

Manufacturing and characterization of 100% biobased insulation materials based on mycelium

Tom LAMBRE, Sandrine MARCEAU, Janette AYOUB, Marielle GUEGUEN
MINERBE

Université Gustave Eiffel, MAST/CPDM, 77454 Marne-la-Vallée Cedex 2, France
sandrine.marceau@univ-eiffel.fr

Abstract. In this study, an alternative biobased matrix is proposed to replace synthetic fibres or mineral binders that are used as binders between plant particles in insulation materials. This binder is produced from mycelium, the filamentous vegetative part of fungi, and allows the manufacture of 100% biobased mycocomposites.

This article presents the results obtained with regard to the optimization of the formulation and processing conditions of mycocomposites. The materials were obtained from *Pleurotus ostreatus* and hemp aggregates. The impact of the plant/mycelium ratio, the addition of a catalyst and the particle size is evaluated on the density, thermal conductivity and mechanical strength of the mycocomposites obtained.

The results show that it is possible to obtain 100% biobased insulating building materials with a density between 115 and 150 kg/m³. Their thermal performance is comparable to that of traditional insulating materials, i.e. around 50 mW/(m.K)⁻¹. Their compressive strength is low and mycocomposites have high elongations at break.

In addition to this work, the durability of these mycocomposites and their end-of-life, recycling or biodegradation, will also be studied in order to obtain an overall assessment of the environmental impact of the materials.

Keywords: biobased, insulation, mycelium, mycocomposites

1 Introduction

Please note that the first paragraph of a section or subsection is not indented. The first paragraph of a section or subsection is not indented. The use of biobased materials in the construction sector is in full expansion and will be accelerated by the application of the 2020 environmental regulation from January 2022. In addition to prioritizing the energy efficiency of buildings, the latter also takes into account the carbon impact of their construction phase. Thus, the future regulation introduces a methodological change that requires the environmental impact of all materials used in the building to be calculated, from its construction to its demolition. Biobased materials, made from renewable resources and allowing carbon storage throughout their life cycle, will thus help to decarbonize the construction sector.

Different types of biobased materials, such as plant wools or hemp concrete, are already used for building insulation. They are made of plant fibers or aggregates and their cohesion is ensured by synthetic fibers (bicomponent fibers based on polyethylene) or by a mineral binder based on lime or cement. The presence of these binders of petroleum or mineral origin has an impact on the overall environmental performance of the materials and on their recyclability. It is therefore necessary to propose alternative bio-based binders that can be used to replace the non-renewable mineral and organic matrices currently in use. In this work, a matrix based on mycelium, the filamentous vegetative part of fungi, is used.

Bricks based on mycelium have already been made and used for the time being in architecture, design and art installations, such as the Hy-Fi tower, consisting of 10,000 bricks at the Museum of Modern Art in New York and built for a young architects' competition in 2014. Made from plant waste and a strain of mycelium, these bricks are completely bio-based and manufactured without chemical or industrial processing. Their density is very low, in the order of 30 to 50 kg/m³, and their thermal insulation and hygrothermal comfort performances make them interesting for building insulation applications with very low carbon impact materials [1,2].

2 Materials and techniques

The samples are made from a mixture of *pleurotus ostreatus*, water, and a substrate of raw (HS) or ground (GR) hemp shiv. The ratio of mycelium to substrate is 1 and 2. Details of the different formulations are presented in Table 1. The mycocomposites obtained are labelled HS1 or 2 for bulk hemp shiv substrate with mycelium/substrate ratio of 1 or 2 respectively. They are labelled GR1 or 2 with the substrate is ground hemp shiv.

Pour la fabrication des échantillons, tous les composants sont mélangés et placés dans des moules cylindriques 11x22 cm. L'incubation a lieu dans les moules fermés pendant 14 jours, avant séchage à 50°C pendant une semaine pour stopper le développement du mycélium.

Table 1. Description of the four formulations.

Substrate	Mycelium/substrate ratio	Water/substrate ratio
Bulk hemp shiv	1 (HS1) and 2 (HS2)	2.61
Ground hemp shiv	1 (GR1) and 2 (GR2)	3.67

After drying, the density of the samples is determined, as well as their thermal conductivity using a hot wire and their mechanical strength with a compression test at 6 mm/min until the samples break.

3 Results and discussion

The densities and thermal conductivities of the manufactured myco-composites are presented in Table 2. Density values show little variability for a given formulation. They increase from 13 to 16% from a mycelium/substrate ratio of 1 to 2, and from 8 to 10% from raw to ground hemp shiv. However, these density variations do not have a significant effect on the thermal conductivity of the materials.

Table 2. Density and thermal conductivity of myco-composites.

Parameter	HS1	HS2	GR1	GR2
Density (kg/m ³)	115 ± 2	133 ± 4	127 ± 2	144 ± 6
Thermal conductivity (W.(m.K) ⁻¹)	0.048 ± 0,002	0.048 ± 0,002	0.048 ± 0,001	0.050 ± 0,001

With regard to the characterization of mechanical performance, the stress-strain curves obtained for four samples containing bulk and ground hemp shiv, for the two mycelium/substrate ratios, are presented in Fig. 1 and Fig. 2 respectively.

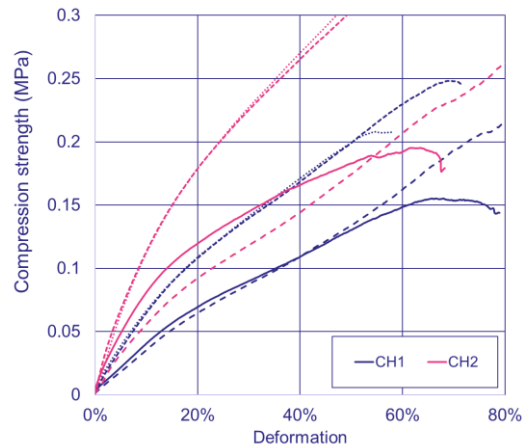


Fig. 1. Stress-strain curves for four samples containing bulk hemp shiv with mycelium/substrate 1 (HS1) and 2 (HS2).

In these figures, a high variability of mechanical properties can be observed for a given formulation.

Nevertheless, it can be observed that:

- the deformations at break are high: between 60 and 80% for bulk hemp shiv and around 20% for ground hemp shiv.
- sample failure is more rarely observed in the case of bulk substrate than in the case of ground substrate.

- Samples with a mycelium/substrate ratio of 2 have a higher mechanical strength than those with a ratio of 1.
- The compressive strength of composites containing ground hemp shiv are lower than for bulk hemp shiv.

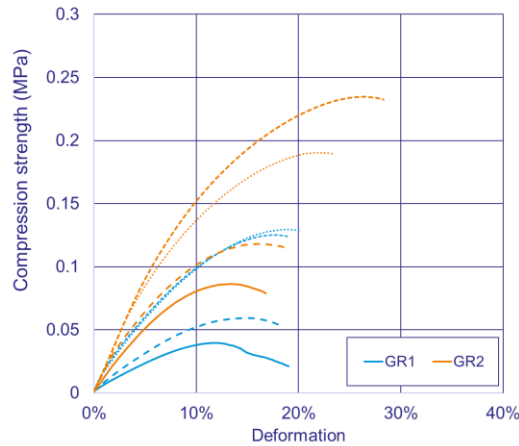


Fig. 2. Stress-strain curves for four samples containing ground hemp shiv with mycelium/substrate 1 (GR1) and 2 (GR2).

These results show that it is still necessary to control the manufacturing process of the samples to reduce the variability of their mechanical performance.

4 Conclusion

This study showed that it is possible to produce 100% biobased insulation materials containing bulk or ground hemp aggregates using mycelium as a binder.

The density of the obtained samples is very close to that of the substrates, and their thermal conductivity, which does not depend on the formulation, is of the order of $0.05 \text{ W} \cdot (\text{m} \cdot \text{K})^{-1}$. This value is comparable to that of traditional insulation materials used in buildings. However, the compressive strength of the manufactured composites is highly variable. It varies from 0.05 to over 0.3 MPa. This work will be continued in order to better control the manufacturing of composites and to reduce the variability of their mechanical performances.

References

- [1] C.H. Koh, F. Gauvin, K. Schollbach, J. Brouwers, Investigation of Material Characteristics and Hygrothermal Performances of Different Bio-Based Insulation Composites, *SSRN Electron. J.* 346 (2022) 128440. doi:10.2139/ssrn.4128574.
- [2] P.P. Dias, L.B. Jayasinghe, D. Waldmann, Investigation of Mycelium-

Miscanthus composites as building insulation material, Results Mater. 10 (2021) 100189. doi:10.1016/j.rinma.2021.100189.