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Pennotec (Pennog Ltd)

UKRI Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials

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Sustainable composite material for building surface maintenance

The Challenge: What we were trying to achieve

The growth of algae on building walls and lichen and moss on roofs (biofouling) can be unsightly and damage building integrity. Current solutions include spraying hazardous 'algaecides' onto affected areas, or fixing copper strips onto roofs. Neither solution offers protection for more than three years and cleaning chemicals in particular are harmful to the environment.

We have developed a new product – a composite material containing mussel shell and copper – to tackle the problem of biofouling. When fitted onto roof and wall surfaces, the composite material will continuously release low levels of copper that prevents the growth of unwanted algae, lichen and moss. This invention is safe and has an expected lifespan of 15 years – providing long-lasting protection compared to current solutions.

At the end of its functional life much of the copper loading of this building material will be depleted, but the remaining shell content can be recovered and recycled. This project explores the technical, commercial and social challenges of recycling this new material at end of life, including:

1. The effect of incorporating recycled composite material on the physical properties (e.g. strength) and technical performance (copper release characteristics) of new composite material.
2. The barriers to adoption of a Circular Economy Business Model (CEBM) including the motivation of stakeholders to return 'spent' composite for recycling.

Our project provides an evidence base for closed loop recycling of end-of-life composite into new, applying circular economy thinking at the pre-commercial, design stage of the product when it can be more easily embedded.

The Approach: How we tackled the challenge

On the product side, we tested the incorporation of recycled material into new composite through a collaboration with Bangor University's BioComposite Centre, assessing:

- How much material could be incorporated.
- The physical strength of the resulting composite.
- The efficiency of biocidal copper release through accelerated weathering.

The results of these tests informed the degree of end-of-life composite which could be effectively incorporated into new composite without impacting the performance and durability of the resulting material.

On the business model side we:

- Collaborated with the BioComposite Centre to run a workshop with key stakeholders in the creation of a CEBM including, problem owners, actors and customers.
- Adopted a system's thinking approach, using the Mode 2 Soft Systems Methodology (Mode 2 SSM) to identify socioeconomic problem situations within the CEBM.

Our decision to take a system's thinking approach to CEBM adoption was key to our success in identifying some of the potential challenges and barriers we might face in implementing our closed loop recycling proposal.

Unexpected Outcomes: What we learned along the way

In terms of the recycling process, an unexpected outcome was that the incorporation of recycled material was limited by the fluidity of the mixture of virgin and recycled material, prior to forming the composite. Limits of physical mixing of the components during preparation

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of the composite on a pilot scale meant that a 20% reduction in fluid content of the composite pre-mix was the maximum achievable.

A further unexpected outcome was that the process for recycling led to different grades of material, only some of which were suitable for re-incorporation into fresh composite. This meant that there was a side-stream of material that was not useable. Unless alternative uses could be found for this side-stream, the supply chain process would not be wholly circular.

Another unexpected outcome was the need for a technology to discriminate between returned composite suitable for reuse, and that which required recycling into fresh composite.

In terms of CEBM adoption, our workshops raised several key questions:

1. Should the only version of the product to launch contain 20% recycled content (i.e. without launching a virgin alternative)?
2. How can we guarantee (i.e. through warrantees) that the quality and provenance of recycled content is equivalent to virgin material, satisfying insurers and lenders?
3. Who should bear the cost of reverse logistics enabling the recycling process (manufacturer, retailer, distributor, installer or end-user)?
4. If a deposit is paid to cover the cost of reverse logistics, would this act as a disincentive to purchase, or be too low to incentivise return?

Key Learning: What we would do differently next time

Our original plan for the project was to conduct workshops to investigate the proposed CEBM once technical challenges had been successfully addressed. However, following advice from Innovate UK, we began work on this strand alongside working on the technical challenges so that the needs of stakeholders could be addressed at an early stage in our CEBM strategy.

Given the pre-commercial state of our technology, we believe we have an advantage in being able to design for recycling from the outset (for example, through the use of material tracking codes), without relying on the creation of a wider infrastructure for capturing the value of used building materials, or competing with an existing linear solution.

The Outcome: What we achieved and how it has impacted the business, society and key stakeholders

The project was successful in overcoming all the technical challenges of recycling. Once processed, around 22% of the used composite material was suitable for incorporation into fresh composite. Importantly, incorporation up to 20% of the total mass of the composite was possible without reducing the mechanical strength and biocidal copper-release performance of the new composite by more than 10%.

Through workshops and consultation with experts at Bangor University's BioComposites Centre and Centre for Photonics Expertise and the UKRI Interdisciplinary Centre for Mineral-based Construction Materials (MCM-ICEC), the project identified several innovative approaches to overcoming barriers to adoption of a CEBM for our composite material. Our key findings included:

1. Placement of laser-etching tracking codes (e.g. QR codes) onto the composite building materials to allow tracking and performance quality assessment of these materials during use and after use. This will enable material recycling and the collection of 'in use' performance data for composites containing recycled material. Such data will provide a strong evidence base for material provenance and warranties to insurers and lenders.
2. Embed a reverse logistics cost in the purchase price of the composite. Stakeholders agreed end users should bear the cost of reverse logistics, but that a return incentive would be paid to installers, recyclers or end users on return of the material.

In terms of stakeholders, we found that architects and insurers were key to the successful introduction of our part-recycled composite material. At the outset, we expect the material to be integrated into a device which can be attached to existing buildings, thereby reducing the risks of incorporating the material into a new building structure.

Due to the absence of an existing system for reuse and recycling of building materials, the reverse logistics system is conceptual. In comparison to electronics manufacturing companies, building materials companies lack management structures with responsibilities for building material recycling, that could come together and form a critical mass to install meaningful change across industry infrastructure.

Looking forward: Next steps and future directions

We continue to promote our functional composite material technology to the building industry, attracting interest from roofing materials companies and architects. Patent applications for our functional composite material are currently going through examination in Europe and North America and we expect them to be granted in 2025.

The project has also attracted the interest of housing associations, which could act as a bridgehead for market entry and adoption of a CEBM. Housing associations own housing stock over a longer-term than individual homeowners, have a strong interest in sustainability and have a strong incentive to reduce maintenance costs and improve the aesthetic appeal of their building stock.

Bangor University's BioComposites Centre and Adra, North Wales' largest housing association, are developing plans for collaboration to test the material in situ. Adra has created a decarbonization hub - Tŷ Gwyrddfai – an innovative, state of the art research and development facility dedicated to testing and trialing new technology and building materials that align with the decarbonisation agenda. The company's close association with building materials manufacturers and retailers at Tŷ Gwyrddfai provides a perfect fit for the further development of the material towards field trials on housing stock.

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