54	0.24	0.45
11	12.8	1.0	3.10	54	0.22	0.46
13	17.3	1.0	3.10	55	0.22	0.47
15	22.2	1.0	3.00	55	0.24	0.42

* *sample made of gypsum without fillers*

Table 4. Microbiological analysis of sawdust and gypsum composites with filler.

No.	Kind of microorganisms	Incubation time [h] (temp. °C)	Sawdust (JTK/g)	Gypsum composite with filler (JTK/g)
I	Bacteria:			
	1. Psychrophilic	72h (20°C)	800	1000
	2. Mesophilic	24h (37°C)	50	7
	3. Autotrophic	72h (20°C)	2	25
II	Fungus	120h (20°C)	none	20
III	Protozoa	96h (20°C)	none	5

4. Discussion

The analysis of gypsum composites samples with non-mineralized sawdust filler showed, that the bending and compression strengths deteriorate with the increase of filler and water content in the mixture. However, it could be concluded, that the amount of filler can exceed the technical standard twice [86], without the compression strength dropping below 3 MPa. The tested samples presented also relatively high bending strength as well as the low apparent density.

The sawdust mineralized with the CaCl₂ solution, shows the tendency to increase the bending strength along with percentage content of filler. Tests focusing on the compressive strength revealed similar trend.

Gypsum composites mineralized with calcium hydroxide show lower bending and compressive strengths than CaCl₂. Compressive strength slightly increases compared to samples containing non-mineralized sawdust, especially at low W/G ratio (0.8 and 0.9). Solution of aluminum sulphate provides the irrelevant impact on the bending strength of gypsum composites, while compressive strength increases especially when the water-gypsum ratio is low (0.8 and 0.9). Nonetheless, the noted values are still the highest of all used mineralizers.

The apparent density of gypsum composites with sawdust filler ranges from 839 to 981 kg / m³, and the highest values have been obtained for the samples with W/G = 0.8.

For more comprehensive assessment of the quality of gypsum composites with sawdust, the extended tests on selected 10 x 10 x 10 cm samples have been conducted.

Simultaneously with the increase of mineralized filler percentage, the increase in compressive strength is noted, regardless of the W/G ratio. This gives the possibility to use up to 21% of sawdust filler in relation to the gypsum mass, even with the W/G = 0.9, without reducing the compression strength below 3 MPa.

Mentioned composites tend to have higher than normal mass absorbability (45 – 55%). They also present a slightly lower softening factor (0.22 -0.25) in comparison to technical standards (>0,35).

The sample “0”, made of pure gypsum without fillers, is included in the table for comparison.

Both the samples of filler and gypsum composites with this filler were subjected to the tests for the presence of bacterial flora. The pH of sawdust (5,5) mixed with pure gypsum (8,5) reached 7,2, therefore the conditions were assessed to be beneficial for the development of bacterial flora. Following microbiological tests have been conducted.

Fungi appeared to be absent in the sawdust, thus their later presence in the gypsum composite might be due to the air infestation. Mesophilic bacteria, the organisms that grow best in the moderate temperatures, formerly present in the sawdust, significantly decreased after gypsum addition. The colonies of psychrophilic bacteria, who are capable of growth in extreme temperatures, and autotrophic bacteria, who produce by themselves the complex organic compounds, were noted to enlarge slightly in gypsum composites. Nevertheless, detected organisms are claimed not to pose any hazard of biological corrosion for examined materials.

The natural radioactivity of the gypsum composite was assessed to meet the requirements of radioactive elements concentration. Radioactivity reached 6,6 Bq/kg, which is 3,6% of maximum permissible value.

Gypsum composites containing sawdust can be widely used in construction. Including the high percentage of filler is an inexpensive and effective way to create the light construction elements, while sawdust is highly available as a waste of wood processing. [8,9,10]

5. Summary

Gypsum composites with the organic sawdust filler (6-10%) mineralized with $\text{Ca}(\text{OH})_2$ are decreasing the mechanical strength of material. Therefore, other mineralizers, like CaCl_2 or $\text{Al}_2(\text{SO}_4)_3$ are more favourable with their ability to increase the bending and compressing strength.

The compression strength for most samples reaches 3 MPa, although with the higher W/G ratio (1.0), the decrease in the strength is noted.

Despite the significant differences between the filler content percentage (11.5 - 22.2%) and W/G ratio (0.8 - 1.0), only slight changes in compressive strength values were noted.

Gypsum composites are characterized by a low density ($<1000 \text{ kg / m}^3$) which decreases even more while organic filler applied (850 kg / m^3). The gypsum composites with sawdust show lower thermal conductivity coefficients than hardened gypsum pulp.

These fillers do not pose a hazard of biological corrosion due to a low number of microorganisms preserved in hardened composites. They have also a very low natural radioactivity. It gives the possibility to apply elements made of this material in constructing the objects designed to accommodate people.

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