Development of an ecological thermal insulation product to a regenerative design

Livia Tavares Cosentino

ltcosentino@hotmail.com

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

1. University of Minho

2. University of Minho

MIT Portugal

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Abstract

Regarding thermal insulation materials, although they contribute to reducing energy demand, the most used materials have high embodied energy. Bio-based thermal insulation products are an eco-efficient alternative to meet climatic goals since they stock CO2 and have lower embodied energy.

The research work aims to develop a modern bio-based thermal insulation product based on reeds (**Arundo Donax and Cortaderia Selloana**), invasive species in Portugal. Its use has a positive impact on controlling the spread and creates a value chain for this resource.

The research work expects to contribute by creating a bio-based material to be used by the building industry.

Objectives

Portuguese vernacular architecture uses reed as a raw material to develop insulation solutions, demonstrating the fibre's potential. Therefore, considering its insulating properties, this work aims to transform the reed (Arundo Donax and Cortaderia Selloana) into a modern bio-based thermal insulation product.

Figure 1: *Arundo Donax. https://invasoras.pt/pt/planta-invasora/arundo-donax*

Figure 2: *Cortaderia Selloana.*

The work plan's objectives are:

- to evaluate the thermophysical properties of both reed species, Arundo Donax and Cortaderia Selloana;
- 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.

This research work aims at answering the following research questions: What type of thermal insulation material can be implemented to improve the VB's thermal performance during the heating season, without compromising their main features (e.g. low embodied environmental impact) and the requirements of the building materials used (e.g. water vapour permeability)? How to develop low-environmental impact thermal insulation products that can be used not only for VB elements but also for conventional solutions? What is the potential to industrialise the production of the new proposed products? What will be the sustainability benefits of using the newly developed insulation products in the construction sector, beyond those resulting from controlling the spread of the reed in the Portuguese territory?

State of art

The rising interest for bio-based materials and techniques in the scope of sustainable/regenerative buildings comes from advantages such as low embodied energy, due to the simpler manufacturing processes, and consequently reduced potential environmental impacts; biodegradable, renewable, CO2 neutral (or negative due to biogenic carbon) and can be framed into a "cradle-to-cradle" life-cycle approach (e.g. straw and reeds) (1,2).

In the past, vernacular buildings (VB) were built using passive strategies, based on available endogenous resources and design principles, derived from local geographical characteristics (3), to reduce thermal discomfort (4). Studies identified some weaknesses in VB, namely the poor thermal behaviour in winter due to the inadequate insulation of the envelopes (5). VB does not comply with current Portuguese Energy Performance legislation (6) and the use of contemporary thermal insulation materials (XPS or EPS) has aggravated the existence of anomalies, considering their incompatibility with the materials typically used in these constructions (adobe, rammed earth and lime-based plasters) (7). There is a need to develop a solution that can be simultaneously eco-friendly and increase the thermal performance of VB and conventional constructions, and this will be the focus of this research.

Work's description

Reeds are abundant throughout the Portuguese territory, have rapid growth and some are invasive species, causing negative impacts on the ecosystems (8). Its use will have a positive impact on controlling its spread and will create a value chain for an underestimated resource.

The development of bio-based insulation products (in addition to all the environmental gains) can contribute to more sustainable construction, to the satisfaction of both the European Commission's and UN's Sustainable Development Goals and has the potential to be exported to other foreign markets.

In this sense, this research work will start by gathering information on bio-based materials and their use in the construction context, with particular attention to their application as thermal insulation material. It will focus on materials that have been used in some VB to improve thermal insulation (e.g. reed). The natural material will be characterised (by physical, thermal-physical, durability and cellular structure). This step is very important because natural materials have substantial variability.

The second stage will focus on studying the properties of different specimens of panels with entire reeds and crushed, and binder bounded ones. Since durability plays an essential role in the life cycle of construction materials (9), the importance of these characteristics on the longevity of the products developed will also be studied.

The third stage will be related to the design, manufacture and validation of the prototypes of the bio-based thermal insulation products.

Afterwards, the potential industrialisation process of the products will be studied, and their economic and environmental performance will be assessed and compared with the conventional insulation materials used. In the end, the contribution of the developed products to improve the thermal properties of some VB systems (adobe and rammed earth) will be validated through experimental assessments.

Figure 3: Cortaderia Selloana harvested and experimental blocks.

Further information

By the time of this conference, the species have been already harvested and experimental blocks have been assembled to initiate thermal experiments, as seen in figure 3. A Hotbox and proper equipment will be used in the University of Minho's laboratory to collect the first results about the thermal potential of the reeds.

It is expected that the *Cortaderia selloana* species will perform better than *Arundo Donax* due to its compactness, at least at this phase (fig.4).

Figure 4: Arundo Donax X Cortaderia Selloana experimental blocks.

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