ICBBM 2021

4th International Conference on Bio-Based Building Materials

MEDIUM DENSITY MATERIALS BASED ON CLAY AND BY-PRODUCTS OF CORN AND SUNFLOWER STALKS. THERMAL AND ACOUSTIC ASPECTS

A.M. Lacasta[1*], E.G. Correa[1], I.R. Cantalapiedra[1], L. Haurie[1], A. Torres-Rivas[1,2]
[1] Escola Politècnica Superior d'Edificació de Barcelona, Universitat Politècnica de Catalunya, Avda. Doctor Marañon 44, 08028 Barcelona, Spain.
[2] Departament d'Enginyeria Química, Universitat Rovira i Virgili, Av. Paisos Catalans 26, Tarragona, Spain
e-mail: ana.maria.lacasta@upc.edu

Abstract

Agricultural by-products obtained from sunflower and corn stalks (pith and bark) can have multiple applications when introduced as aggregates in clay-based materials. Due to their low weight, these plant by-products can provide lightness and good thermal and acoustic performance, making them suitable for use as interior elements (cladding, wall panels or false ceilings). This article explores these two aspects, thermal and acoustic, in a variety of formulations. Thermal conductivity has been correlated with density, obtaining, as expected, that the lower the density, the lower the conductivity. In general, samples with a higher percentage of plant aggregates shown a higher acoustic absorption. Significant differences have been observed depending on the type of aggregate (corn pith, sunflower pith, or a mixture of pith and bark).

MATERIALS AND METHODS

Agricultural by-products

The two agricultural by products used in this work were corn and sunflower stalks. In the case of sunflowers stalks, they were ground and then separated and sieved to obtain both isolated pith or a mixture of pith and bark. In the case of corn stalks, they were manually peeled to obtain the pith and they were then ground and sieved.

Figure 1. Sunflower mixture of pith and bark (left), sunflower pith (centre) and corn pith (right).

Sample preparation

The aim of this study is, on the one hand, to analyse the effect of the amount of plant aggregates on the thermal and acoustic properties. On the other hand, to evaluate the differences between sunflower and corn pith. Two main types of samples have been prepared:

a) CSPB samples

They are composed of clay, sand, and the sunflower mixture of pith and bark. Sand has a particle size between 0.125 mm and 1 mm and the sunflower particles have mainly a size higher than 1 mm.

Table 1. Composition of the CSPB samples. The Sunflower aggregate amount is presented as % in weight with respect of the sum of clay, sand and sunflower aggregate.

Sample	Sunflower aggregate (% mass)	Dry density (kg/m^3)
CSPB_0	0	2150
CSPB_50	4.9	1668
CSPB_100	9.4	1312
CSPB_150	13.4	1175
CSPB_200	17.1	1078

b) CP samples

They are composed of clay and pith, both from sunflower and corn. Because of the lack of sand, CP samples are much lighter than CSPB samples.

Table 2. Composition of the CP samples. The pith aggregate amount is presented as % in weight with respect of the sum of clay and sunflower aggregate.

Sample	Composition	Pith percentage (% mass)	Dry density (kg/m^3)
CP-S	Clay and sunflower pith	18	689
CP-C	Clay and corn pith	18	500

In all the cases, CSPB and CP, specimens of different form and size have been prepared: square plates of 10 cm sides and 3 cm thick for the thermal analysis and cylinders of 5 cm diameter and 3 cm thick for the acoustic characterization. At least 3 specimens have been used in each test.

Thermic and acoustic measurements

Thermal conductivity were measured with a Quickline-30 Electronic Thermal Properties Analyser using a surface probe with a disk sensor. Such equipment is based on the analysis of the transient temperature response of the material to heat flow induced by electrical heating.

Sound absorption measurements were performed in an impedance tube following the standard EN ISO 10534-2 protocol. The principle is based on measurements of the transfer function between two microphones. The sound pressures are measured at two positions in the tube by the two microphones mounted at 5 cm distance between them. From these signals, the complex acoustic transfer function is determined for frequencies in the range 400-3150 Hz. The specimens are cylindrical, 50 mm in diameter and between 10 and 20 mm thick.

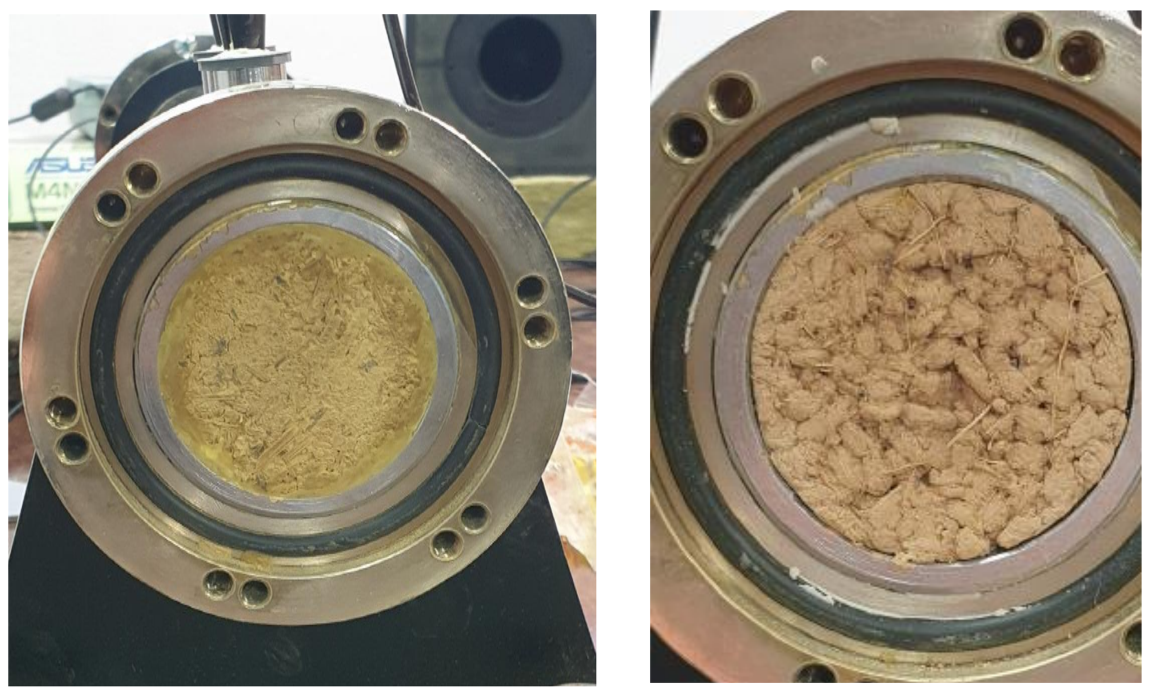

Figure 2. Specimens placed in the impedance tube

RESULTS

Thermal Conductivity

Figure 3 shows the average thermal conductivity of all the specimens corresponding to the 7 formulations. Figure 4 shows the thermal conductivity of each specimen as a function of their density. As expected, the lower the density the lower the conductivity.

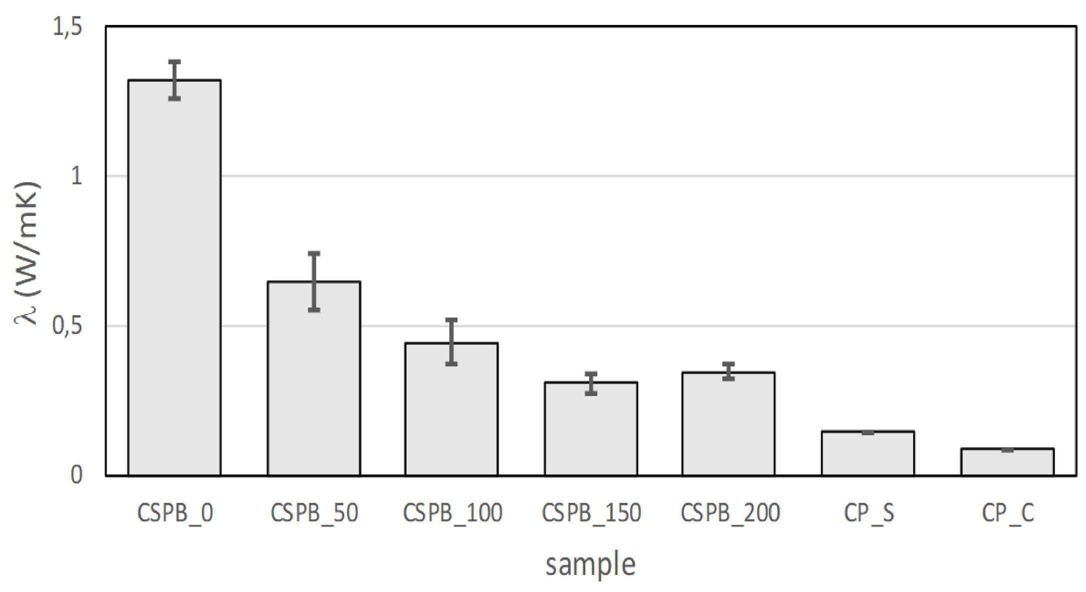

Figure 3. Average thermal conductivity for the different formulations.

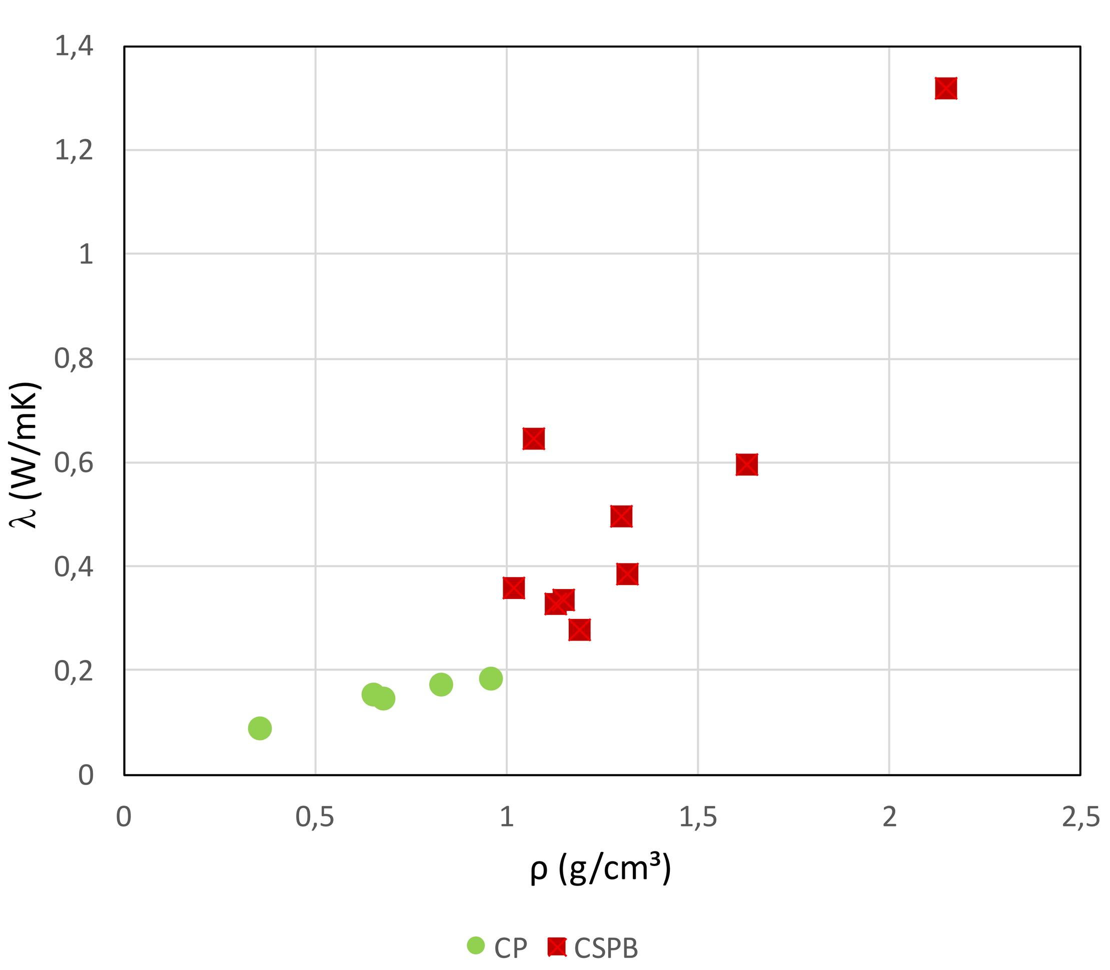

Figure 4. Thermal conductivity as a function of the density. The red square symbols correspond to CSPB specimens and the green circular symbols correspond to CP specimens.

Sound absorption

The sound absorption coefficient (α) for frequency ranging from 400 to 3150 Hz is shown in Figs. 5 (for CSPB samples) and 6 (for CP samples). The sound absorption values for the frequency of 2000 Hz are shown in Figure 7.

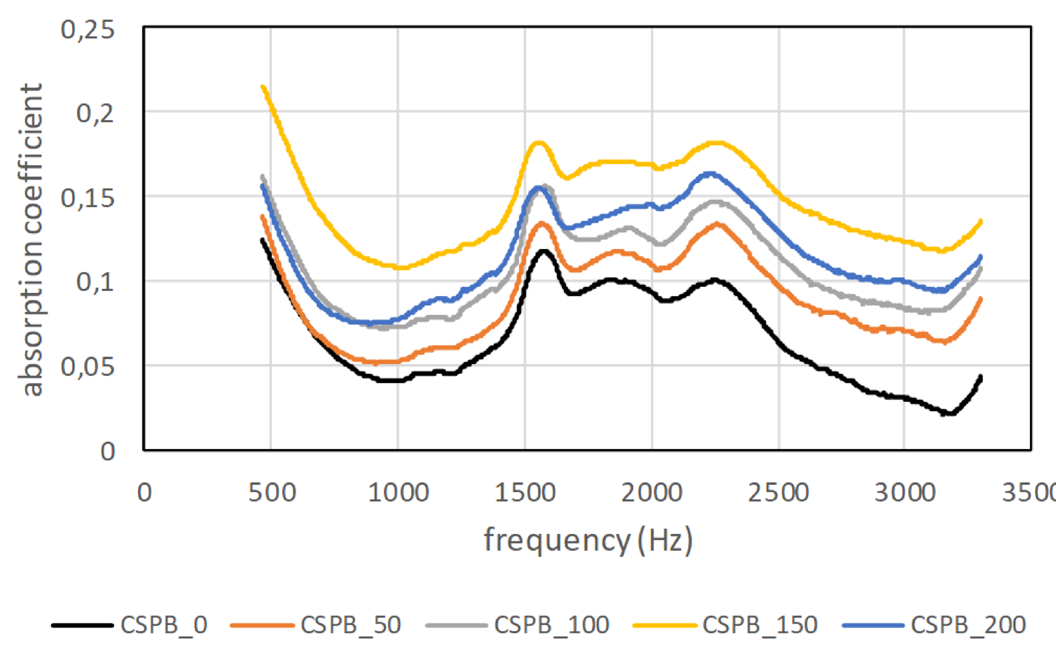

Figure 5. Sound absorption coefficient for the CSPB samples. The curves are an average of 3 specimens.

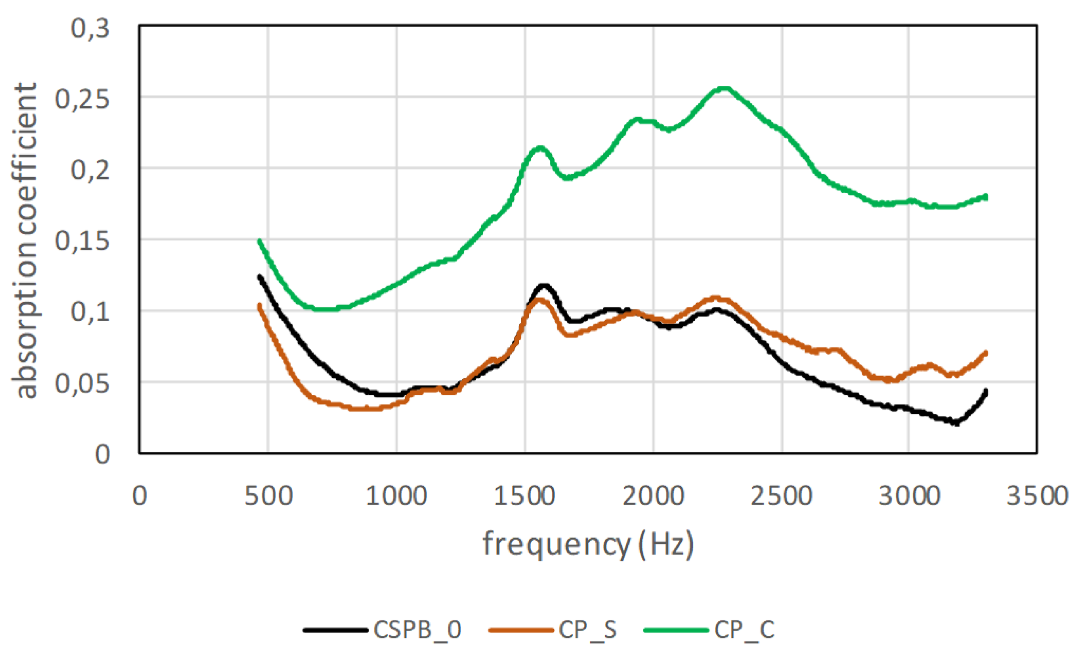

Figure 6. Sound absorption coefficient for the CSPB samples. The curves are an average of 3 specimens. CSPB_0 case is included for comparison.

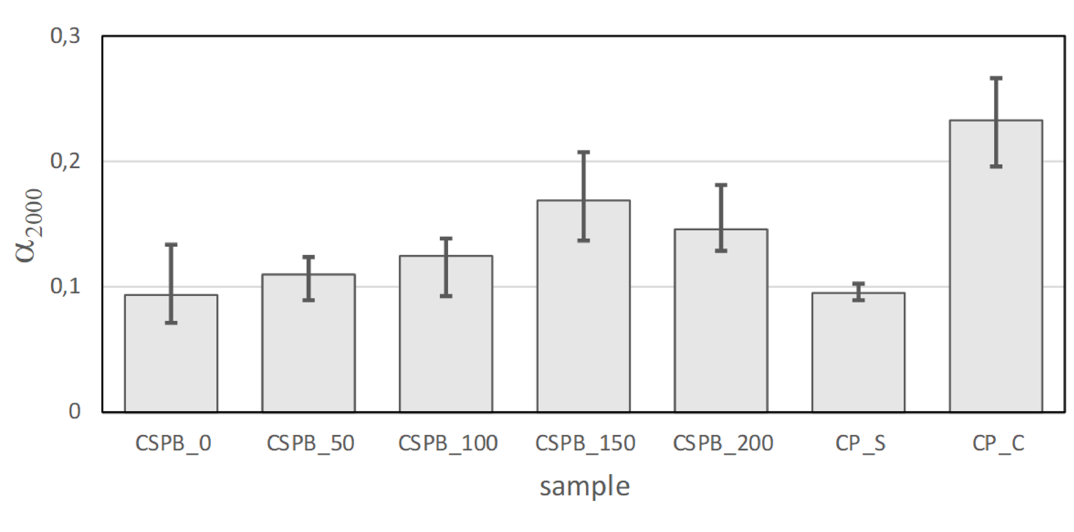

Figure 7. Sound absorption coefficient for frequency 2000 Hz corresponding to all the specimens analysed. The errors are also indicated.

CONCLUSIONS

The stalks of both corn a sunflower plants consist of an outer bark and a white, spongy pith inside. Because of its spongy structure, pith is characterised by an extremely light weight and low thermal conductivity. In previous papers [1,2] a thermal insulation system based on corn pith was developed and characterized in terms of hydrothermal behaviour. In the present work, medium density panels formulated with clay and the aforementioned plant by-products have been developed and analysed with the aim of obtaining satisfactory solutions from the thermal and acoustic points of view. The results obtained are satisfactory and promising.

Materials formulated with clay and vegetable granules of sunflower and corn show thermal conductivity values that depend on the density of each specimen. CP samples, formulated without sand and with a high percentage of corn or sunflower, show values below 0.2 W/mK.

Acoustic absorption has been determined in an impedance tube 3,4]. In general, samples with a higher percentage of plant aggregates (lower density) have a higher acoustic absorption for all the frequencies. However, there seems to be a maximum for samples with a percentage in volume of 150% (CSPB-150 percentage). On the other hand, the results are quite different for samples containing only pith. The sunflower pith samples (CP_S), despite their low density, show a very poor absorption, similar to that obtained for the samples without any vegetal aggregate. The corn pith specimens (CP_C) are the ones that have the higher sound absorption for most of the frequencies.

Acknowledgments

This research is partly funded by Spanish Ministry of Economy and Competitiveness (MINECO) under the project BIA2017-88401-R AEI/FEDER/UE and SAVASCO EFA 353/19 Interreg Poctefa.

Both the clay and the sand used in this work were supplied by the Spanish company Ecoclay.

References

[1] Palumbo, M., Lacasta, A. M., Holcroft, N., Shea, A. and Walker, P. (2016). Determination of hygrothermal parameters of experimental and commercial bio-based insulation materials. Construction and Building Materials, 124, 269-275.
[2] Palumbo, M., Lacasta, A. M., Giraldo, M. P., Haurie, L. and Correal, E. (2018). Bio-based insulation materials and their hygrothermal performance in a building envelope system (ETICS). Energy and Buildings, 174, 147-155.
[3] Novais, R. M., Carvalheiras, J., Senff, L., Lacasta, A. M., Cantalapiedra, I. R., Giro-Paloma, J., Seabra, M.P., Labrincha, J. A. (2020). Multifunctional cork-alkali-activated fly ash composites: A sustainable material to enhance buildings' energy and acoustic performance. Energy and Buildings, 210, 109739.
[4] Novais, R. M., Senff, L., Carvalheiras, J., Lacasta, A. M., Cantalapiedra, I. R. and Labrincha, J. A. (2021). Simple and effective route to tailor the thermal, acoustic and hygrothermal properties of cork-containing waste derived inorganic polymer composites. Journal of Building Engineering, 102501.