Bio-based construction materials for Finnish infrastructure development.
-Evidence, Opportunities & Challenges.

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Contents

Bio-based Minerals and Materials in Civil and Environmental Engineering (BIOM-MCE) group

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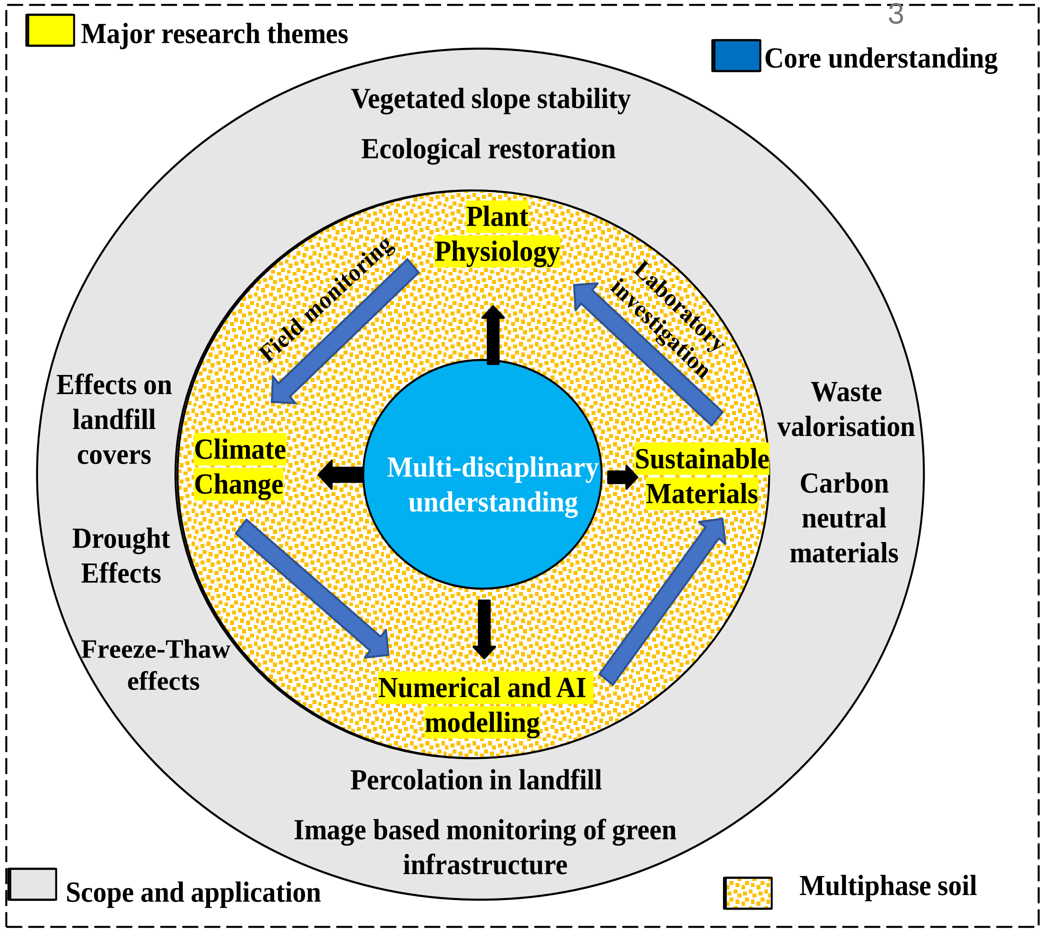
Team Leadership and Track Record

- **Assistant Professor** in Civil Engineering (2023-Present) Aalto University.
- **PhD in Civil and Environmental Engineering** (2019) from Indian Institute of Technology Guwahati, IITG
- Post-Doctoral Researcher (2019-2021) at **Hong Kong University of Science and Technology**, HKUST, Hong Kong.
- Post-Doctoral Researcher (2021-2023) at **University of Illinois at Urbana Champaign**, UIUC, USA.
- 60+ SCI indexed journals, H-index: *28*
- *https://scholar.google.co.in/citations?user=ajlJZ4wAAAAJ&hl=en*

New team formed at A!

- **3 Post-Doc** (Mohamad Hanafi , Anoosheh Iranavanian, Bhaskar Das).
- **2 PhD students** (Elis Kivi, Soumya Roy) at School of Engineering.
- **5 Master Student Supervision** (Enni-Maria Peltola, Otso Laurila, Istiak Nur, Udesh Kahanda, Berket Aktas)
- **3 Graduate level Research Interns.**
- **Research Team Nationality**: India, Finland, United States, France, Pakistan, Sri Lanka, China, Lebanon, Bangladesh, Cyprus, Turkey
- **Current research areas**: $C0_2$ sequestration in construction materials, Bio-polymer and biochar amended materials, Electroosmosis remediation, Frost effects on materials

Research Philosophy



Experimental (70%) *Field monitoring (20%)* *Numerical modelling (10%)*

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Bio-inspired engineering. How do they manifest in built environment?

The Living?

- Vegetation (Mechanical, surficial and Transpiration features)
- Microbial Induced Calcite Precipitation
- Enzyme induced Calcite Precipitation

The Dead?

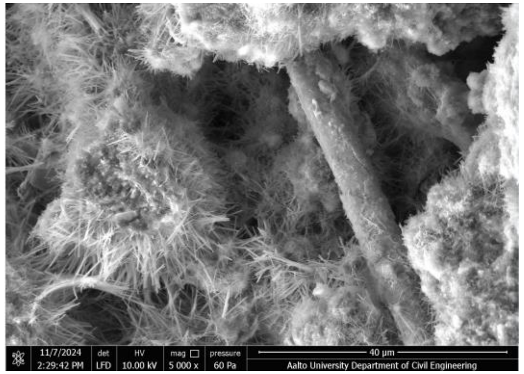
- Bio-fibers for soil/cementitious materials
- Timber structures
- Bio-polymers for stabilization
- Rubber based composites

The Inspired?

- Snake inspired components
- Anchorage piles by Mussels
- Water Repellency by biological surfaces
- Genetic/AI programming

The "Resourced" Dead?

- Bio-char from pyrolysis of organic waste
- Carbon nano tubes from organic waste
- Cellulose/Lignin fibers from packaging industry
- Fatty acids from pyrolysis and petroleum by-products



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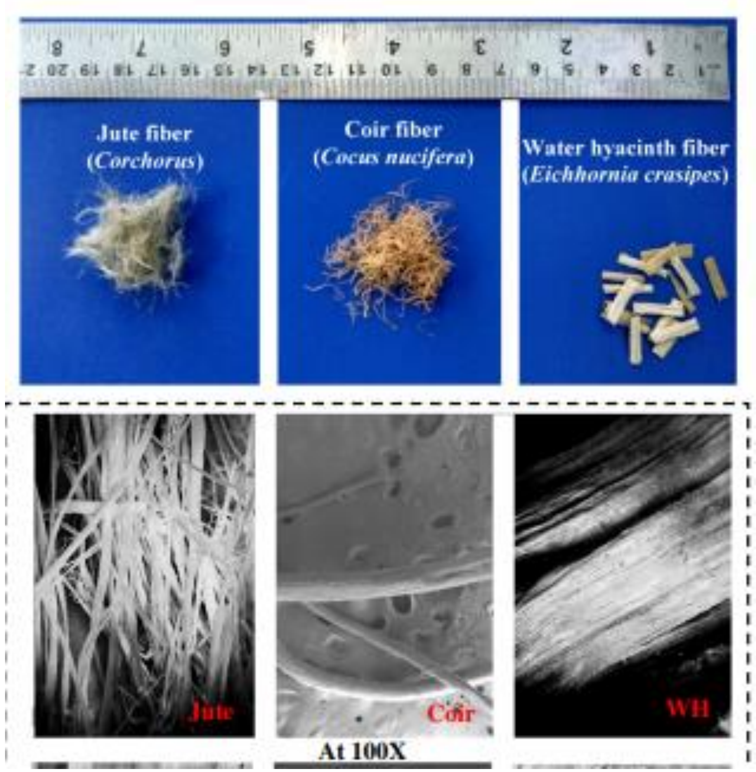
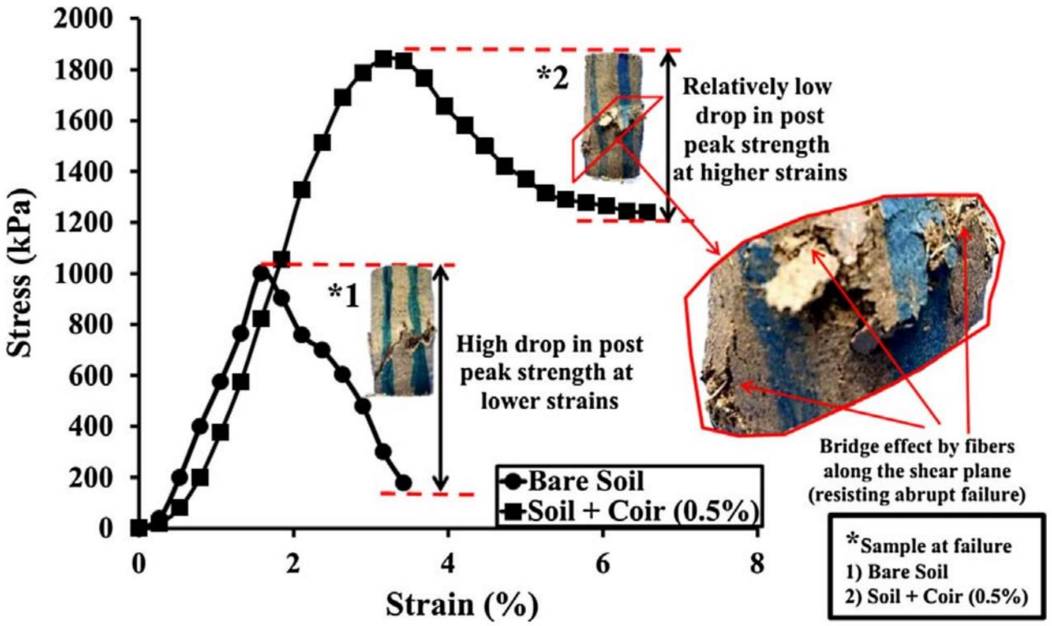
The Dead- *Biofibers*



- Utilized lignocellulose based biofibers for rammed earth composites leads to higher strengths and increased ductility.
- Performance of fibers are based on relative distribution of bio-polymers.
- Fibers can be modified further for increasing lifespan.

Rammed earth walls



Bordoloi et al. (2018) https://doi.org/10.1016/j.measurement.2017.08.044

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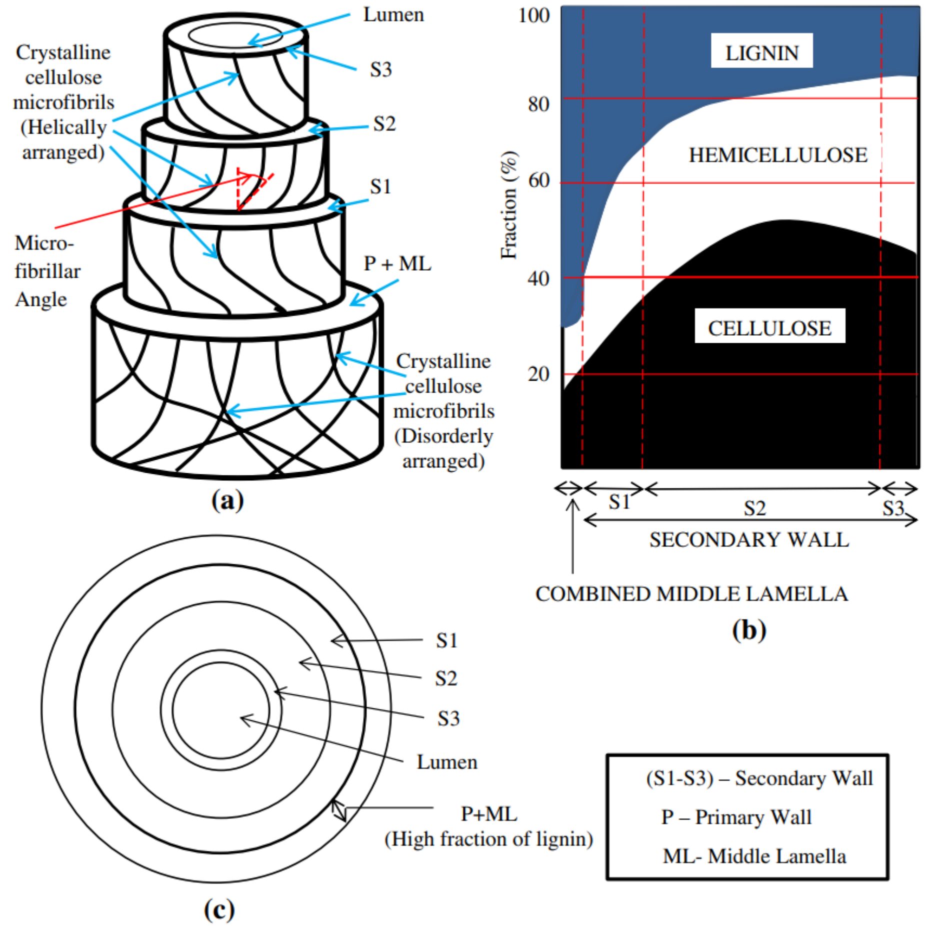
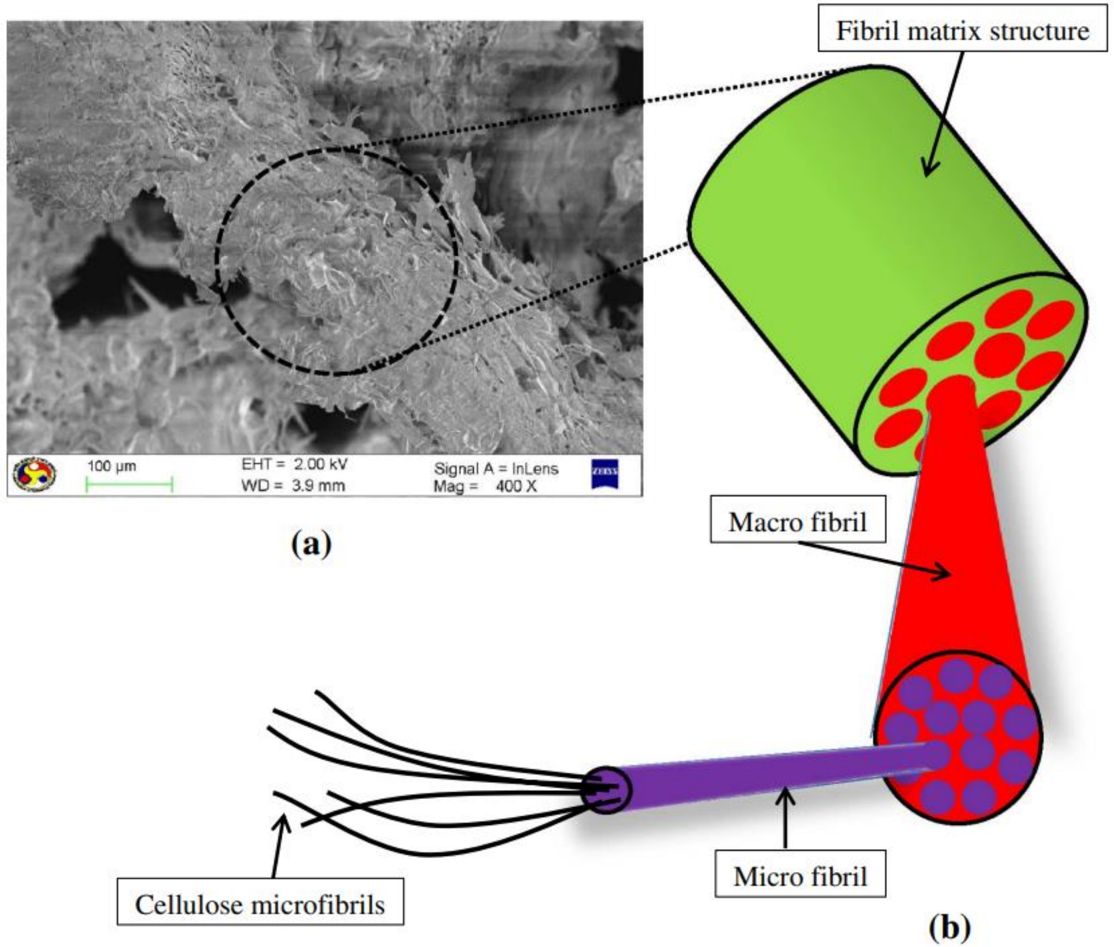
Bio-materials- Structure, Fractionated properties and Degradation response: Pre-cursors for Resourced dead materials





- Cellulose, hemicellulose and lignin are bio-polymeric fractions that make most organic waste.
- Each fraction has specific properties and are intricately placed by nature for its functioning.
- Their unique biopolymer arrangement can be manipulated to develop multifunctional materials-biochar, fibers, etc.

Source: Bordoloi et al. (2017) https://doi.org/10.1520/ACEM20160076

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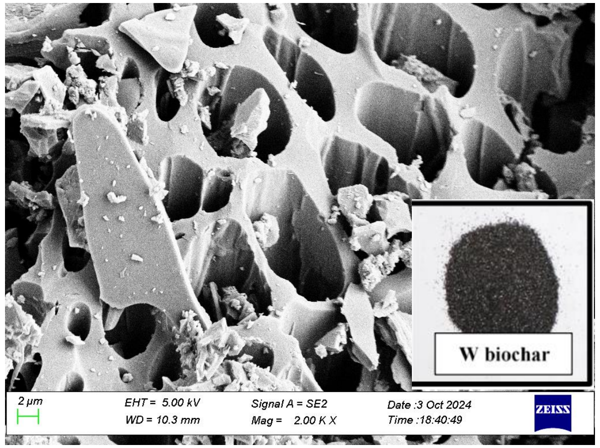
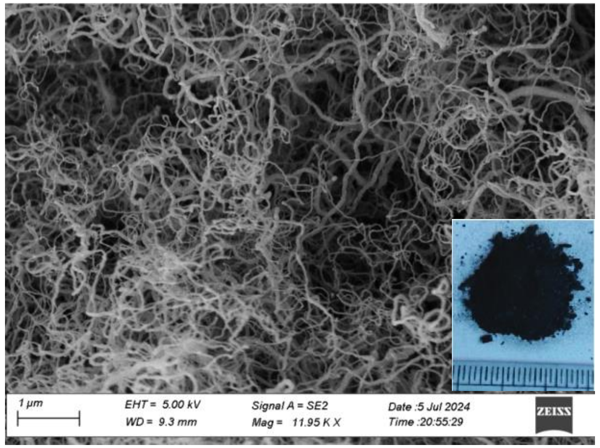
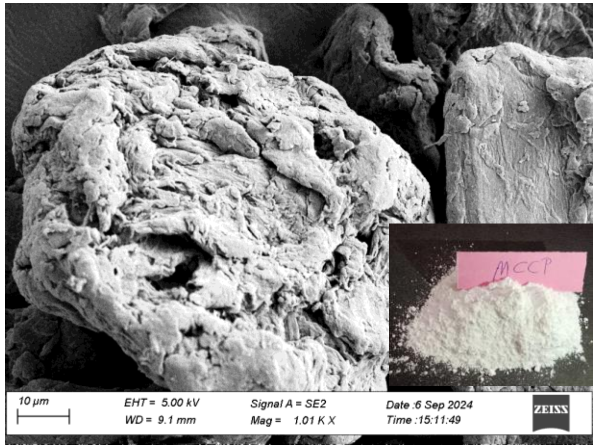
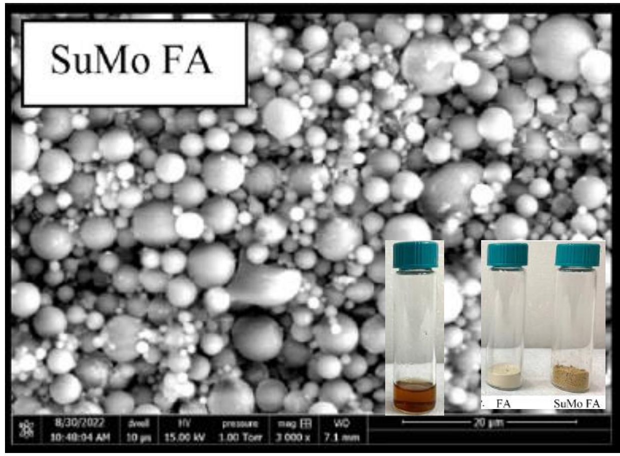
The Resourced Dead- *Biochar, Carbon nanotubes, Cellulose, Fatty acid polymers*









- Biochar-carbonaceous material with high porosity, surface functionality and polar behavior.
- Produced through pyrolysis of organic waste.
- Explored primarily for agricultural and environmental applications.

- Carbon nanotubes have similar properties to biochar with relatively higher porosity
- Produced through pyrolysis of organic gases.
- Explored primarily for electronics and polymers.

- Micro-crystalline cellulose from pulp industry.
- Mechanical and chemical treatment of cellulose rich waste.
- Explored primarily for pharma-medicine industry.

- Fatty acids can be used for developing polymers and use as coating.
- Produced through pyrolysis of organic waste.
- Explored primarily for chemical industry applications.

Source: Bordoloi et al., 2024, Hanafi et al. (2024) https://doi.org/10.1016/j.trgeo.2024.101370 https://doi.org/10.1016/j.conbuildmat.2024.137333

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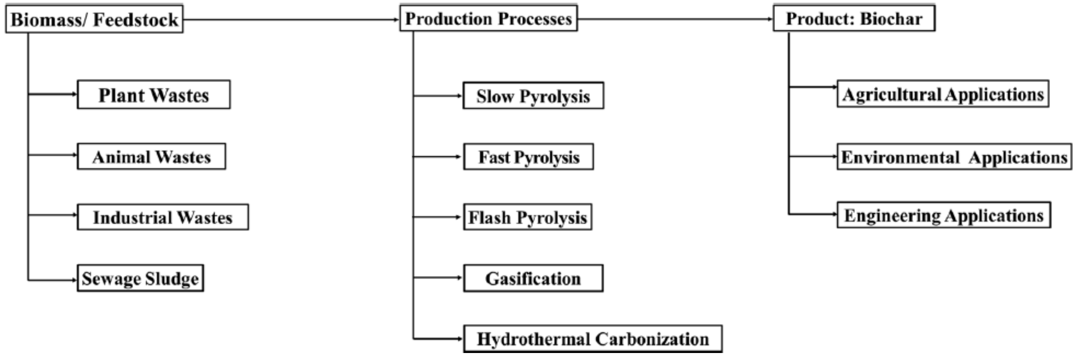
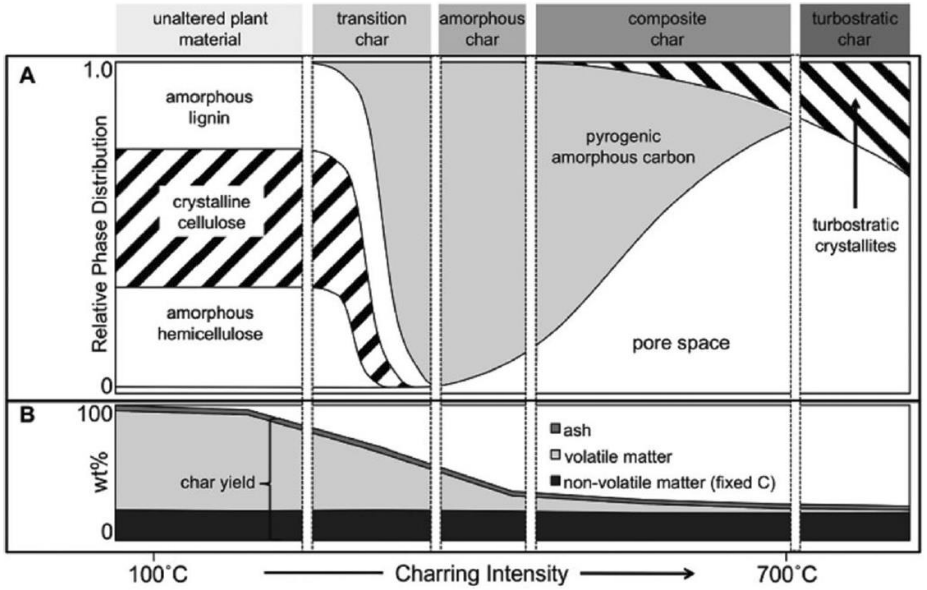
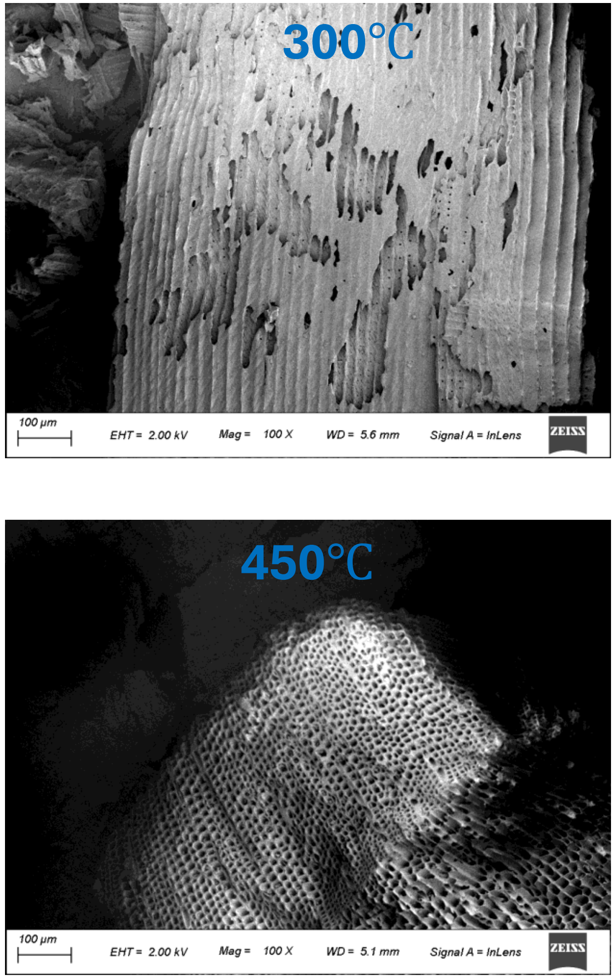
Evidences in BIOM-MCE lab for bio-based materials

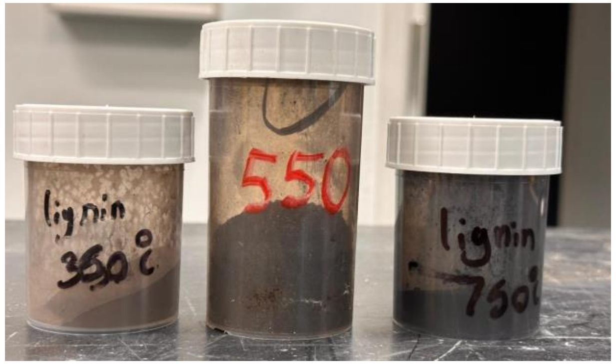




Schematic image of phase changes in biochar (Wani et al., 2021)



Transition of surface morphology in biochar with temperature



Biochar developed at different conditions from waste lignin

Wani et al. (2021) https://doi.org/10.1007/s13399-022-02795-5

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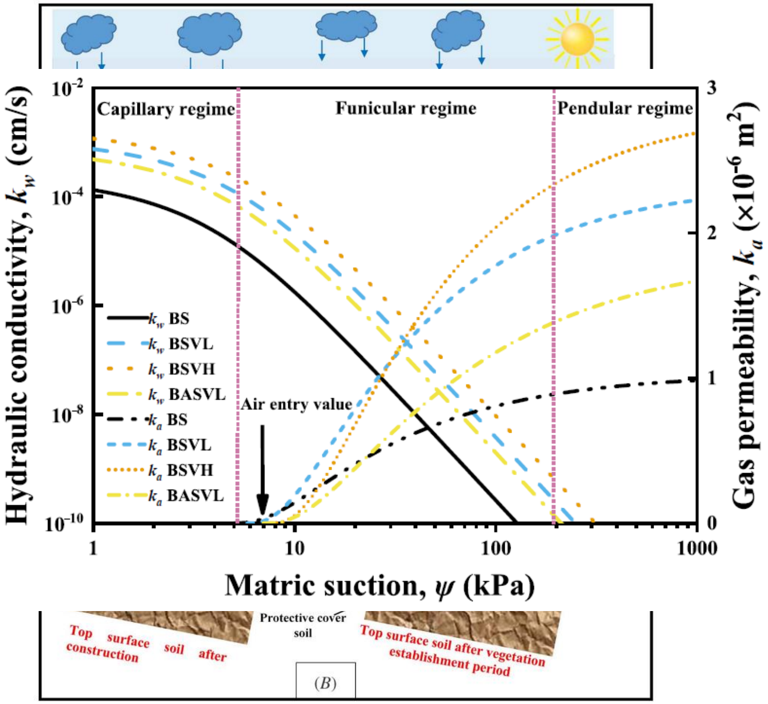
Biochar application expertise in BIOM-MCE

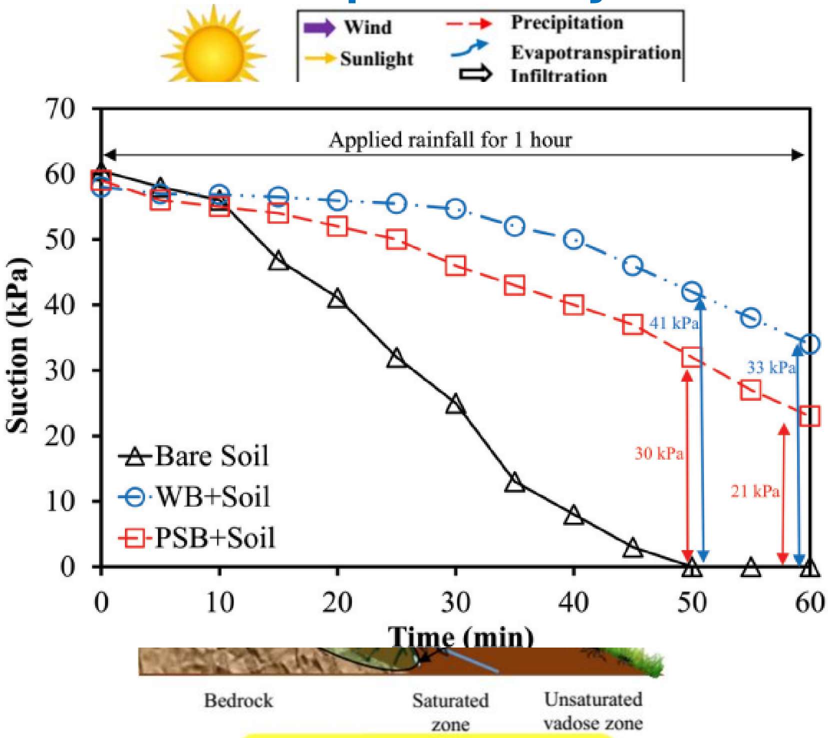
MSW landfill cover



- Biochar based hydraulic and gas barriers in landfill covers were designed.
- They provide both ecological, environmental and geotechnical benefits to the final cover layers.

Source: Huang et al (2024)
https://doi.org/10.1016/j.geoderma.2024.116882

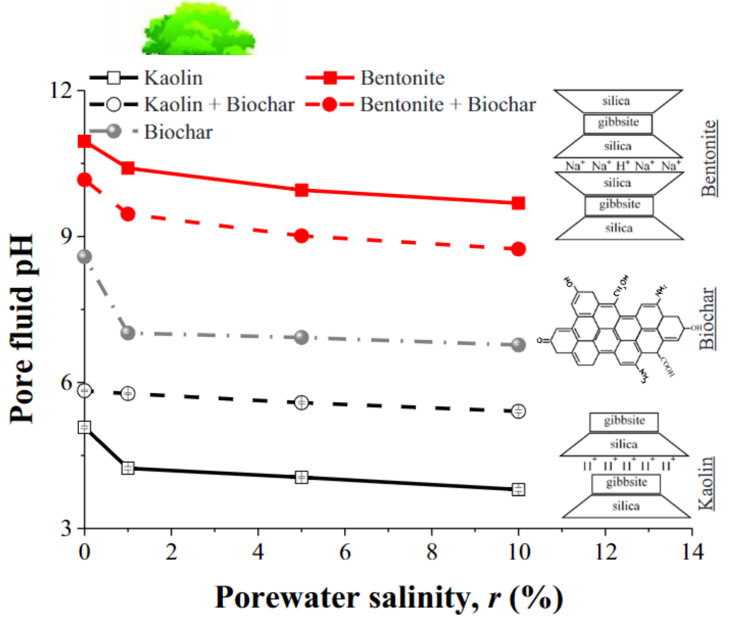
Green slope stability



- Biochar amended surface layers is used to develop green slopes.
- Provides higher suction due to evapotranspiration effects. Thus, efficient for slope protection and infiltration measures during heavy rainfall.

Source: Ng et al (2022)
https://doi.org/10.1139/cgj-2020-0666

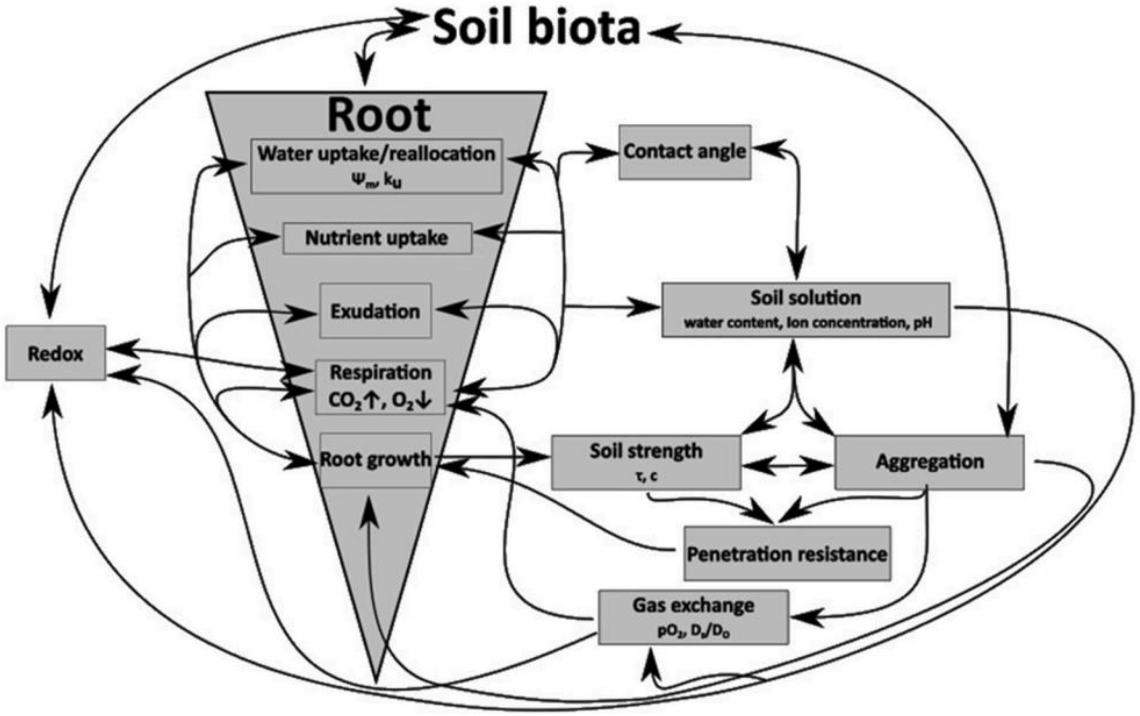
Hazardous Waste Containment



- Provides adequate sorption against contaminants.
- Improves rheological and mechanical advantage to clay barriers.

Source: Cai et al. (2022)
https://doi.org/10.1016/j.scitotenv.2022.156493

Ecological restoration in terms of microbial communities- 3-year field study in Quarry Site

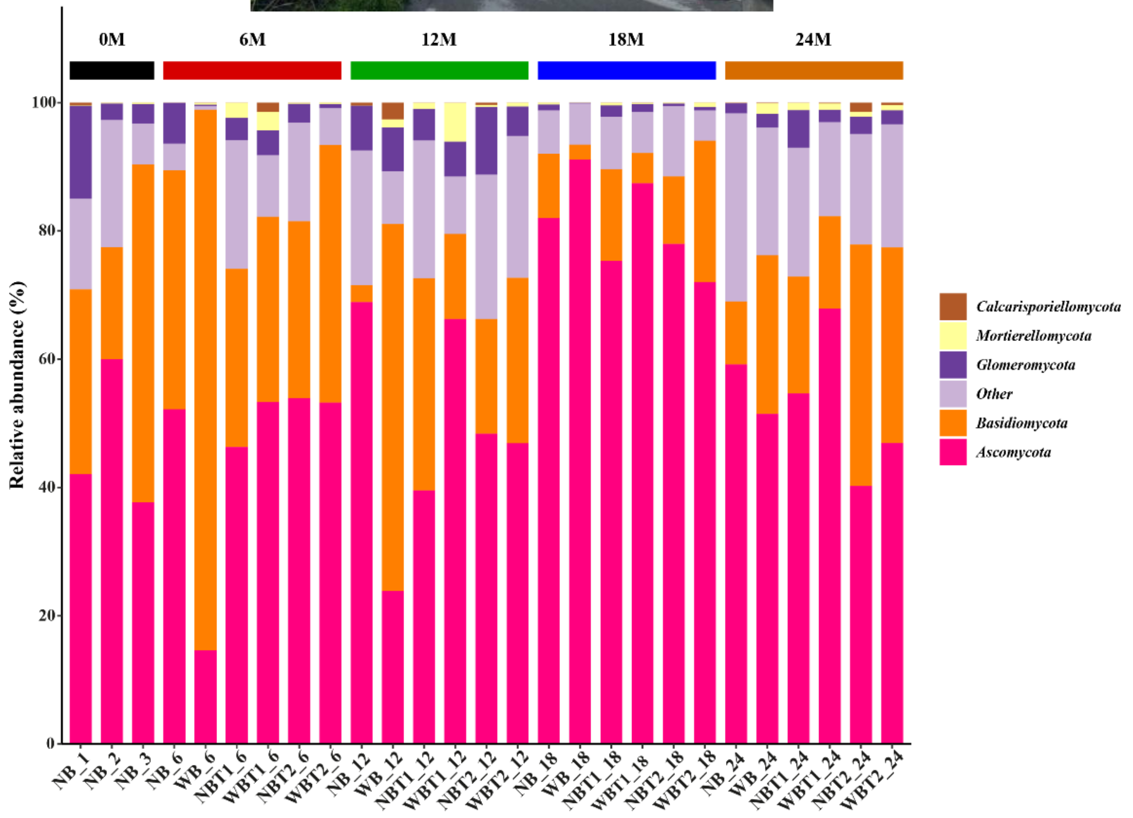


Haas and Horn, R., 2018. https://doi.org/10.3389/fenvs.2018.00090

- Bacterial and fungal diversity magnified by biochar amendment.
- Long term ecological succession are directly related to abundance and diversity of microbial community.

Dynamics of soil fungal communities in a biochar-restored quarry site

Jiaxin LIAO, Pui San SO*, Sanandam BORDOLOI, Haowen GUO, Billy Chi Hang HAU, Liwen HU, Charles Wang Wai NG



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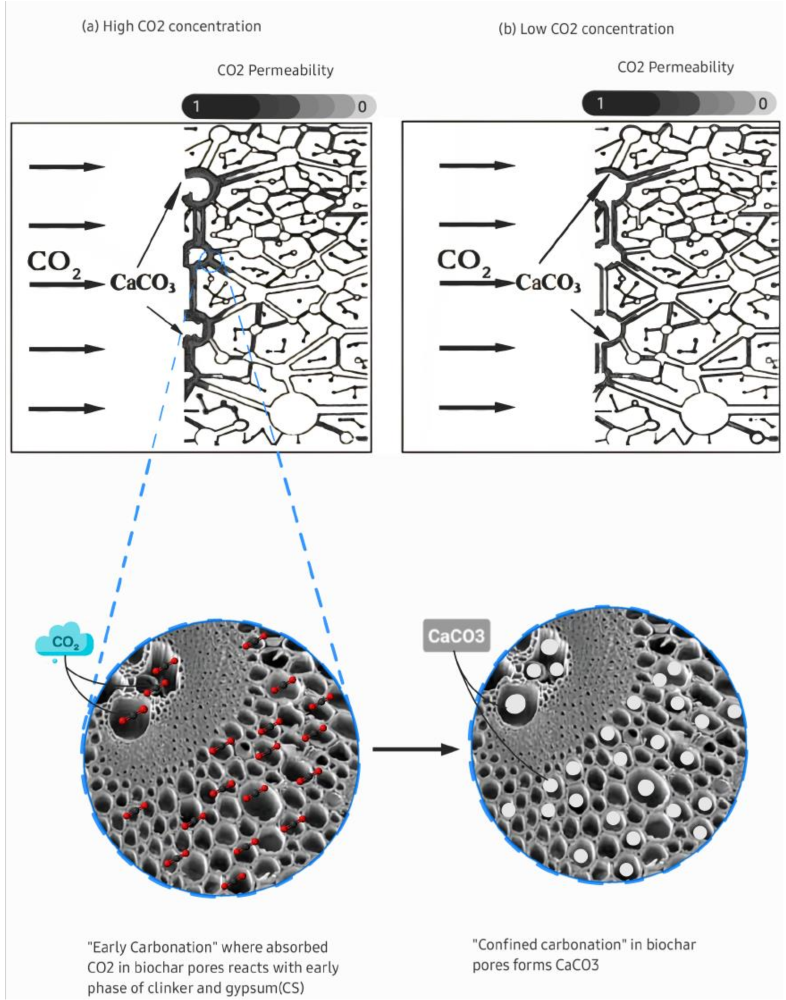
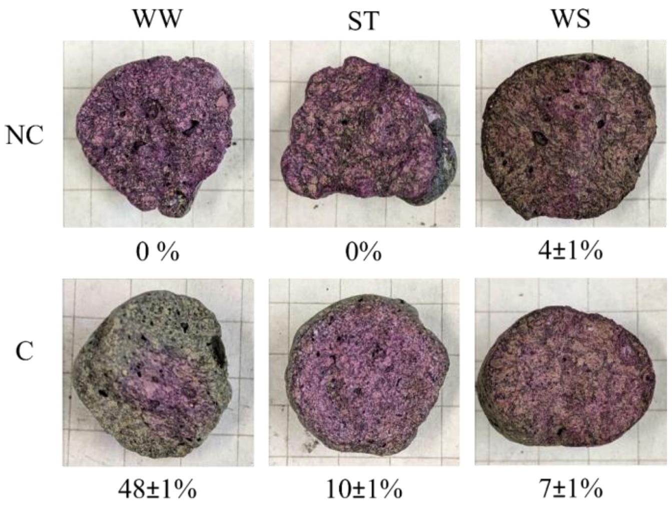
Biochar in cementitious materials



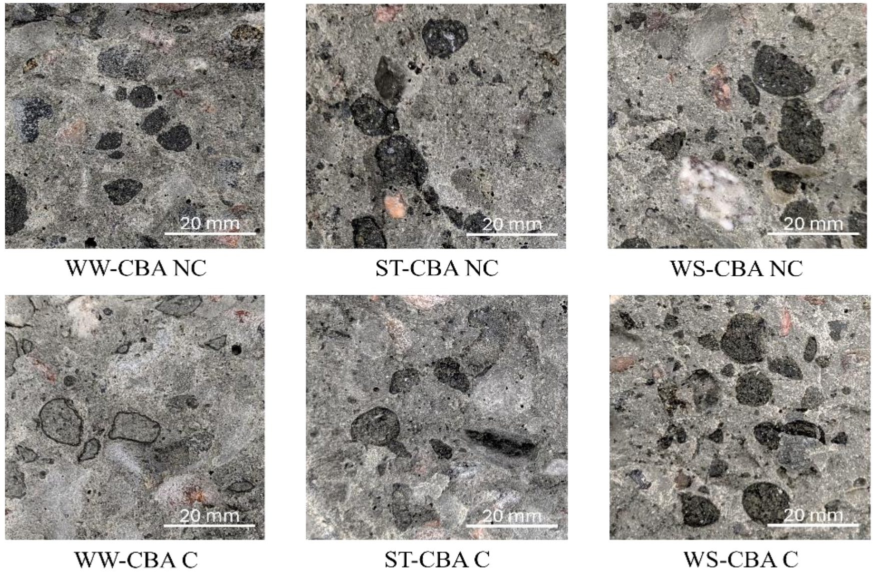
Mechanism of CO_2 precipitation in cementitious materials

Source: Soumya et al. (2024) (1st Revision)

Carbon-negative Rigid Inclusions



Soft clay aggregate developed from different biochars



Soft clay aggregate as artificial aggregate

Patent: FI 20247154

Biochar in ground improvement (DEMICO project)

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RAKENTAMINEN

Suomessa kehitettiin ensimmäinen CO_2-kaasua sitova sementinkorvike – Suuri vaikutus infrarakentamisen päästöihin

Käytännössä sideaineen avulla on onnistuttu sitomaan hiilidioksidia infrarakenteisiin, mikä tekee niistä hiilinieluja.

Työmaalla. Maaperän pehmeys voi aiheuttaa ongelmia pohjarakenteiden kestävyydelle. Siksi suomalaisilla rakennustyömailla maaperää joudutaan vahvistamaan. KUVA: LEENA KORKIALA-TANTTU / AALTO-YLIOPISTO

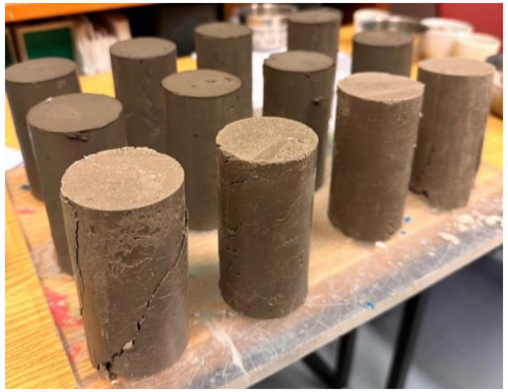
Lukuaika noin 2 min

Tallenna

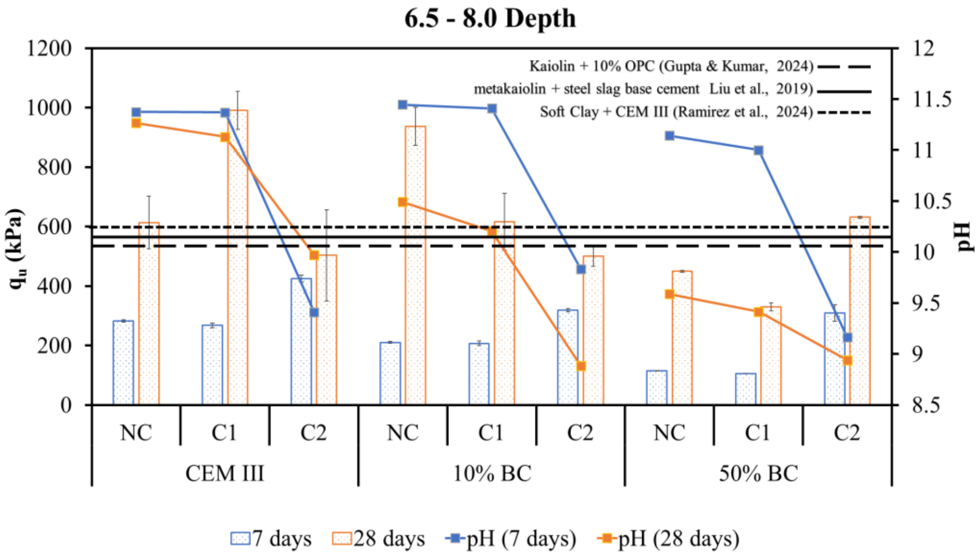
Aalto-yliopiston tutkijat ovat kehittäneet ensimmäisen hiilinegatiivisen sideaineen. Käytännössä sideaineen avulla on onnistuttu sitomaan hiilidioksidia infrarakenteisiin, mikä tekee niistä hiilinieluja.

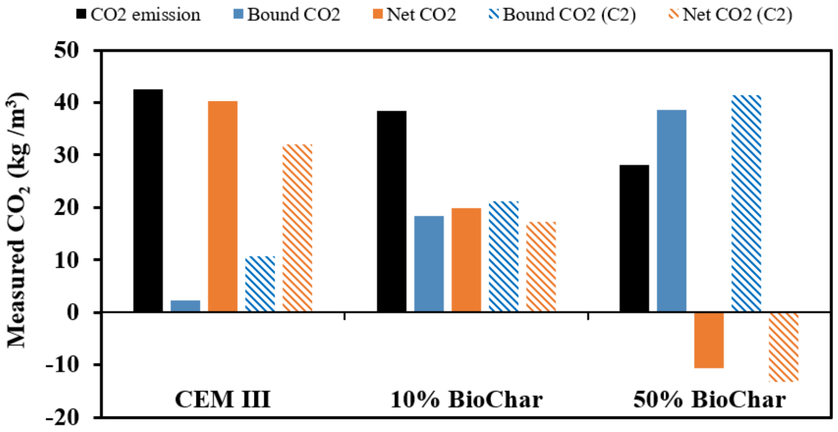
1.10.2024 12:12

Lotta Jalli



Soil-biochar composites after CO_2 precipitation (use in soft clay stabilization)





Strength and CO_2 capture capacities of developed composites

Hanafi et al. (2024) https://doi.org/10.1016/j.trgeo.2024.101370

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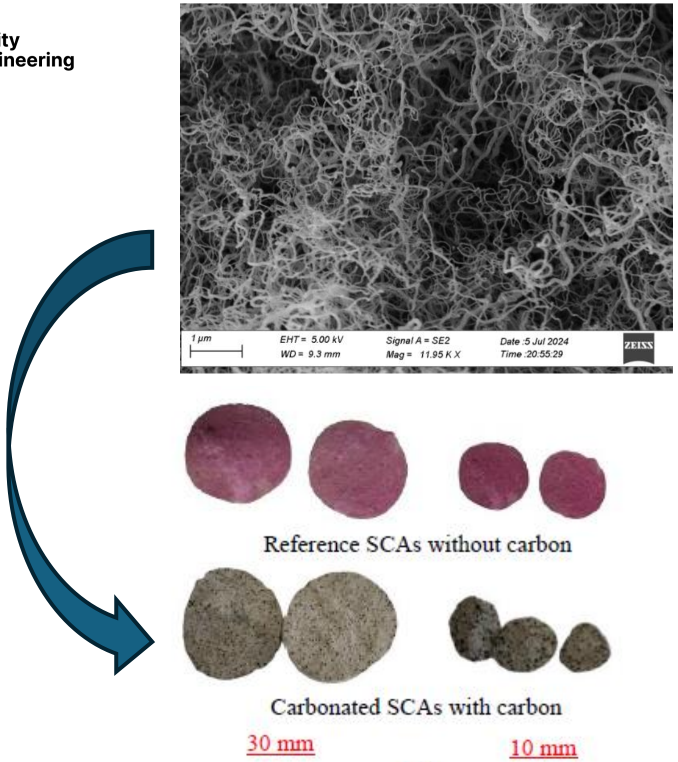
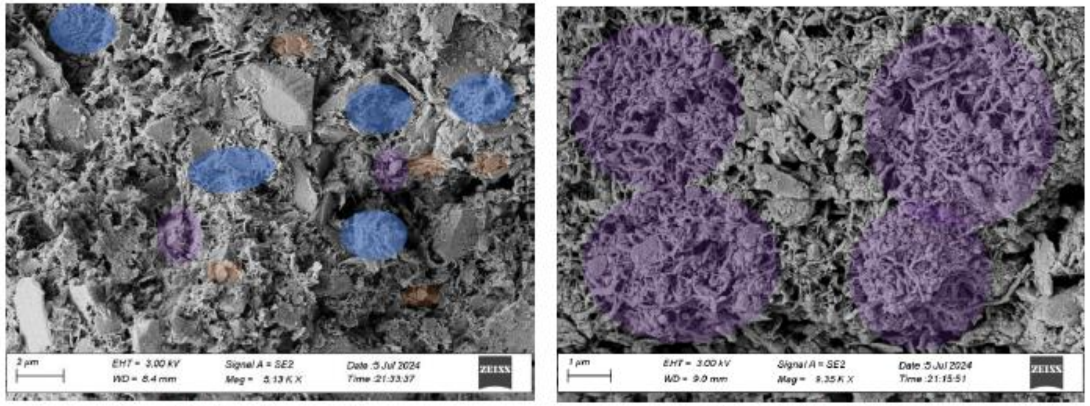
Carbon nanotube application

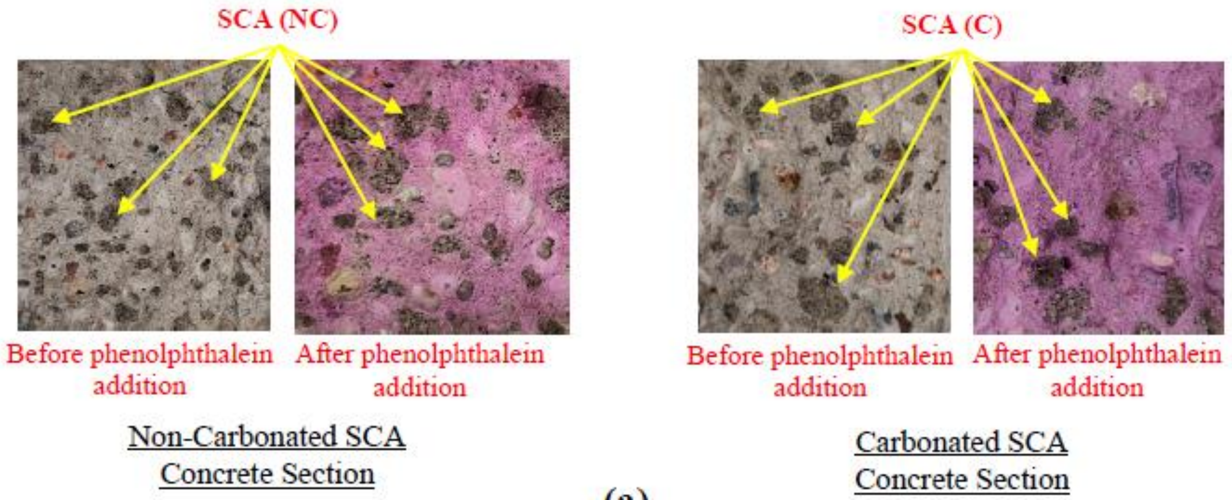


(a)

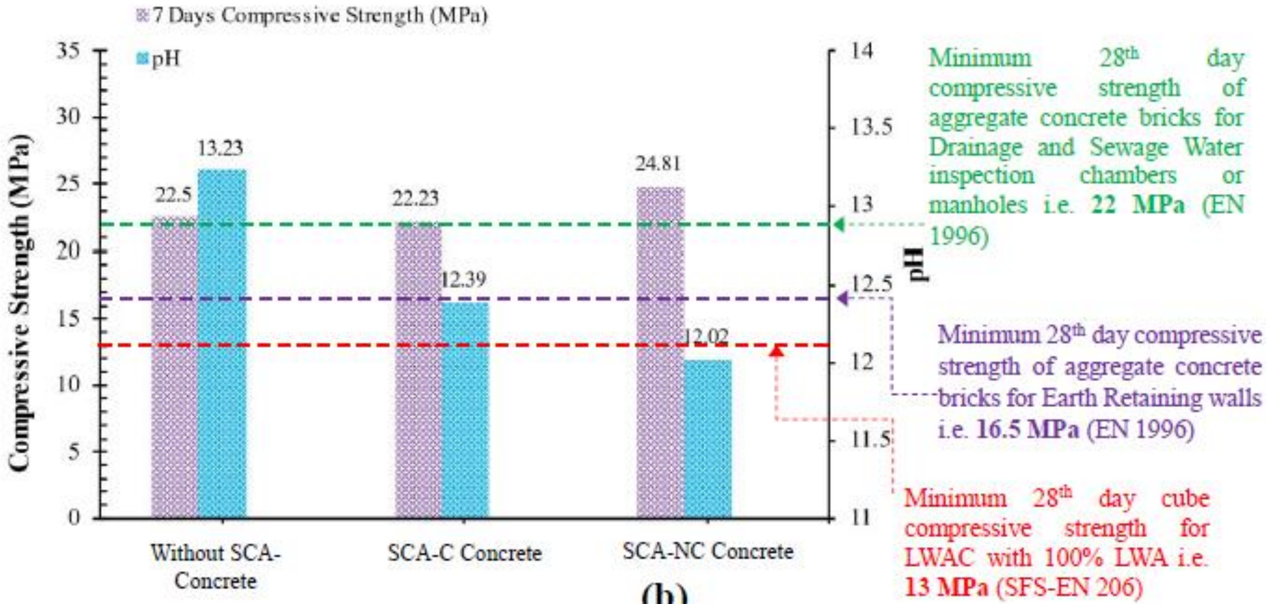


Control SCA without carbon

SCA-C with 20% carbon



(a)



(b)

Source: Majid et al. (2025) (Under review)

Crystalline cellulose (Micro and Nano) application

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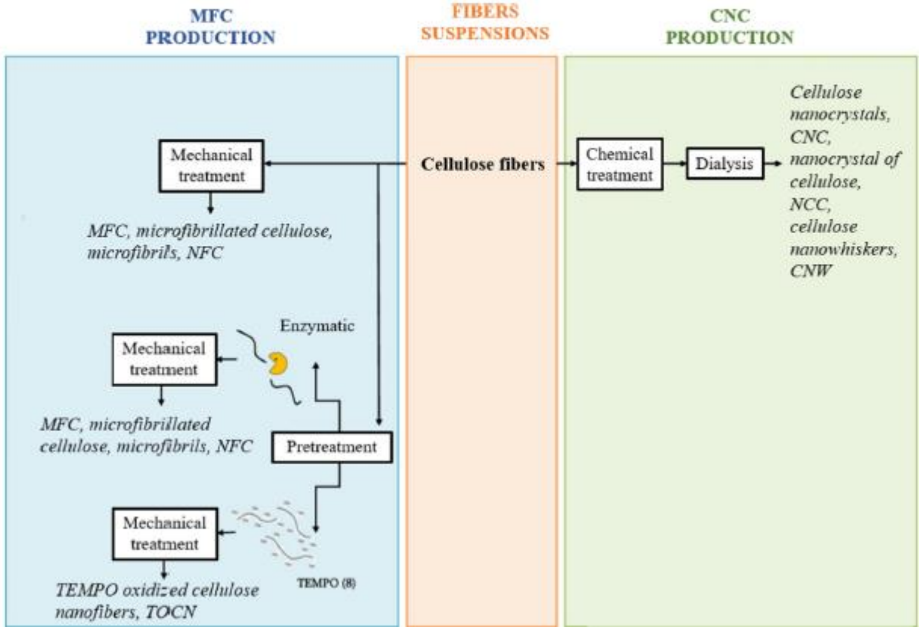
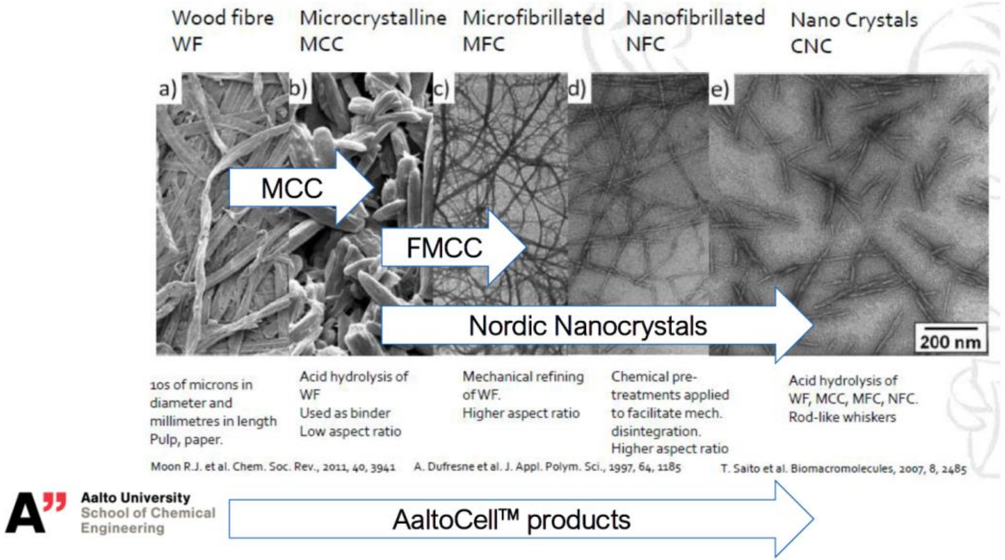


Source: Santos et al. (2021)
https://doi.org/10.1016/j.conbuildmat.2021.123122

From paper pulp to micro- and nanocellulose



Istiak Ongoing Master’s thesis

Fatty acid polymer application

Polysulphide coatings

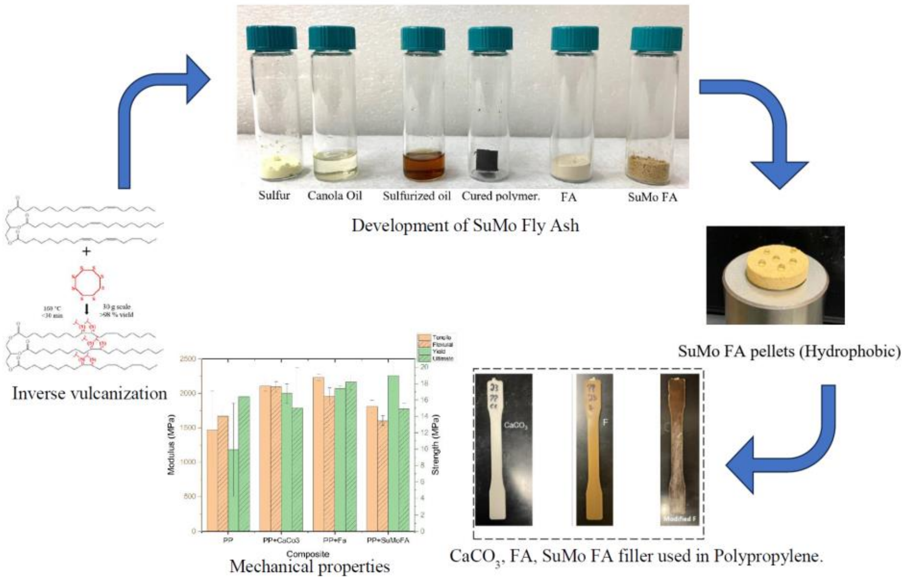


Fig. Schematic setup of development of SuMo carbons for use as fillers in plastic composites

- Developed surface modified (SuMo) carbon utilizing petroleum by-products.
- For instance, SuMo fly ash usage as fillers in plastic and rubber composites.

Source: Bordoloi et al. (2024a,b), Zhao et al. (2024)
https://doi.org/10.1016/j.indcrop.2024.119190
https://doi.org/10.1016/j.conbuildmat.2024.137333
https://doi.org/10.1016/j.envpol.2024.123706

Hydrophobic tailings composites

Fig. Hydrophobization of tailings through fatty acids impregnation and use as fillers for hydrophobic mortars

- Hydrophobization of hazardous tailings for use in developing novel water-resistant mortar for Nordic conditions.

Prof. Antonio Nanni
Editor in Chief
5 Feb 2024

Journal of Materials in Civil Engineering

Sub: **Hydrophobized Iron Tailing Based Cementitious Composites for Low to Medium Load Bearing External Applications**

ACCEPTED

Authors: Roy, S., Chah, CN., Banerjee, A., **Bordoloi, S***., Sreedeep, S

Opportunities and Challenges

Opportunities

- Traditional recycled construction materials (fly ash, steel slag) are being phased out gradually. Bio-based materials are renewable.
- Unused annual traditional organic materials (38M tons as per Valtioneuvoston julkaisuja 2024 report) in Finland pose resources that can be used for developing bio-materials for the construction sector.
- Bio-based materials are multifunctional (meaning can be used as fillers, binders and other applications).
- The pyrolysis process also generates value added products that can be utilized for specific applications.
- Quite established in terms of R&D on the materials globally. Extensively used in US, Canada, China, Developing economies.
- Opens door towards lowering CO_2 emissions (by a great deal). Carbon negative solutions.

Challenges

- Heterogeneity in feedstock. Boon or Bane?
- TRL3-4 at most in the utilization of bio-materials in construction material.
- Field scale study and monitoring required to utilize them in practice (reach TRL7 and more).
- Bold/Brave steps required by policy makers to invest RnD in these emerging materials.
- Participation of Municipalities and Industry in facilitating technology growth.
- Multidisciplinary expertise require to deal with production of bio-based materials.

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- Dr. Hossein Baniasadi

Relevant partners

- Dr. Mirva Koskinen
- Dr. Juha Forsman
- Dr. Monica Löfman
- Linda Roman
- Esko Salo

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Helsinki Helsingfors

RAMBOLL

AFRY

NORDIC BIOPRODUCTS GROUP

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HSY

CARBOFEX

SIBELCO

LKAB

SSAB

Kysymyksiä ja Vastauksia