BUS GoCircular

Shaping a Circular Sustainable Future

Module 3

Bio Based Material Implementation and Application in Circular Economy

Circular Economy in the Construction Industry

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Summary

The trainee should leave with a good understanding of biomaterials in construction regarding what exists to their profession and what needs to be done to implement these building materials successfully. They should also gain a good understanding of how this can then be implemented in Multi-functional Green Roofs Facades and Interiors Elements.

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Objectives/Learning Outcomes

- 1 – Design roofs, façades, and interior elements with bio-based materials as an alternative for conventional construction materials
- 17 – Manage and preserve biological products on the construction site to stretch the lifetime materials
- 68 – Apply bio-based, non-critical, non-toxic, and/or reusable products on site whilst maintaining material efficacy
- 83 – Increase (access to) understanding of biobased construction materials for applications to multifunctional green roofs, façades, and interior elements

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Bio-based materials

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Definition

Biobased materials refer to products that mainly consist of a substance (or substances) derived from living matter (biomass) and either occur naturally or are synthesized, or it may refer to products made by processes that use biomass.

Image source: Sheeps wool insulation
https://www.biobasedconsultancy.com/en/database/alchimea-lana-sheep-wool-insulation1

Source- https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=231873

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What are biobased materials?

Biobased materials are organic resources produced by plants and animals, such as

- Timber
- Sheep’s wool.
- Bio-concrete
- Hemp
- Straw
- Clay
- Earth

Image source: Cob Construction https://www.homecrux.com/cob-house-cost-why-cob-house/97115/

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Positive Impact of Biobased Materials

In the context of construction, biobased materials can have several benefits over conventional ones:

- They are renewable and can be sustainably produced long-term
- They can naturally absorb carbon from the atmosphere during cultivation, contributing to climate change mitigation
- They promise performance gains in terms of moisture absorption and breathability
- They are generally less harmful to people and the natural environment in terms of pollutant emissions
- They can be disposed of more easily and sustainably at their end of life

Source- https://www.rics.org/eu/wbef/megatrends/natural-environment/are-biobased-materials-the-key-to-a-more-sustainable-construction-industry/

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Existing Bio-based Materials and Techniques

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Existing Bio-based Materials and Techniques

- Earth
- Timber
- Straw
- Wool
- Hemp

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Cob Construction

Cob, like adobe, is comprised of a mixture of clay, coarse sand, fine sand, silt and water; it also uses a binder of fibrous or organic material such as start, or dung.

The soil for making cob and cob bricks is usually of local material, and ideally from the property itself. Therefore, cob is also one of the most affordable types of building material, and can be built often without the use of engineers or architects, as ‘non-engineered construction’.

Source- https://globalgreen.org/latest-posts-home/green-building-cob-building/

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Advantages of Cob Construction

- Can easily be built up to 3 storeys
- High thermal mass is very energy efficient in both summer and winter, and ideal for passive solar heating and cooling. Indoor temperatures vary only about 5 degrees Celsius between summer and winter (17-22 degrees Celsius), making it naturally cool in summer and warm in winter.
- Environmentally friendly: Low carbon footprint and embodied energy.
- Relatively easy to build for owner builders and unskilled labour.
- Lends itself to free-form walls

Source- https://globalgreen.org/latest-posts-home/green-building-cob-building/

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Advantages of Cob Construction

- Excellent sound insulation
- Cob buildings are capable of withstanding seismic activity, but must have a ring beam
- Fireproof
- Cob can easily be recycled.

Source- https://globalgreen.org/latest-posts-home/green-building-cob-building/

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Disadvantages of Cob Construction

- Labour intensive
- Relatively slow to build
- Obtaining a mortgage from lending institutions is difficult
- Cob walls cannot be laid in wet or freezing weather
- Insects, notably termites and small rodents can burrow into the walls and weaken them. The use of dung in the mud mix and lime plaster can negate this problem

Source- https://globalgreen.org/latest-posts-home/green-building-cob-building/

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Timber Construction

One kind of timber construction is Timber Frame Construction.

A timber-framed house is a house where the primary load-bearing structure is made of timber. A typical design features a frame of beams and posts that make up the internal and external structure of the building and supports the entire home without the need for interior load-bearing walls.

Source- https://passivehouseplus.ie/magazine/guides/the-ph-guide-to-structural-timber

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Advantages of Timber Frame Construction

- Design flexibility afforded by a fully engineered construction system
- High levels of thermal / airtightness performance
- Predictability and speed of programme
- Certification of performance and regulatory compliance
- Improved health and safety
- Considerably less impact on the environment
- Reduction of on-site wastage
- Lifetime cost savings from energy-efficient structure
- Engineered to the highest level of accuracy and quality

Source- https://www.kingspan.com/ie/en/knowledge-articles/advantages-of-timber-frame/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Timber In Construction

Press play on video or go to - https://www.youtube.com/watch?v=ieBVNgMkcpw

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Straw/Typha

The Griesfwald Mire Centre, in collaboration with a company called Wetland Products, has trialled the creation of various products from Typha, including insulation materials for buildings. This has been found to be an effective material, with fungal resistant and fire resistant properties.

The video below gives a short introduction to the growing of Typha in Mecklenburg Vorpommern, Germany, and using it to manufacture wall insulation.

*Source-*https://caraghnurseries.ie/product/typha-latifolia/

Source- https://northsearegion.eu/canape/paludiculture/typha/

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Press play on video or go to - https://www.youtube.com/watch?v=DxdKI1usYe8

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Press play on video or go to - https://www.youtube.com/watch?v=uFKUPEmzgT0

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Advantages of Typha

- Provides structural and insulation properties in a single layer construction
- Sustainable new buildings made by typha
  - Timber frame structures – stiffening, insulation, and passive climate control
  - 100% typha structures
  - TYPHABOARD as insulation in building structures

*Source-*https://materialdistrict.com/material/typha-insulation/

Source- https://typhaboard.com/advantages/

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Advantages of Typha

- Existing building retrofit: easy-to-install indoor insulation
- Resource saving installation – low material and installation time costs
- By using TYPHABOARD ventilation systems become unnecessary
- Paludiculture (the type of farming used for this process) is a regenerative process trapping carbon in the earth.

Source- https://typhaboard.com/advantages/

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Wool in Construction

Homes need insulation to provide adequate noise absorption, to control heat levels and make a building more comfortable. Of the many insulation materials on the market, wool stands out as the ideal natural option for sustainable building insulation.

A sustainable insulation material like wool is a key component of eco-friendly buildings, with growing environmental trends meaning every building is aiming towards becoming more sustainable overall.

Source- https://www.sheepwoolinsulation.com/about/

Source- https://iwto.org/the-benefits-of-using-wool-for-natural-insulation-in-buildings/

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Advantages of Wool in Construction

- Wool as a building and/or furnishing material can meet several sustainability criteria.
- Wool is a natural product that is less toxic than many alternatives, and fire retardant.
- Wool is an available resource that is biodegradable and easy to dispose of.
- The natural qualities that wool has allow it to dampen sound and absorb pollutants.
- Wool regulates humidity and are hypoallergenic. They perform better than synthetics in smell and staining tests. They absorb moisture when the air is moist and releasing it when the air is dry.

Source- https://www.procurement.govt.nz/assets/procurement-property/documents/benefits-of-wool-construction-procurement.pdf

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Advantages of Wool in Construction

- Wool is a very effective insulator, suitable for thermal and acoustic building insulation. Sheep wool insulation is safe, eco friendly and energy efficient.
- Wool is ideal for structures made from wooden frames, as the wool has a natural synergy with timber.
- There are opportunities in new technological applications of wool, such as effective ways to deconstruct the fibre and reconstitute it in a range of useful forms.
- Wool is a readily available resource.

Source- https://www.procurement.govt.nz/assets/procurement-property/documents/benefits-of-wool-construction-procurement.pdf

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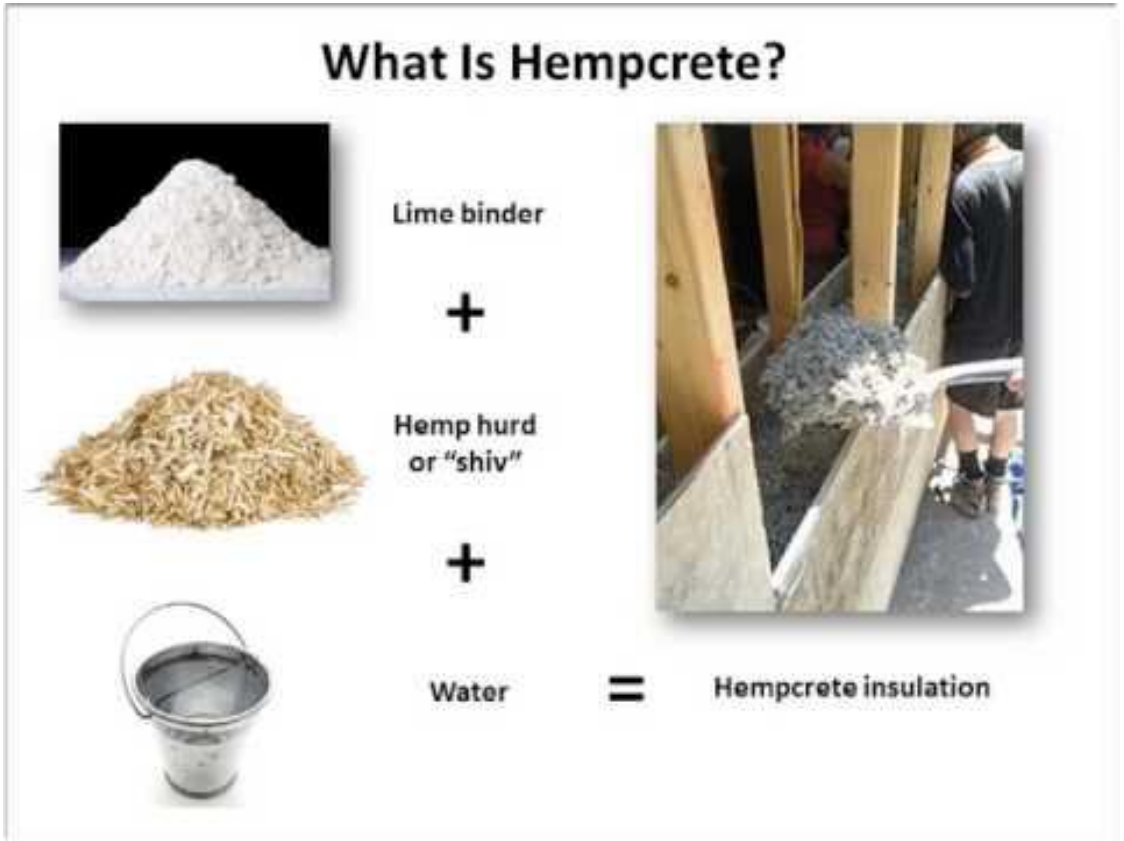
Hemp in Construction

Hempcrete is a bio-composite made of the inner woody core of the hemp plant mixed with a lime-based binder. The hemp core or “Shiv” has a high silica content which allows it to bind well with lime.



Source- https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DyIldL6QRtLo&psig=AOvVaw2T4DIL4LFacrWegkZXkWNq&ust=1673110425163000&source=images&cd=vfe&ved=0CBAQjRxqFwoTCLCDva-0s_wCFQAAAAAdAAAAABAJ

Source- http://www.americanlimetechnology.com/what-is-hempcrete/

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Hemp in Construction

The result is a lightweight cementitious insulating material weighing about a seventh or an eighth of the weight of concrete.

It is not used as a structural element, only as insulating infill between the frame members though it does tend to reduce racking.

Wood stud framing is most common making it suitable for low-rise construction.

Hempcrete buildings ten stories high have been built in Europe.

Source- http://www.americanlimetechnology.com/what-is-hempcrete/

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Advantages of Hempcrete

- High thermal insulation.
- CO2 sequestration.
- Passive, low energy.
- Negative carbon footprint.
- 50% – 80% energy savings.
- Healthy living environment.
- Fireproof.
- Inherently airtight.
- Termite resistant.
- High acoustic performance.
- Breathable walls.
- No waste.
- Design flexibility.
- No dry rot.
- Prevents mould.
- Low air infiltration.
- No landfill.
- Self-build friendly

Source- https://www.hempbuild.ie/

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Further Example of Existing Bio Based Construction Methods and Materials

Hemp Bricks

http://www.cannabric.com/catalogo/cannabric_bloque_de_canamo_autoportante_portante_/

Cross Laminated Timber (CLT) construction

https://www.cedarlan.ie/c-l-t-cross-lam-timber

Stone Construction

https://nationalinventoryich.chg.gov.ie/dry-stone-construction/

Rammed Earth

https://www.archdaily.com/933353/how-rammed-earth-walls-are-built

Compressed Earth Blocks

https://arquitecturaviva.com/articles/btc-system

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New Bio-based Materials and Techniques

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Bio-based Materials and Techniques

- Bio Plastics
- Mycelium
- Biochar
- Bio-based Concretes and Cement
- 3D-Printing

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Bio-Plastics

Bio-based plastics refer to those materials or products that are wholly or partially derived from organic biomasses (bio-based materials)

- such as corn
- sugarcane
- cellulose

One of the main applications of bioplastics in the construction industry concerns their use in concrete mixtures and dry premixed mortars, as additives that optimize these products. In several applications, bio-based aggregates compete on par with those of synthetic origin; their market is, therefore, likely to expand, especially with the increasing advances achieved by technology

Source-https://www.mdpi.com/2673-8392/2/3/95/pdf#:~:text=Bioplastics%20provide%20an%20attractive%20sustainable,production%20of%20non%2Dbiodegradable%20waste

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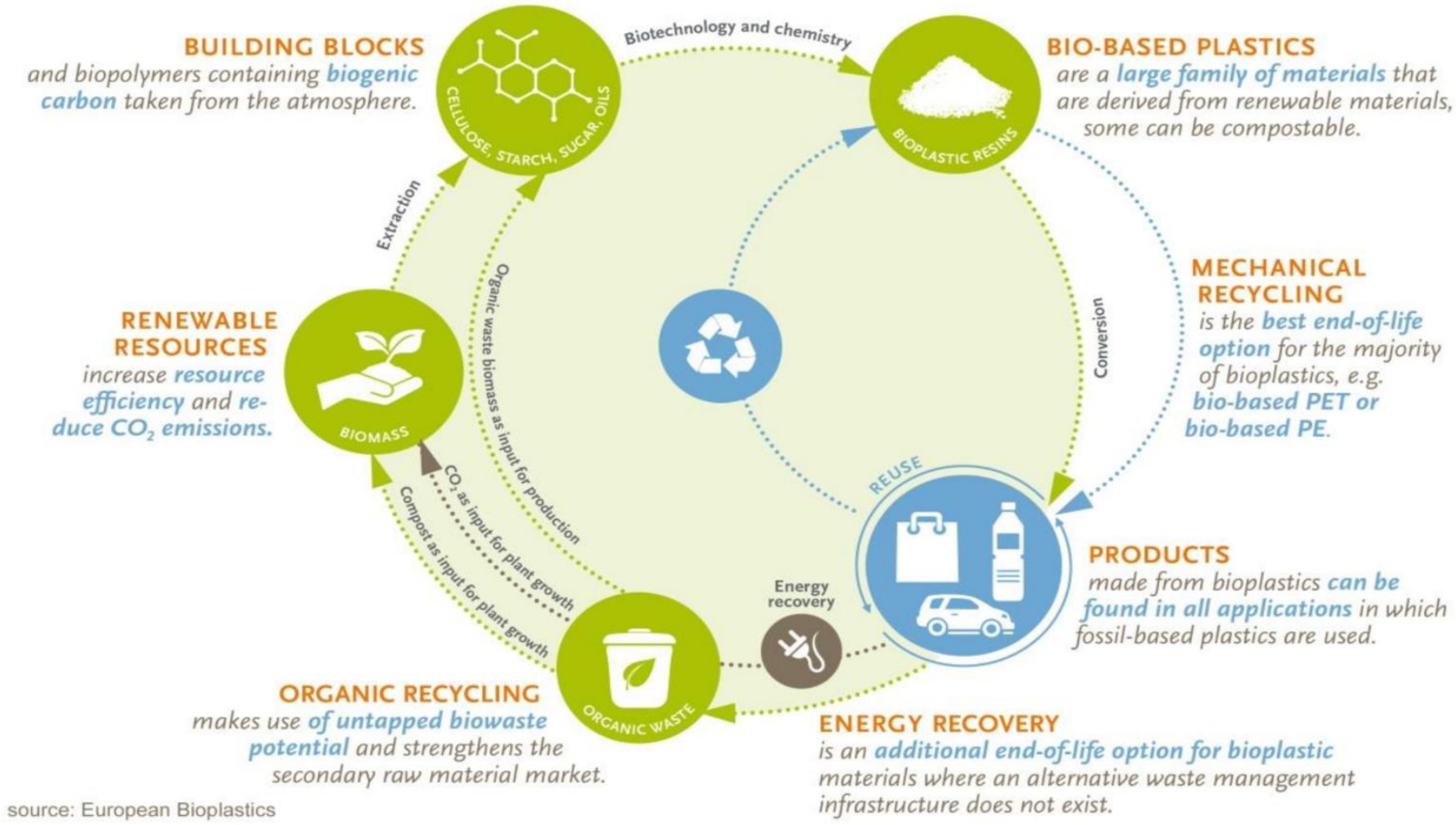
Bioplastics – closing the loop



source: European Bioplastics

Source- https://www.mdpi.com/2071-1050/14/8/4855

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Advantages of Bio-Plastics

- Less oil is used.
- The common bioplastics can be injection molded and shaped to take the same form as traditional thermoplastics.
- Bioplastics are more marketable, for example, their usage may improve the value-add of a product through a green marketing campaign.
- Less plastic litter is needed. In the UK, it was found that 90% of litter on beaches was plastic. Bioplastic break down naturally by composting or degrading naturally.
- Many bioplastic polymers are naturally occurring and don't have the carbon footprint of oil-based plastics because they don't require the refinement of oil to produce.
- Common bioplastics are often non-toxic and of 'no health concern'.

Source- https://qualityinspection.org/advantages-of-bioplastics-vs-disadvantages/

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Disadvantages of Bio-Plastics

Bio-plastics should only be used as a last resort. Bio-plastics, even if they are "bio", should be reduced to uses that cannot be replaced by other materials. Due to the need for further processing in their manufacture and the fact that not all bioplastics are biodegradable or recyclable, they should be reduced to uses that cannot be replaced by other bio-based materials.

Source- https://www.moulding-injection.com/bio-plastic-pla-thermoplastic-injection

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Disadvantages of Bio-Plastics

- First, bioplastics are generally not cost-competitive compared to their oil-based counterparts.
- There is a concern that bioplastics based on terrestrial crops could harm food supplies.
- Crop-based bioplastics require fertile land, water, fertilizers, and are reliant on weather conditions. This means that the supply of raw materials for bioplastics are at risk of natural phenomena, such as drought.
- Some bioplastics have a shorter lifetime than oil-based plastics due to weaker mechanical properties.
- Many bioplastics must follow a specific disposal procedure and require industrial composting in order to avoid being incinerated or going to landfill.

Source- https://qualityinspection.org/advantages-of-bioplastics-vs-disadvantages/

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Example of Bio-Plastic in Construction

ArboSkin pavilion made from bioplastic by ITKE

The pyramidal modules are made by extruding bioplastic granules into sheets before thermoforming them to create the faceted shapes and trimming off the excess material.

Follow the link for full video - https://www.dezeen.com/2013/11/09/arboskin-spiky-pavilion-with-facademade-from-bioplastics-by-itke/

Source- https://www.dezeen.com/2013/11/09/arboskin-spiky-pavilion-with-facademade-from-bioplastics-by-itke/

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Mycelium

Mycelium are the thin root-like fibres from fungi which run underneath the ground, when dried it can be used as a super strong, water, mould and fire resistant building material that can be grown into specific forms, thus reducing the processing requirements.

Source- https://www.dezeen.com/2021/06/25/carbon-negative-buildings-mycelium-insulation-fire-proofing/

Source-https://www.certifiedenergy.com.au/emerging-materials/emerging-materials-mycelium-brick#:~:text=Mycelium%20are%20the%20thin%20root,thus%20reducing%20the%20processing%20requirements.
https://www.biohm.co.uk/mycelium#:~:text=Mycelium%20not%20only%20outperforms%20petrochemical,of%20flames%20during%20a%20fire.

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Mycelium

Mycelium not only out performs petrochemical/plastic based construction materials in thermal and acoustic insulation but, as a natural material, it is also safer and healthier.

Mycelium does not contain the synthetic, resin-based compounds that can cause harmful toxic smoke and the quick spread of flames during a fire.

Source-https://www.certifiedenergy.com.au/emerging-materials/emerging-materials-mycelium-brick#:~:text=Mycelium%20are%20the%20thin%20root,thus%20reducing%20the%20processing%20requirements.
https://www.biohm.co.uk/mycelium#:~:text=Mycelium%20not%20only%20outperforms%20petrochemical,of%20flames%20during%20a%20fire.

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Advantages of Mycelium

- Thermal Capacity: Initial testing indicates that mycelium panel is a highly effective thermal insulating product.
- Fire Performance: Mycelium does not contain the synthetic resin-based materials that cause the harmful toxic smoke and quick spread of flames during a fire.
- Acoustic Performance: Mycelium provides excellent acoustic insulation and tests show an acoustic absorption of at least 75% at 1000Hz (the typical frequency of road traffic noise).
- Sustainability: Mycelium consumes organic and synthetic waste to grow into desired shapes and can achieve a range of thermal and mechanical material properties.

Source- https://www.biohm.co.uk/mycelium#:~:text=Mycelium%20not%20only%20outperforms%20petrochemical,of%20flames%20during%20a%20fire.

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Advantages of Mycelium

- Durability: Research on the long-term in situ performance of bio-based materials such as mycelium has demonstrated that they are at least as durable as conventional materials and maintain their insulative properties over the course of their life.
- Buildability: Mycelium is designed to replace carbon intensive and toxic insulation boards with a high performing natural bio-based alternative.

Source- https://www.biohm.co.uk/mycelium#:~:text=Mycelium%20not%20only%20outperforms%20petrochemical,of%20flames%20during%20a%20fire.

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Mycelium Project

Follow Link for Video on Mycelium and Food Byproduct Construction and Image Source

http://thelivingnewyork.com/hy-fi.htm

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Bio-Based Concrete and Cement

Mixing a new type of bacteria and calcium lactate capsules into the initial concrete mixture, *Jonkers* (http://edition.cnn.com/2015/05/14/tech/bioconcrete-delft-jonkers/index.html) created a type of concrete that can actually rebuild itself as moisture enters the inevitable cracks, gaps, and holes, a form of self-maintenance.

Bacteria is used to “grow” durable cement in ambient temperatures between loose grains of aggregate; producing building materials without emitting greenhouse gases, and without the depletion of non-renewable resources.

Source- https://www.bdcnetwork.com/dutch-teams-bioconcrete-can-heal-itself

Source- https://circle-lab.com/knowledge-hub/1629/biobased-cement https://www.generalkinematics.com/blog/what-is-bio-concrete/

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Advantages of Bio-Concrete

- Overall maintenance cost of this concrete becomes low. The use of bioconcrete significantly enhances the strength of the concrete.
- It has lower permeability when compared to conventional concrete.
- It has also lower water absorption when compared to conventional concrete.
- It offers great resistance against freeze and thaw attacks.
- The chances of corrosion or reinforcement are reduced to negligible.
- Redressing of cracks can be done efficiently.
- It basically increases durability of the structure to a large extent.

Source- https://gharpedia.com/blog/bioconcrete-self-healing-concrete/

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Disadvantages of Bio-Concrete

- Cost of this concrete is comparatively higher than conventional concrete; it's about 10-30% more than conventional concrete.
- The germination of bacteria is not suitable in every possible environment.
- The investigations to observe calcite precipitation are costly.
- Bacteria that are used in concrete are not good for human health; hence its usage has to be limited to the structure.
- No design guideline for bacterial concrete are yet available in Codes of Design.

Source- https://gharpedia.com/blog/bioconcrete-self-healing-concrete/

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Biochar

Biochar, a highly porous material produced from plant waste

- is mostly used in agriculture as a soil conditioner
- in livestock farming as a feed supplement
- in metalworking as a reducing agent.

It can also be used for cleaning “grey water”, as an absorber in sports clothing, in batteries and many other uses.

Every tonne of biochar used in a building’s envelope means that the equivalent of more or less one tonne of CO2 is prevented from re-entering the atmosphere.

Source- https://www.biochar-journal.org/en/ct/3

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Biochar

As well as having excellent

- insulating properties
- improving air quality
- being able to soak up moisture
- protect from radiation

biochar also allows buildings to be turned into carbon sinks.

Biochar wall paneling

Source- https://www.biochar-journal.org/en/ct/3

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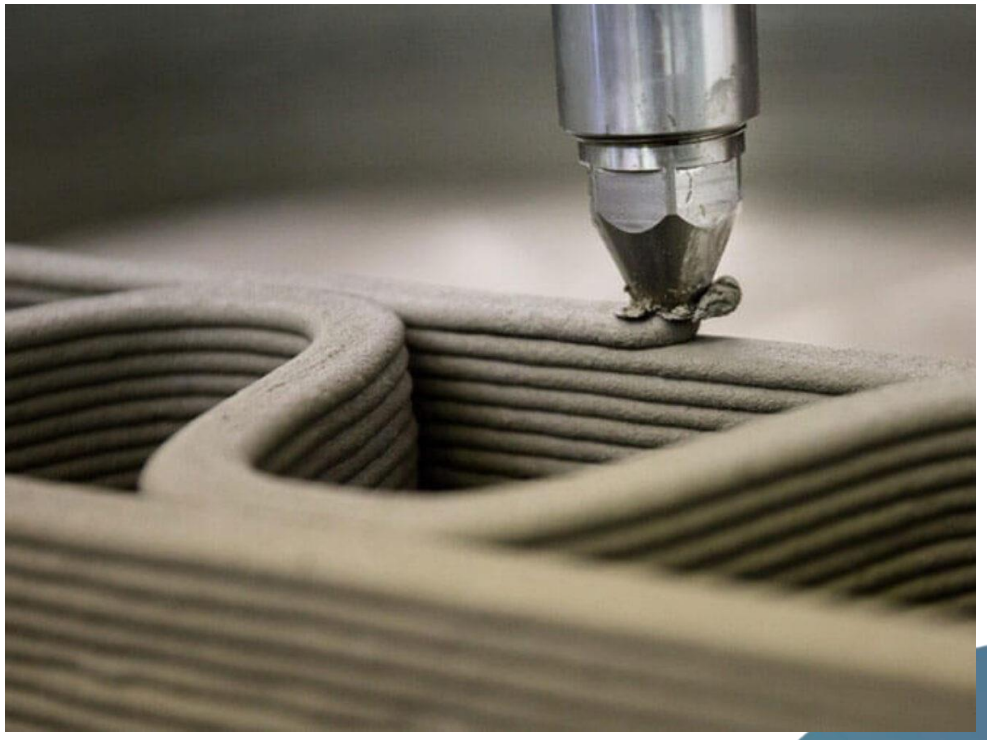
3D-Printing

3D printing is an industry that is already sustainable right now. The process produces a fraction of the waste of traditional construction manufacturing, because builders simply print exactly and only what they need. It only requires a small factory with minimal space for storage materials, and unlike a traditional production line, 3D printing does not require energy to move the same parts from one step to the next.



Source- https://www.sculpteo.com/en/3d-learning-hub/applications-of-3d-printing/construction-and-architecture/

Source- https://www.weforum.org/agenda/2022/06/3d-printing-can-help-make-construction-carbon-neutral-heres-how/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

3D-Printing Earth

Inspired by the potter wasp, since 2012, WASP (World's Advanced Saving Project) has been developing construction processes based on the principles of the circular economy and digital manufacturing. On the market since 2021, it creates 3D printed homes in the shortest possible time and in the most sustainable way with the first Crane WASP multi-printer system , the corporate pride of the construction line and the newco WASP On Site , the corporate reference point in the field of architecture.

Source- https://www.sculpteo.com/en/3d-learning-hub/applications-of-3d-printing/construction-and-architecture/

Source- https://www.3dwasp.com/casa-stampata-in-3d-tecla/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Press play on video or go to - https://www.3dwasp.com/casa-stampata-in-3d-tecla/

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Advantages of 3D-Printing

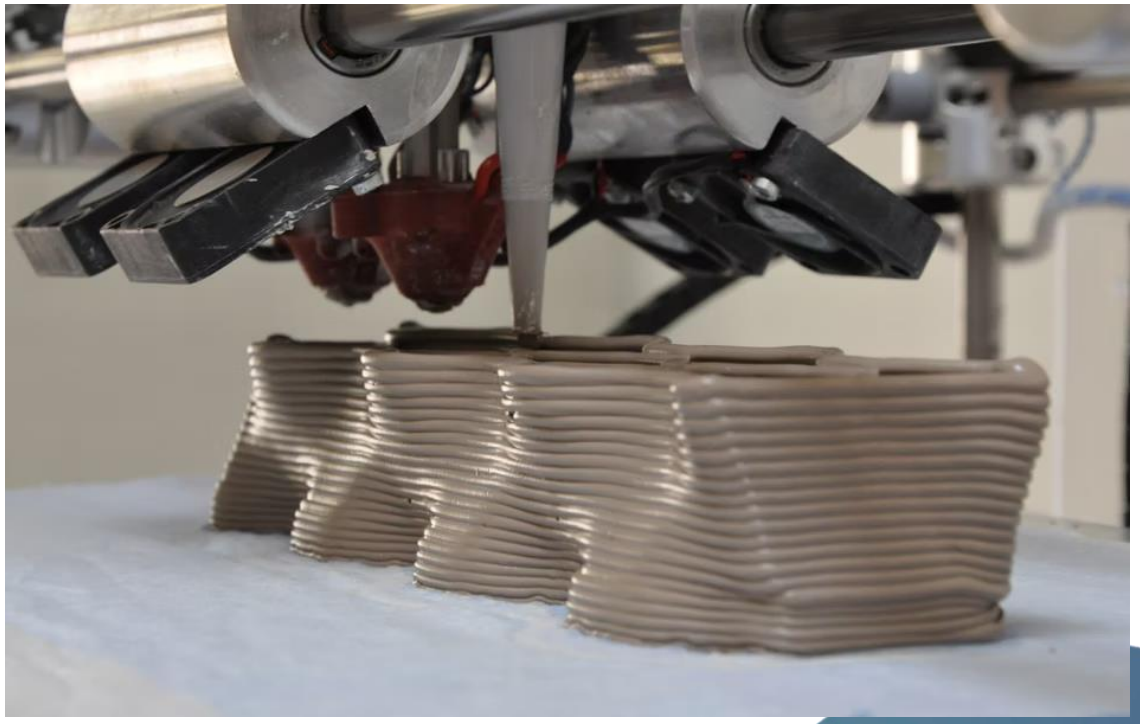
- Shorter supply chain and quicker design process: On-site 3D printing means that various time-consuming steps can simply be cut out from the design process.
- Fewer logistical processes and less waste: Many parts get damaged in transit, parts are over-engineered in order to withstand transportation, secure transportation and hoisting means additional features and 3D printing removes the need for wooden moulds.
- Making customised houses available to the wider market: The digitisation of a large part of the production process means that complex products can be customised at a minimal added cost.
- Simpler and more efficient installation of pipes and electrics: In conventional construction, heating systems, insulation, running water and electricity all require labour-intensive on-site installation, with 3D printing of concrete, some of these functions can become integrated in the 3D printing process.

Source- https://www.emeraldgrouppublishing.com/archived/realworldresearch/innovation/how-3D-printing-can-make-construction-better.htm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Disadvantages of 3D-Printing

- Material is limited to to what the 3D printer can process
- Size of product is limited by the size of the printer
- Time consuming and not very cost effective when constructing
- Manufacturers can face issues with copywriting their designs as the models can be easily repeated.



Source-https://www.forconstructionpros.com/blogs/construction-toolbox/blog/12059477/how-3d-printing-is-affecting-the-construction-industry

Source-https://www.twi-global.com/technical-knowledge/faqs/what-is-3d-printing/pros-and-cons

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Further reading on biobased materials used in construction

Overview on Bio-based Building Material Made With Plant Aggregate

https://pureadmin.qub.ac.uk/ws/portalfiles/portal/47919763/Overview_on_bio_based_building.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101033740

Bio Based Material - Multi-functional Green Roofs Facades and Interior Elements

Presentation

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Bio Based Material - Multi-functional Green Roofs Facades and Interior Elements

- Case Study
- Existing Bio-based Materials and Techniques
- New Bio-based Materials and Techniques
  - Materials
  - 3D-Printing

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Case Study - Senior Citizen Community Center by F451 Arquitectura, Spain

Text description provided by the architects. This proposal is based on the redefinition of ready-made components and their assembly to try to optimize the environmental performance of the building as well as the possibility of recycling used elements. The building was based on dry construction, except the ground, and formally displayed in such a way that increases its capability to interact with the surroundings-both architecturally and environmentally.

Source- https://www.archdaily.com/22310/senior-citizen-community-center-f451-arquitectura

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Existing Bio-based Materials and Techniques

Bio based building materials need to be tested and experimented with further in many cases as despite years of utilising bio based materials in building we have moved away from these kind of construction recently, such as -

- Thatched roofs
- Accessible roofs on bio based buildings

Source- https://www.sculpteo.com/en/3d-learning-hub/applications-of-3d-printing/construction-and-architecture/

*Source-*https://restorbuilders.com/tar-gravel-roof/

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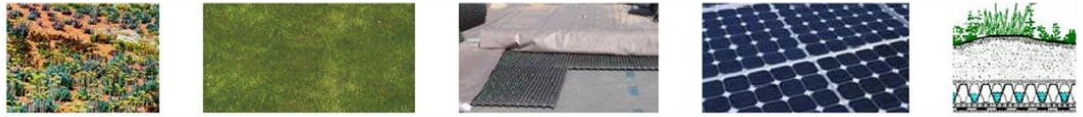
Existing Bio-based Materials and Techniques

For this given example - Senior Citizen Community Center by F451 Arquitectura

bio based structure and insulation could be utilised in this building. The building is located in spain meaning insolation such as sheeps wool would cool the building in summer and heat the building during winter.

What other examples could be suggested?

VISTA AERA DE LA COBERTA ECOLÒGICA



Source- https://karmatrendz.wordpress.com/2009/06/03/senior-citizen-community-center-by-f451-arquitectura/#jp-carousel-6531

Source- https://www.archdaily.com/22310/senior-citizen-community-center-f451-arquitectura

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New Bio-based Materials

New bio based building materials can be utilised in many ways in buildings. One of the most obvious and easy to implement options is adding substances such as biochar to the soil used in the green roof. This will reduced the release of carbon from the plants and soil and actively sequester carbon further throughout the buildings life.

What are some other examples that can be suggested for this project.

Source- https://www.carbongold.com/biochar-bringing-soil-life/

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QUIZ/ASSIGNMENT/ACTIVITY

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EXTRA READING/STUDY

Activity

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EXTRA READING/STUDY

For Further Case Studies and Training Material Please Follow the Link Below

https://docs.google.com/spreadsheets/d/1DTte4Ph8pQ4lKzYGFt2_S-d1Z_Rmd9-i/edit?usp=sharing&ouid=112148808974461842163&rtpof=true&sd=true

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EXTRA READING/STUDY

Sustainable Building Materials

https://www.stonecycling.com/

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https://busgocircular.eu/

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https://www.linkedin.com/company/busgocircular

https://www.youtube.com/channel/UCXu4Rjs5WDXBE-yqda5kt5A

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Colophon

BUS GoCircular

Partners

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