Circularity for Educators

02. Circular Definitions

Introduction to bio-composites

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Material composites consist of at least two different constituent materials which -when brought together- form a combined material that exceeds the performance of the individual constituent materials.

Composite materials are used extensively in construction. Think of reinforced concrete that consists of concrete and steel reinforcing bars; Fibreglass that consists of synthetic polymer resin and glass fibres, or Wood that consists of natural lignin resin and natural cellulose fibres.

Composites made from bio-based constituent materials, namely use *natural plant fibres*, which give the composite its strength and stiffness, and the *matrix* (or resin), which binds the fibres together and protects the fibres from the environment. The ratio of fibres to resin has a big influence on the properties of the composite and is known as the volume fraction or mass fraction.

There is a growing interest in these *bio-composite materials* because they are *relatively strong* and *cheap*, they are *produced from local renewable sources*, and they can be *completely recyclable*. In addition, the plant fibres have a hollow structure, which makes them *lighter* than conventional non-renewable construction materials as well as *good insulators* against noise and heat. *But they generally perform below par in* other aspects such as *environmental durability and fire resistance.*

So, what is a bio-composite actually made of?

The Fibres' constituent

Let us first take a look at the fibres' constituent.

The plant-based fibres are obtained from *crops grown for their fibre content* or from *by-products of crops grown for other uses*, for example, the left-over parts of a food crop after the edible part is removed.

The fibres can originate from different plants and from various parts of the plant structure, for example: (i) *Stalks* for example from Wheat, Corn and Rice; (ii) *Leaves* like Abaca, Sisal and Pineapple; (iii) *Basts* which is the outer part of the stalk, from Jute, Flax, Hemp, or Kenaf, (iv) *Seeds* like Coir, Cotton and Kapok; (v) *Grasses* such as Bagasse, Bamboo, Esparto, and (vi) *Wood* like Balsa, Birch, and Beech. But they can also be obtained from *natural fibre products at the end of their first lifecycle* e.g. from recycled wastepaper.

Bast fibres have the best mechanical properties amongst all the typical plant fibre types, with Flax, Jute and Hemp fibres reaching strength values similar to construction grade steel.

Fibres can be in the form of *continuous long filaments, short fibres* or *small discrete particles. Long fibres* such as those form flax, hemp and jute *can also be processed* further, for example *by weaving*, into *filaments, sheets, or mats* which makes it much easier and quicker to handle and position them in the production process. The fibres can be laid out in a composite to enhance properties like increased strength and stiffness where they are most needed. This layout is known as the *fibre architecture*.

The Matrix constituent

Now let us consider the matrix that bonds the fibres together.

This is nearly always a *polymer.* Some well-established polymers such as *polyesters, epoxies* and *vinyl esters* are derived from fossil fuels. They are stronger and more durable than bio-derived resins, but they are non-biodegradable thermosets, which means they do not decompose naturally at end of life, and they cannot be easily remoulded (remanufactured) into a different product after first use. These petroleum-based polymers can also have a poor adhesion with some of the plant fibres leading to weaknesses in the bio-composite.

Alternatively, it is possible to use bio-based polymers such as *PLA, PHA* or *Furan* resin. These biopolymers are thermoplastic and biodegradable, which makes it possible to remanufacture the bio-composite product are the end of life or it can be used as ecologically safe biomass or for bio-decomposition. They are generally more costly than the petroleum-based resins, but they provide better adhesion to the plant fibres.

Matrices can sometimes consist of a blend of fossil fuel and bio-based polymers. Consequently, bio-based composites can be either fully biobased when the matrix is a 100% bio-based polymer or partially biobased when the matrix is a blend of petroleum and bio-based polymers.

Bio-composite fabrication

Lastly, let's look at how a bio-composite is fabricated.

There are many alternative fabrication methods for bio-composites ranging from low tech methods to high tech ones. *A low-tech method* is *hand lay-up* where fibre weaves are impregnated with resin and laid by hand onto mould. A method requiring *moderate technology* is *resin transfer moulding* where the fibres are laid onto a sealed mould and the resin is then injected into the mould to impregnate the fibres. Lastly, *pultrusion, hot pressing or even 3D-printing,* require more supplicated computer-controlled equipment.

Some fabrication methods are better suited to certain types of resins and fibre types: long, short or particle, while the fabrication process chosen will also influence the quality of the composite.

So, to sum up bio-composites are a promising class of materials that can be derived from locally sourced plant fibres and bio-resins. They have a much lower embodied carbon then conventional non-biobased construction materials. They can be fabricated and shaped into many forms from linear prismatic components to continuous plates and shells and therefore they have many possible applications in the construction industry and beyond. But they must be used carefully when fire resistance and environmental durability are required.