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BIO-CIRC Project

European Regional Development Fund

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Bio(and)**C**ircular **I**nsulation for **R**esourceful **C**onstruction

Industrial Process Repurposing, Material Sourcing and Prototype Production

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Review and Input from Bio-Circ Partners

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nomadéis

ASBP The Alliance for Sustainable Building Products

thermafleece Nature's finest insulation

backtoearth

Abstract of the project

The BIO-CIRC Project, Bio(and)Circular Insulation for Resourceful Construction, intends to tackle the building sector's high carbon, energy and resources dependencies while taking advantage of an unused waste resource: polyester from waste bedding.

The project aims to conceive, develop and deploy 3 prototypes of innovative low-carbon thermal insulation material made from polyester and combined with natural fibres. It intends to promote the emergence of a bespoke waste polyester valorisation industry and the use of virtuous Natural and Recycled Fibre Insulation products.

This project is carried out by a cross-channel partnership of 4 key and complementary links in the building sector's value chain:

- Nomadéis (lead partner)
- Alliance for Sustainable Building Products
- Eden Renewable Innovations
- Back to Earth

Planned over 2 years, the BIO-CIRC project receives funding from the European Regional Development Fund (ERDF). The ERDF's contribution amounts to €399,600 for a total budget of €499,500.

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Prototype insulation specification

Four fibre components were utilised to produce the prototypes:

1. Reclaimed and refiberised polyester sourced from waste duvets (**rcPET**) – fibres created by cutting duvets and pulling to open the fibres apart.
2. Scoured sheep's wool (**Wool**) – loose wool fibres that were cleaned and degreased.
3. Recycled polyester staple fibre made from waste polyester packaging (**rPET**) – an extruded fibre created from cleaned waste polyester (PET) bottles and other packaging.
4. Polyester bi-component binder fibre (**bi-co**) – a binder fibre commonly used in non-wovens comprising a high melting point core fibre surrounded by a low melting point polyester sheath that adheres to surrounding fibres.

Table 1: Prototype composition

Prototype	Target Thickness (mm)	Target Width (mm)	Target Length (m)	Target Density (kg/m^3)	Content (% w/w)			
					rcPET	Wool	rPET	bi-co
P1	100	370	4.5	16	65%	-	25%	10%
P2	100	370	5.0	20	25%	65%	-	10%
P3	100	370	5.0	20	39%	51%	-	10%

Raw materials

All raw materials were baled and labelled with an appropriate reference number that denoted the material and referred to the raw material specification.

Polyester Bi-component binder

A fibre used in the process of thermal bonding as a binding agent, comprising 2 components, the sheath (thermo-bonding component polyester) and the core (regular polyester). Sheath melting point is 110ºC. 4.4 Decitex fibre diameter. 30-50 mm fibre length.

Recycled Polyester (rPET)

Non-food grade recycled polyester staple fibre. Diameter 4.4 Decitex. 30-100 mm fibre length.

Reclaimed Polyester (rcPET)

Refiberised synthetic polyester duvets. Reclaimed from duvets. Min 95% polyester; >99% synthetic (Polyester, Polyprop, Nylon); <1% cotton/cellulosic; Diameter - mixed, 1-4 Decitex; 20-50mm fibre diameter.

Sheep's Wool

Mixed grades. Cleaned and scoured. Max 45-micron diameter. 25-200 mm fibre length.

Production process

Duvet Collection and Sorting

Pillows and duvets are deposited in textile recycling banks across the UK. Banks are collected and delivered to collection centres where the duvets are unloaded and transferred to a sorting platform. On the sorting platform, duvets and pillows are segregated and sorted. Visibly soiled duvets are discarded. Non-soiled duvets are segregated by the description on the washing label. Synthetic filled duvets are separated into wheelie bins and then to a large bailer where they are compressed into 200kg bales.

Figure1: Textile collection and sorting facility

Incoming Raw Materials

All raw materials were label-checked for identification and referenced to the material specification. Duvets underwent a secondary sorting.

Prior to entering the refiberizing line, all duvets were manually segregated. Visibly soiled duvets were discarded, and remaining duvets were sorted by washing label as an additional quality check ensuring that the material specification was met.

Figure 2: Inbound inspection of duvets

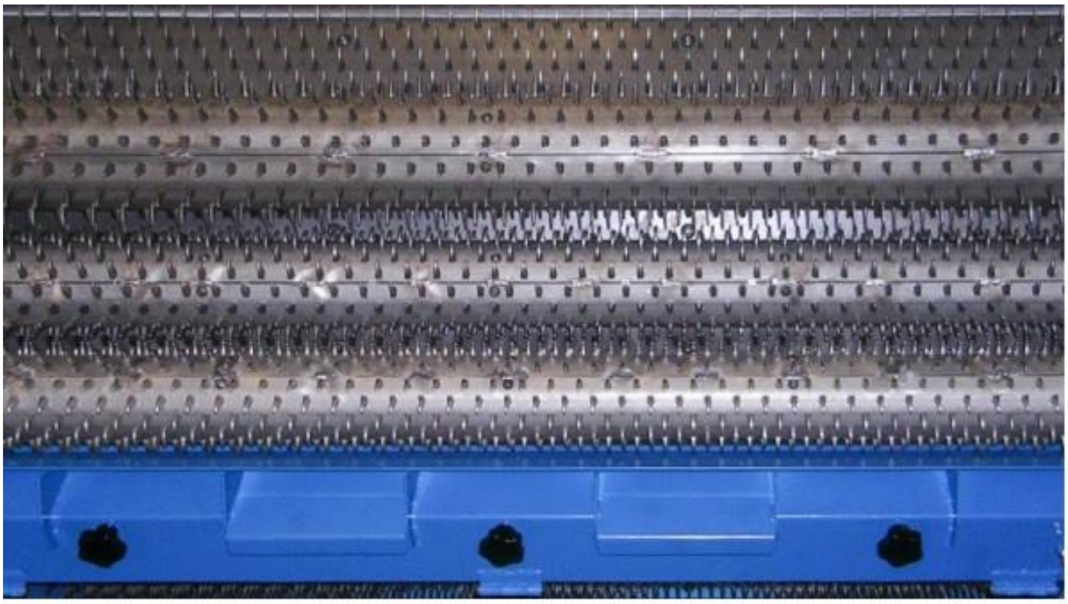
Refiberisation

Duvets were fed into a line where they passed through two slitter-cutters. This comprised a series of sharp rotating blades that cut the duvets and pillows into pieces approximately 100mm x 100mm. Flow rate was approximately 200kg/hr although this could be improved two or threefold.

Figure 3: Cut and sliced duvets

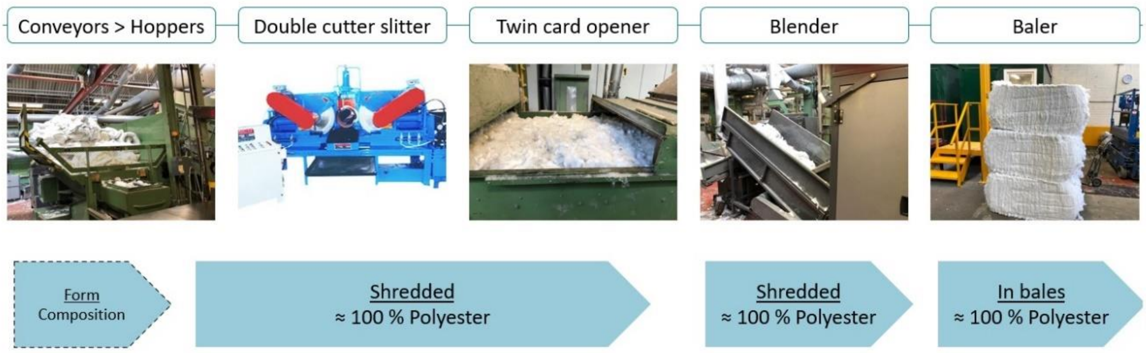
The insulation then passed to a twin card opener where the material passed over a series of pinned drums that pulled the fibres apart.

Figure 4: Pinned drums



The material then entered a blend hopper where the fibre was blended into a uniform mix and finally to a bailer where the blended fibre was baled into 200kg bales. The bales were then ready for insulation production.

Figure 5: Refiberisation process



Options for Nonwoven Production

Nonwoven production involves a continuous process in which a web of fibres is laid prior to entering a stage where the fibres are bonded to form a final non-woven material. The method of web formation depends largely on the nature of the raw material and end-use of the non-woven material.

Of the three methods of web formation (dry, wet or polymer laid), the dry laid process is the most adequate technique fort insulation manufacture. The web can be bonded by thermal, chemical, or mechanical means, the former being most appropriate in this instance. Natural fibres can be mechanically bonded. However, the high density and low thickness of the finished product render this technique ineffective for insulation where relatively low density and greater product depth is required.

Web Formation

Two options are available for the dry laid process, air-laying or carding (and cross lapping). The web formation processes involve 3 steps; fibre opening and blending which is the same for both methods followed by web-formation and web stacking (where both techniques differ).

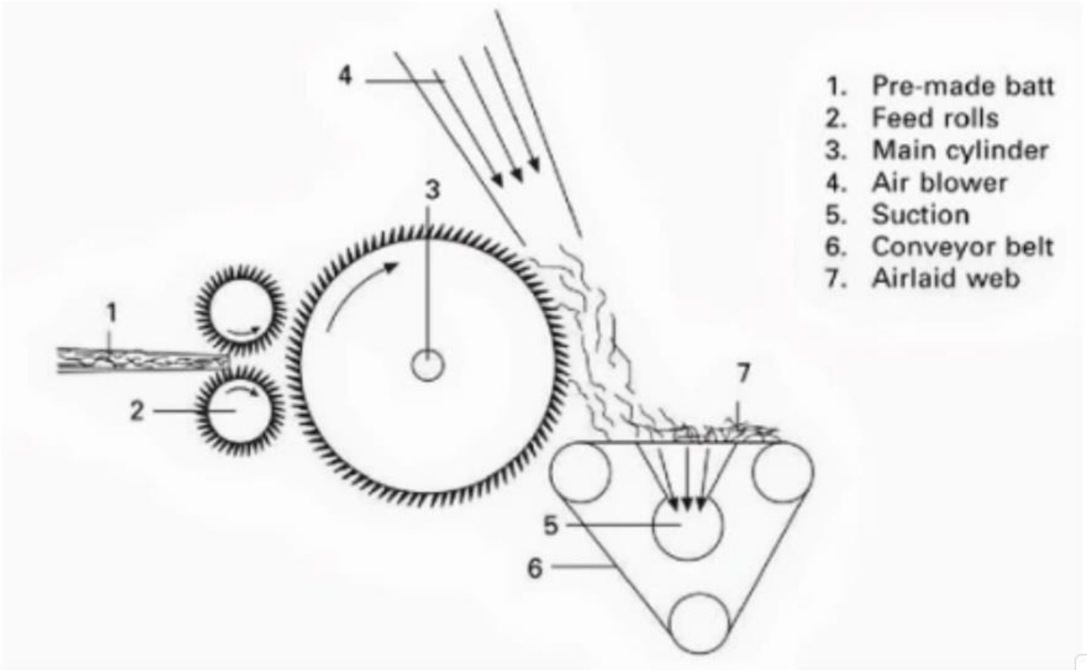
Carding

The objective of carding is to separate the fibres into individual fibres with minimum fibre breakage and opening and blending of different species of fibres thoroughly. Fibres pass through a series of needled drums where they are formed into a thin sheet of fibres. The web is created by layering each of these on top of the other to build up the desired thickness of web. In the carding process, fibres run in line with the machine direction. To create a more random matric of fibres, the web can be cross lapped either perpendicular or parallel to the line of the machine.

Air Laying

Air laying utilises a stream of air to create the web. Firstly, opened blended fibres are fed into a spiked roller, then into a continuous air stream. The fibres are then collected on a condenser screen where they form a web. The flow rate and direction of the air stream can be used to adjust the fibre orientation and density of the web. Air laying is well suited to shorter fibres. Higher production speeds can be achieved. Air laying is limited to non-woven weights greater than 30 gsm (which is below the lower limit for the thinnest insulation, 300gsm). Air lay is used to create voluminous, isotropic and uniform webs from a mixture of synthetic and or natural fibres.

Figure 6: Web formation using air lay



Web Bonding

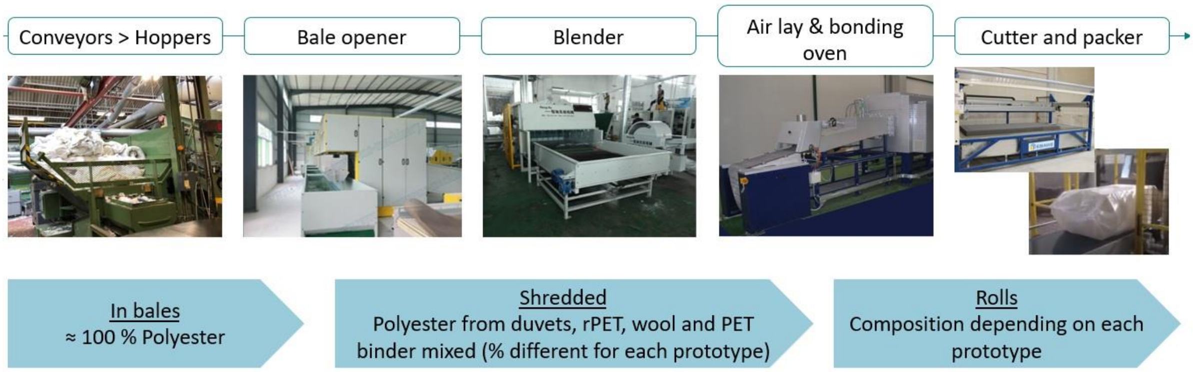
When the web is formed, it needs to be bonded. The web can either be thermally, mechanically, or chemically bonded. The method used will depend on the end-use and the nature of the web formation.

Chemical bonding is not often used for non-wovens used on natural insulation. Although latex has previously been used, it has a limited service life and its breakdown can result in fibres moving and insulation slumping in service. Mechanical bonding is usually achieved by needle punching, which is very effective for thin high-density webs. If mechanical bonding is used to manufacture insulation, there is a possibility that fibres will dislodge, causing the insulation to slump in service. Thermal bonding involves incorporating a fibre into the web that melts and bonds fibres within the web when the web passes through a bonding oven. It is a reliable method for creating durable non-wovens at a lower density and greater thickness. Thermal bonded insulation is much less prone to slumping in service.

Production Process – Air Lay & Thermal Bonding

Existing non-woven technology was used to manufacture the insulation prototypes. Non-wovens are used in insulation, wipes, medical products, feminine hygiene products disposable diapers. Air lay was principally chosen due to the variability of the fibre length arising from the duvet waste. It may be possible to use carding and cross lapping, but this may result in a slower process. Thermal bonding using a bi-component binder was considered essential.

Figure 7: Insulation production process



Opening fibres is particularly important for insulation production: this will result in a more uniformly dense insulation which, in turn, provides more consistent insulation performance across the entire section of the insulation. Variations in density can provide hot or cold spots in the insulation resulting in non-uniform performance.

Packaging

Insulation passed from the bonding oven to the packaging line where the insulation was rolled and packed in LDPE bags, 3 rolls per bag. The sealed LDPE bag protects the insulation from rain and ensures that the insulation remains in the same condition as when it left the bonding line. This means that the insulation is very dry, and the packaged insulation will have very low water activity, ensuring that microbial growth is prevented prior to handling and installation.

Performance

The insulation prototypes underwent a series of tests that are fully reported in the deployment report (see report T1.3.4.1). The following tests were conducted:

- ISO 8301:1991 Thermal Conductivity – minimum 0.044 W/mK thermal conductivity.
- EN 11925 - Fire performance –ignitability. Flame spread <150mm.
- ISO 12572 - Water Vapour Diffusion Resistance Factor – as determined.
- EN 1602 – Bulk Density – as determined.
- BS EN ISO 12571:2013 - Moisture Storage Function – as determined.
- BS ISO 15901-1:2016 – Porosity – % as determined.
- EN ISO 15148 - Liquid Transport Co-efficient – as determined.

Conclusion

The prototype production trials demonstrated that **insulation containing refiberised duvet waste could be manufactured at scale**. Repeat trials are necessary to determine the variation in fibre properties and quality arising from the duvet waste stream. Because of the limited time available for production runs, it was however not possible to conduct repeat runs.

The main challenges that require further consideration are:

- Consistency of raw material quality. First, it may be possible to utilise IR detection technology to speed up the sorting process and ensure greater consistency.

  Variability in the consistency of the duvet fibres may alter the feed rate and cause inconsistencies in the web formation, although the tests didn't show any proof of it.
- The polyester fibre diameter used in duvets is generally thinner than polyester fibre typically used in insulation. The production of lab samples provided a good indication of the proportions of co-fibres, but repeated full-scale production would be required to optimise fibre blends.
- It was not possible to produce an insulation prototype containing entirely reclaimed polyester. However, this may be possible if density is significantly increased. This would only be viable if the cost of the raw material was sufficiently low.

Overall, the prototype production trial demonstrated the technical feasibility to manufacture commercial insulation from waste polyester duvets and pillows at scale.

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