Development of an ecological thermal insulation product for a regenerative design

Livia Tavares Cosentino

ltcosentino@hotmail.com

Supervisor(s): Ricardo Filipe Mesquita da Silva Mateus[1], Jorge Emanuel Pereira Fernandes[2]

1. Institute for Sustainability and Innovation in Structural Engineering (ISISE), Associate Laboratory Advanced Production and Intelligent Systems (ARISE), Department of Civil Engineering, University of Minho
2. Institute for Sustainability and Innovation in Structural Engineering (ISISE), Associate Laboratory Advanced Production and Intelligent Systems (ARISE), Department of Civil Engineering, University of Minho

IDEAS TO IMPACT

MIT Portugal
2024 Annual Conference

While thermal insulation materials help reduce energy demand in building comfort, many commonly used materials have high embodied energy. In contrast, bio-based thermal insulation products stock CO_2, lowering embodied energy.

The research aims to develop an innovative bio-based thermal insulation product based on invasive species in Portugal. Its application not only helps control the spread of these species but also creates a value chain for this resource.

Portuguese vernacular architecture has traditionally used reed as a raw material for insulation solutions, highlighting the potential of its fibres. This study aims to characterise *Cortaderia selloana* reed (see Fig. 1) to explore its suitability as an insulation material.

Main objectives:

- to develop and study the manufacturing processes of two prototypes of insulation panels, in compliance with regulatory requirements: one with the whole sections of culms and the other using the waste of the first in a crushed reed agglomerate;
- to analyze the environmental and economic life cycle performance of the new insulation products, comparing them with conventional ones;
- to contribute to a circular economy by developing low environmental impact, low raw material processing, and low-cost and biodegradable products.

Figure 1: *Cortaderia Selloana field in the urban landscape.*

The increasing interest in bio-based materials and techniques for regenerative buildings and resilient interior thermal comfort is driven by several key advantages, particularly their low or even negative embodied energy. In this context, fast-growing plants are especially important, as their shorter growth cycle enables them to capture more CO_2 from the atmosphere, enhancing their environmental benefits.

Limited research has been conducted on the environmental performance of bio-based insulation materials. Through comprehensive environmental studies, the advantages of these materials can be better understood, encouraging their wider adoption. Ecological innovations have the potential to replace conventional materials, offering similar energy efficiency during the operational phase of buildings' life cycle while delivering added environmental benefits.

Among recent publications, a lack of characterization of thermal mass and thermal inertia, which can be characterized by heat capacity and diffusivity parameters, was also identified. This characterization can enhance the development of more effective construction solutions, especially for the renovation of vernacular buildings, as they are linked to the decrement delay of materials. This delay is crucial in extreme weather conditions, as it helps to prevent rapid temperature fluctuations indoors, keeping buildings cooler during hot days and warmer during cold nights.

Achieving a comprehensive understanding of both the existing and new materials allows straightforward and cost-effective building renovation, helping to avoid issues like excessive condensation and poor use of the passive energy potential offered by these materials.

In this scope, *Cortaderia Selloana* stems were evaluated on several physical and mechanical characteristics for a better understanding of the material.

The characterization tests of the panel with stems (see Fig. 2) shows that:

- The found natural moisture content of around 9% is similar to other reed species.
- *Cortaderia Selloana* has a hydrophobic outer wall with a highly hydrophilic interior, especially at the nodes, probably due to its internal structure.
- The thermal conductivity of *Cortaderia Selloana* panels is similar to commercialized cork insulation panels.
- The first microscopic observations showed a fibrous internal structure with many voids (see Fig. 3), explaining the low density of the material.
- In mechanical characterization, it was observed that the structure of the stem is quite elastic, as it tends to return to its original shape after flexural strength tests.

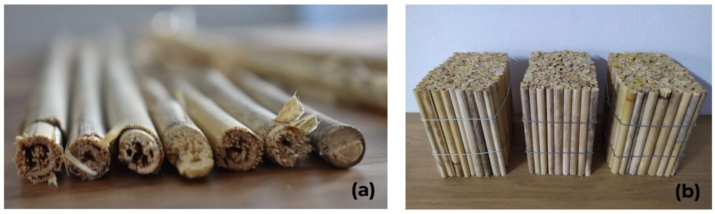

Figure 2: (a) *Cortaderia Selloana* stems and (b) experimental blocks.

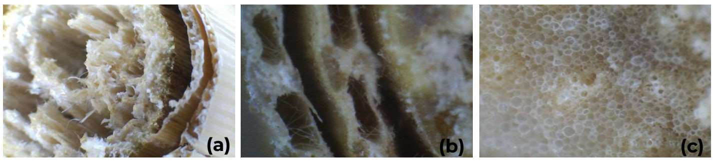

Figure 3: Microscope images, (a) Stem section ampliation of 100x, (b) external walls ampliation of 400x, (c) internal ampliation of 400x.

The second part of the development of the panels considered the crushed reed of different sizes and different binders (see Fig 4). The production process shows that:

- The panels made with bigger particles of the material have higher thermal conductivity, likely because they contain more of the stem's outer layers. The softer inner part of the stem generally forms finer particles, while the thicker particles are mostly made up of the tougher exterior layers.
- The mixtures with lime showed lower thermal conductivity, however, mechanical strength is an issue without a pozzolanic agent.
- Fibre and lime mixture can have its mechanical strength enhanced by adding silica content to the mixture.
- Clay binder performs very well as expected but increases density and therefore thermal conductivity of the samples.

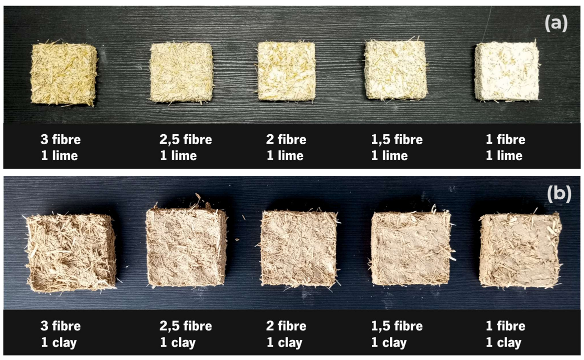

Figure 4: (a) *Mixtures of fibre and lime and* (b) mixtures of fibre and clay.

The following work to be done will focus on the complete hygrothermal and mechanical characterization of the panels with crushed reed and binders to evaluate performance and propose a commercialized insulation material.

Funded by:

Fundação para a Ciência e a Tecnologia

MIT Portugal

under the Doctoral Grant PRT/BD/152839/2021 | Sustainable Cities