



DOI: [10.71167/uaceg.2026.590114](https://doi.org/10.71167/uaceg.2026.590114)

Received: 15.10.2025

Accepted: 20.01.2026

## MECHANICAL AND ACOUSTIC PROPERTIES OF GYPSUM COMPOSITES WITH CELLULOSE WASTE

J. Mockienė<sup>1</sup>, D. Vaičiukynienė<sup>2</sup>, D. Nizevičienė<sup>3</sup>

**Keywords:** waste gypsum, cellulose fiber waste, compressive and flexural strength, sound pressure level

### ABSTRACT

Gypsum building materials are widely used in the construction sector and their use is growing steadily. At the end of the life cycle of a building, these gypsum materials become demolition waste. Thus, the increased consumption of gypsum building materials leads to an increased amount of demolition waste. The recycling of such demolition waste is becoming more and more relevant and important, as the recycling of gypsum waste would save natural raw materials and reduce waste. The main objective of this study was to investigate the effect of waste cellulose fibers on the physical and mechanical properties of gypsum samples. First of all, gypsum waste board was shredded and the cellulose separated from the gypsum. The gypsum particles were then ground in a ball mill to a fine powder. Calcination was carried out at 160 °C for 1,50 hours of 1 kg of gypsum. Citric acid was used as a set retarder and the amount was 0,05 wt. % by weight of the gypsum powder. The amount of waste cellulose fibers was 1, 3, 5 and 10 wt. % and as reference sample used gypsum sample without cellulose. The density, flexural and compressive strength were determined for all the samples. The microstructure was assessed by optical microscopy and the acoustic insulation properties were determined. The results showed that it is possible to obtain 5,75 MPa of compressive strength and 1,2 MPa of flexural strength by including 3 and 5 wt. % of waste cellulose fibers. The results of the sound

<sup>1</sup> Jūratė Mockienė, Lietuvos Inžinerijos Kolegija Higher Education Institution, Faculty of Industrial Engineering and Technology, 35 Tvirtovės Al., LT-50155 Kaunas, Lithuania, e-mail: [jurate.mockiene@lik.tech](mailto:jurate.mockiene@lik.tech)

<sup>2</sup> Danutė Vaičiukynienė, Kaunas University of Technology, Faculty of Civil Engineering and Architecture, 48 Studentu St., LT-51367 Kaunas, Lithuania, e-mail: [danute.vaiciukyniene@ktu.lt](mailto:danute.vaiciukyniene@ktu.lt)

<sup>3</sup> Dalia Nizevičienė, Kaunas University of Technology, Faculty of Electrical and Electronics Engineering, 48 Studentu St., LT-51367 Kaunas, Lithuania, e-mail: [dalia.nizeviciene@ktu.lt](mailto:dalia.nizeviciene@ktu.lt)

insulation performance of gypsum composites with different amounts of waste cellulose fibers show that the highest levels of sound insulation were achieved when the composite contained 3 % and 5 % by weight of waste cellulose fibers. The findings of the study indicate that the utilization of recycled gypsum can yield environmental benefits when compared with the use of natural gypsum.

## 1. Introduction

Gypsum plaster and gypsum board are widely used building materials, as they are the most popular interior finishing materials. After a while, these materials become demolition waste and account for a large proportion of demolition waste [1]. The recycling of gypsum-based building materials is particularly important. In order to be able to utilize gypsum waste, it must be calcined. This process removes some of the water from the gypsum and gives it binding properties. Erbs et al. [2] found that gypsum waste can be recycled three times, but recycling more than three times results in a loss of the basic physical and mechanical properties of gypsum board. Plasterboards waste and flue gas desulphurization gypsum was investigated by Pedreno-Rojas et al. [3, 4]. It was found that commercial gypsum can be replaced with gypsum board waste, and the best calcination temperature is 180 °C for 6 hours. The setting time of recycled gypsum waste is shorter, so a setting retarder should be used in this case. In study [5], citric acid was added to recycled gypsum plaster to extend the setting time. The use of this additive significantly changed the microstructure of the gypsum plaster. It gradually changed from a needle-like structure to a cubic structure, which had a negative effect on the mechanical properties.

Composite gypsum materials are very often used as gypsum building materials. Del Rio-Merino et al. [6] conducted a study based on gypsum mortars with different waste aggregates. This study described new composites with a gypsum matrix. Various materials can be used as fillers, e.g., concrete, ceramics, plastics, etc. Geraldo et al. [7] investigated composite bricks with a commercial and recycled gypsum plaster matrix. In this case, ceramic and porcelain waste was used as aggregate. The compressive strength of these bricks ranged from 12,3 to 33,9 MPa. According to Fantilli et al. [8], biofibers can also be incorporated into the gypsum matrix as reinforcement. Two types of biofibers were studied: wool and hemp fibers. Due to their better adhesion and rougher surface, wool fibers give the gypsum composite better mechanical properties than hemp fibers. In another study [9], various biofibers, such as jute, flax, palm fiber, and coconut fiber, were incorporated into a gypsum matrix. Using natural biofibers, a composite material with good thermal insulation and acoustic properties was created. El Hammouti et al. [10] investigated and characterized a composite material by combining straw as reinforcement and gypsum plaster as a matrix. When straw (4 % by weight) is mixed into gypsum plaster, thermal conductivity decreases by about 68 % and compressive strength by about 60 %. Nindiyasari et al. [11] prepared and investigated building composite based on gypsum and cellulose. The cellulose fibers were in the range of 1 and 2 wt. % with 0,5 wt. % of sodium alginate. The addition of sodium alginate improved the final deformation values. Brittle matrices such as gypsum matrix were reinforced with recycled cellulose pulp in the study made by Carvalho et al. [12]. The samples contained 10 % by weight of calcium carbonate additive. The samples were formed using compression molding with vacuum dewatering technology. This type of fiber accumulates a large amount of water, which allows the fibers and gypsum matrix to bond well. The best results were achieved using 12,5 % by weight of cellulose fiber, which is closely related to the high mechanical strength of the composites. Gypsum plasterboards consist of two materials – a gypsum matrix and two layers of paper. A study [13] investigated the possibility of recycling gypsum plaster and recycled lining paper. It was concluded that both types of

plasterboard waste, lining paper and gypsum plaster, can be completely recycled. These new plasterboards, made from secondary raw materials, met all physical and mechanical requirements. In this study, the waste paper from gypsum plasterboards was crushed and reused into a gypsum composite material. The aim of this study was to determine the possibility of using waste cellulose fibers in gypsum matrix and to determine the main physical and mechanical properties of these gypsum composites.

## 2. Initial materials and methods

Gypsum composite was prepared from gypsum matrix and cellulose fiber as reinforcement. First, the gypsum cardboard waste was crushed and the cellulose separated from the gypsum. The gypsum pieces were ground into a fine powder using a ball mill. In order for the aforementioned waste to acquire binding properties, it had to be thermally treated. The calcination process was carried out according to the following regime: 1 kg of gypsum was calcined at a temperature of 160 °C for 1,50 hours [14]. The resulting gypsum binder set very quickly, so setting retarders had to be used. In this case citric acid was used as a setting retarder, at a concentration of 0,05 % of the gypsum powder mass. A similar setting retarder was used by other researchers [15]. The reinforcement for this composite was prepared from cellulose fiber extracted from gypsum plasterboard (Fig. 1). The bulk density of cellulose and gypsum from gypsum board waste was determined. The bulk density of cellulose was found to be 180,16 kg/m<sup>3</sup>, while that of construction gypsum waste was 484,9 kg/m<sup>3</sup> according to LST EN 1097-3:2002 [16].



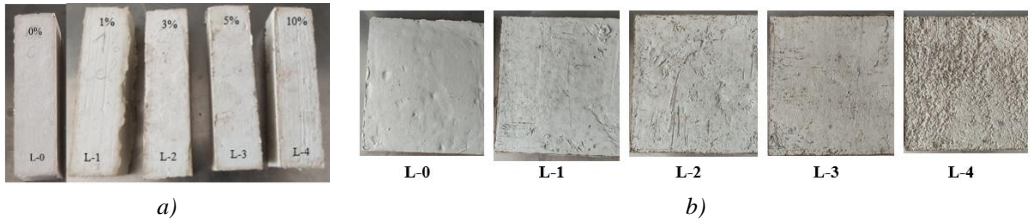
Figure 1. Optical image of cellulose waste fibers enlarged 200x

The cellulose fiber waste content was 1, 3, 5 and 10 % by mass, and a gypsum sample without cellulose was used as a reference sample (Table 1). In all samples, the water-to-gypsum ratio varied and was between 0,800 – 0,876.

Table 1. Samples of the following composition were formed

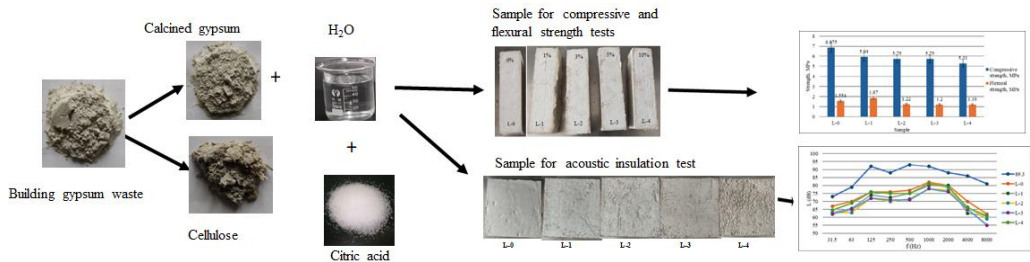
Samples	Building gypsum waste, %	Citric acid, %	Cellulose fiber waste, %	W/G ratio
L-0	100	0,05	0	0,800
L-1	99	0,05	1	0,820
L-2	97	0,05	3	0,836
L-3	95	0,05	5	0,852
L-4	90	0,05	10	0,876

Two types of gypsum composite material samples were formed. Samples measuring  $4 \times 4 \times 16$  cm were formed to determine mechanical properties and density (Fig. 2,a), and samples measuring  $1,9 \times 25 \times 25$  cm were formed to determine sound insulation (Fig. 2,b).



**Figure 2. Prepared gypsum samples:**  
*a) for compressive and flexural strength; b) for acoustic insulation testing*

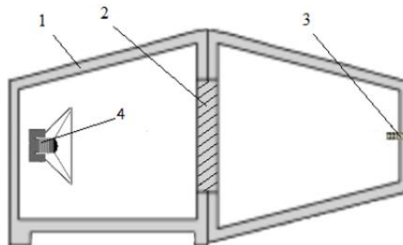
The density, flexural and compressive strength, and acoustic insulation testing were determined for all types of samples. The experimental work was carried out according to the scheme presented in Figure 3.



**Figure 3. Schematic representation of the influence of cellulose waste fiber on the main properties of gypsum composites**

The microstructures cellulose waste fibers were assessed using optical microscopy images taken with an optical microscope from CETI (Brussels, Belgium).

In order to determine the mechanical properties of gypsum and phosphogypsum, prisms were formed from paste of a normal consistency. The water/cement ratio and the setting time of the mixture (normal consistency) were determined in accordance with EN 196-3 [17]. The cubes were compressed with the press ELE AutoTest. The compressive strength of gypsum samples was measured according to EN 196-1 [18].

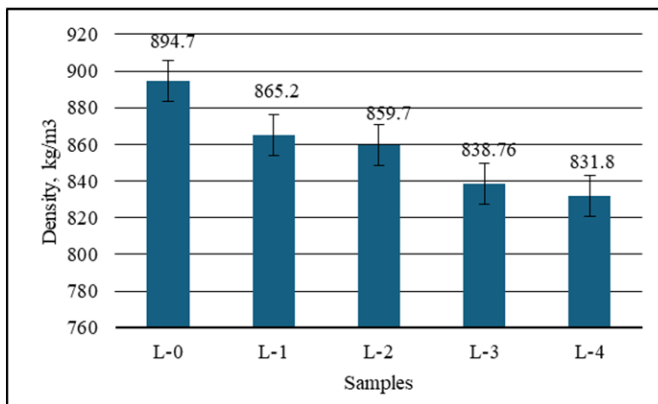


**Figure 4. Scheme of the measuring stand**  
*1 – Sound-insulating body of the stand; 2 – Sample opening; 3 – Microphone; 4 – Noise source (loudspeaker)*

A soundproof booth with a noise source and a microphone was used to measure the acoustic insulation properties of gypsum composites with cellulose waste. The work diagram is shown in Figure 4.

### 3. Results and discussion

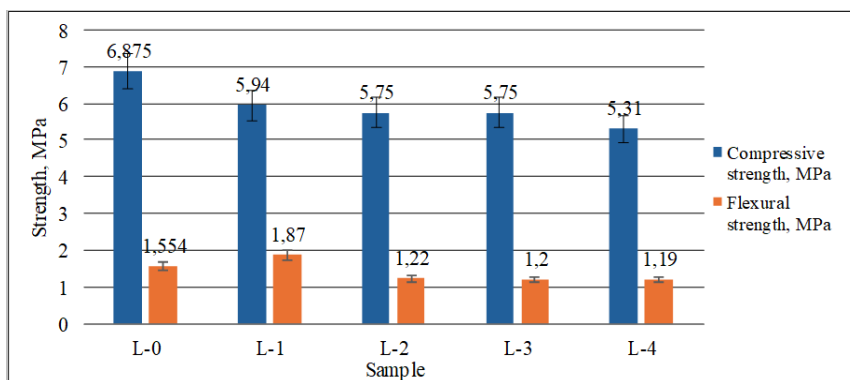
At the beginning of the study, the density of the samples was assessed. It was found that as the cellulose fiber content increased, the density values gradually decreased (Fig. 5). The reference sample without cellulose fibers had a density of 895 kg/m<sup>3</sup>. The density of samples containing 10 % cellulose fiber waste decreased to 832 kg/m<sup>3</sup>. Cross-sectional images of gypsum composites confirmed a decrease in sample density with increasing fiber content in the composite.



**Figure 5. Density and cross-section photos of gypsum composites with cellulose waste fiber. The cellulose content is shown in Table 1**

In the next stage of the research, the compressive and flexural strength of the samples were determined. These results are presented in Figure 6. The compressive strength of the sample without cellulose was 6,88 MPa, and the flexural strength was 1,56 MPa. Meanwhile, the compressive strength of the sample containing 1 % cellulose decreased to 5,94 MPa, and the flexural strength increased to 1,87 MPa.

Compared to the sample without cellulose, the compressive strength decreased by about 14 %, but the flexural strength increased by about 17 %. However, when a larger amount of cellulose waste fibers (3 % and 5 %) was added, the compressive strength was 5,75 MPa in both cases, and the flexural strength was similar – 1,22 and 1,20 MPa. When the composition contained 10 % cellulose waste fibers, the compressive strength decreased by about 23 % compared to the samples without cellulose.



**Figure 6. Compressive and flexural strength of gypsum samples with citric acid + cellulose**

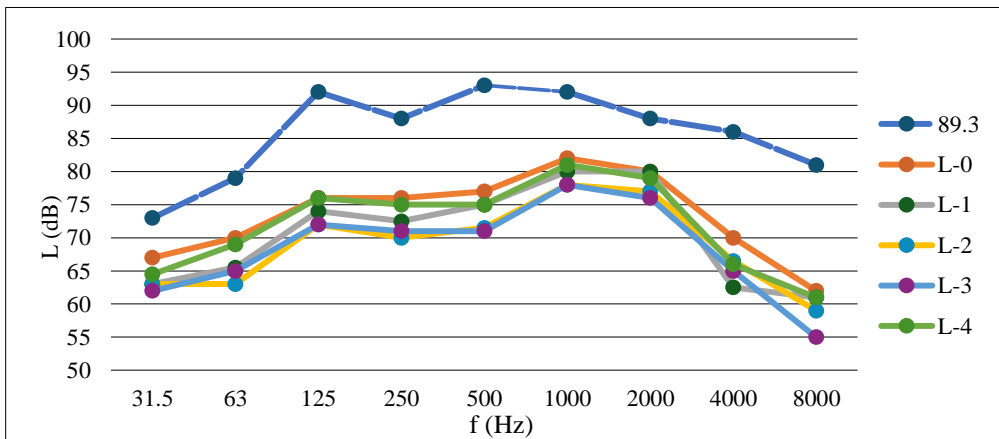
The work investigated constant noise. Permissible noise levels are regulated by HN 33:2011 “Noise limit values in residential and public buildings and their environment” and the Regulations on the protection of workers against noise risks. The results of the noise test readings are presented in Table 2. First of all, the generated natural noise in the stand was investigated. The sound pressure of 89,3 dBA measured in the studied environment exceeded the exposure limit value LEX, 8h = 87 dB(A). Partitions made of gypsum and cellulose fiber waste were used to reduce noise. The partition made of gypsum reduced the sound level to 79 dBA. After adding cellulose fiber waste, the sound pressure decreased by another 3 dBA, i.e. to 76 dBA. The sample with 5 percent cellulose fiber waste gave the greatest effect (Table 2 L-3 – 5 %).

**Table 2. Acoustic insulation test results for the gypsum composites with cellulose waste**

Sample marking	Weighted sound pressure level La, dBA	Sound pressure levels, dB, in octave bands with geometric mean frequencies, Hz								
		31,5	63	125	250	500	1000	2000	4000	8000
Natural noise	89,3	73	79	92	88	93	92	88	86	81
L-0 – 0 %	79	67	70	76	76	77	82	80	70	62
L-1 – 1 %	78,5	63	65,5	74	72,5	75	80	80	62,5	61
L-2 – 3 %	80	63	63	72	70	71,5	78	77	66,5	59
L-3 – 5 %	76	62	65	72	71	71	78	76	65	55
L-4 – 10 %	78	64,5	69	76	75	75	81	79	66	61

The sound was also filtered using standard frequency octaves. The results are presented in Figure 7. The results show that gypsum boards with cellulose fiber reduced sound pressure levels similarly in all octave ranges.

Since human hearing is more sensitive to sounds of medium or higher frequencies (from 1000 to 8000 Hz), it can be stated that the highest level of sound insulation was achieved when the composite contained 3 % and 5 % by weight of cellulose fiber waste.



**Figure 7. Dependence of the sound pressure level of natural noise on the amount of cellulose fiber waste in gypsum composite at a standard octave frequency**

## 4. Conclusion

The results of the study showed that the use of recycled gypsum can be beneficial to the environment compared to the use of natural gypsum. Lignocellulosic fibers, such as cellulose fiber waste, are also useful when incorporated into a gypsum matrix. This solves the problem of ecological waste and creates a gypsum composite. Based on experimental studies, it has been found that the optimal amount of cellulose waste is 1 – 3 %. When 1 % cellulose fiber waste is added, the density is 865,2 kg/m<sup>3</sup>, the compressive strength is 5,94 MPa and the flexural strength is 1,87 MPa. When 3 % cellulose fiber waste is added, the density is 859,7 kg/m<sup>3</sup>, the compressive strength is 5,75 MPa and the flexural strength is 1,22 MPa.

The study demonstrated that gypsum partitions effectively reduce noise levels, while the incorporation of cellulose fiber waste further enhances sound insulation. The highest noise reduction was achieved with the addition of 5 % cellulose fiber waste, lowering the sound pressure level from 89,3 dBA to 76 dBA.

## REFERENCES

1. Weimann, K., Adam, Ch., Buchert, M., Sutter, J. Environmental Evaluation of Gypsum Plasterboard Recycling. // *Minerals*, 2021, 11(2): 101, <https://doi.org/10.3390/min11020101>.
2. Erbs, A., Nagalli, A., de Carvalho, K. Q., Myrmin, V., Pasig, F. H., Mazer, W. Properties of recycled gypsum from gypsum plasterboards and commercial gypsum throughout recycling cycles. // *Journal of Cleaner Production*, 2018, 183: 1314 – 1322, <https://doi.org/10.1016/j.jclepro.2018.02.189>.
3. Pedreno-Rojas, M. A., Flores-Colen, I., De Brito, J., Rodriguez-Linan, C. Influence of the heating process on the use of gypsum wastes in plasters: Mechanical, thermal and environmental analysis. // *Journal of Cleaner Production*, 2019, 215: 444 – 457, <https://doi.org/10.1016/j.jclepro.2019.01.053>.

4. *Pedreno-Rojas, M. A., De Brito, J., Flores-Colen, I., Pereira, M. F. C., Rubio-de-Hita, P.* Influence of gypsum wastes on the workability of plasters: Heating process and microstructural analysis. // *Journal of Building Engineering*, 2020, 29: 101143, <https://doi.org/10.1016/j.jobbe.2019.101143>.
5. *Camarini, G., Cavalini Pinto, M. C., de Moura, A. G., Manzo, N. R.* Effect of citric acid on properties of recycled gypsum plaster to building components. // *Construction and Building Materials*, 2016, 124: 383 – 390, <https://doi.org/10.1016/j.conbuildmat.2016.07.112>.
6. *Del Rio-Merino, M., Vidales-Barriguete, A., Pina-Ramirez, C., Vitiello, V., Cruz-Astorqui, J. S., Castelluccio, R.* A review of the research about gypsum mortars with waste aggregates. // *Journal of Building Engineering*, 2022, 45: 103338, <https://doi.org/10.1016/j.jobbe.2021.103338>.
7. *Geraldo, R. H., Souza, J. D., Campos, S. C., Fernandes, L. F. R., Camarini, G.* Pressured recycled gypsum plaster and wastes: Characteristics of eco-friendly building components. // *Construction and Building Materials*, 2018, 191: 136 – 144, <https://doi.org/10.1016/j.conbuildmat.2018.09.193>.
8. *Fantilli, A. P., Joźwiak-Niedźwiedzka, D., Denis, P.* Bio-Fibers as a Reinforcement of Gypsum Composites. // *Materials*, 2021, 14(17): 4830, <https://doi.org/10.3390/ma14174830>.
9. *Mini, K. M., Sathyan, Dh., Jayanarayanan, K.* Biofiber composites in building and construction. // *Advances in Bio-Based Fiber. Moving Towards a Green Society. The Textile Institute Book Series*, 2022: 335 – 365, <https://doi.org/10.1016/B978-0-12-824543-9.00019-0>.
10. *El hammouti, A., Charai, M., Channouf, S., Horma, O., Mezrhab, Ah., Karkri, M., Tankari, M. A.* Application analysis and environmental impact of straw reinforced gypsum plaster for improving the energy efficiency in buildings in the six climate zones of Morocco. // *Journal of Building Engineering*, 2023, 74: 106829, <https://doi.org/10.1016/j.jobbe.2023.106829>.
11. *Nindiyasari, F., Griesshaber, E., Zimmermann, T., Manian, A. P., Randow, C., Zehbe, R., Fernandez-Diaz, L., Ziegler, A., Fleck, C., Schmahl, W. W.* Characterization and mechanical properties investigation of the cellulose/gypsum composite. // *Journal of Composite Materials*, 2015, 50(5): 657 – 672, <https://doi.org/10.1177/0021998315580826>.
12. *Carvalho, M. A., Junior, C. C., Junior, H. S., Tubino, R., Carvalho, M. T.* Microstructure and mechanical properties of gypsum composites reinforced with recycled cellulose pulp. // *Materials Research*, 2008, 11(4): 391 – 397, <https://doi.org/10.1590/S1516-14392008000400002>.
13. *Erbs, A., Nagalli, A., de Carvalho, K. Q., Mazer, W., de Moraes Erbs, M., Paz, D. H. F., Lafayette, K. P. V.* Development of plasterboard sheets exclusively from waste. // *Journal of Building Engineering*, 2021, 44: 102524, <https://doi.org/10.1016/j.jobbe.2021.102524>.
14. *Sinka, M., Vaičiukynienė, D., Nizevičienė, D., Sapata, A., Fornés, I. V., Vaitkevičius, V., Šerelis, E.* (2024). Utilisation of By-Product Phosphogypsum Through Extrusion-Based 3D Printing. *Materials*, 17(22), 5570.
15. *Camarini, G., Pinto, M. C. C., de Moura, A. G., Manzo, N. R.* Effect of citric acid on properties of recycled gypsum plaster to building components. *Construction and Building Materials* 124 (2016) 383 – 390.
16. LST EN 1097-3:2002 – Tests for mechanical and physical properties of aggregates – Part 3: Determination of loose bulk density and voids.
17. EN 196-3:2016 – Methods of testing cement – Part 3: Determination of setting times and soundness.
18. EN 196-1:2016 – Methods of testing cement – Part 1: Determination of strength.