Stabilized soft clay as CO_2 sinks for infrastructural development

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Department of Civil Engineering

Agenda

- BIOM MCE group in Aalto
- Excavated waste clay: Scenario in Finland
- Valorization strategies
  - Soft-clay aggregates (Exterior applications)
  - Clay based foams (Interior applications)
- Towards TRL7 from TRL3.
- QnA

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

Team Leadership and Track Record

- Assistant Professor in Civil Engineering (2023 Oct.-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.
- 80+ SCI indexed journals, H-index: *30*
- *https://scholar.google.co.in/citations?user=ajlJZ4wAAAAJ&hl=en*

Supervision at A!

- 1 University Lecturer (Monica Lofman)
- 3 Post-Doc (Hanafi Mohamad, Bhaskar Das, Anoosheh Iravanian).
- 3 PhD students (Elis Kivi, Soumya Roy, Udesh Wijepala) at School of Engineering.
- 1 Graduate level Research Assistant (Yunlong Zhu)
- 5 Master Student Supervision (Nur, Joshua, Jaakko, Johannes, Raphael)
- Research Team Nationality: India, Switzerland, Finland, United States, France, Turkey, Sri Lanka, China, Lebanon, Bangladesh

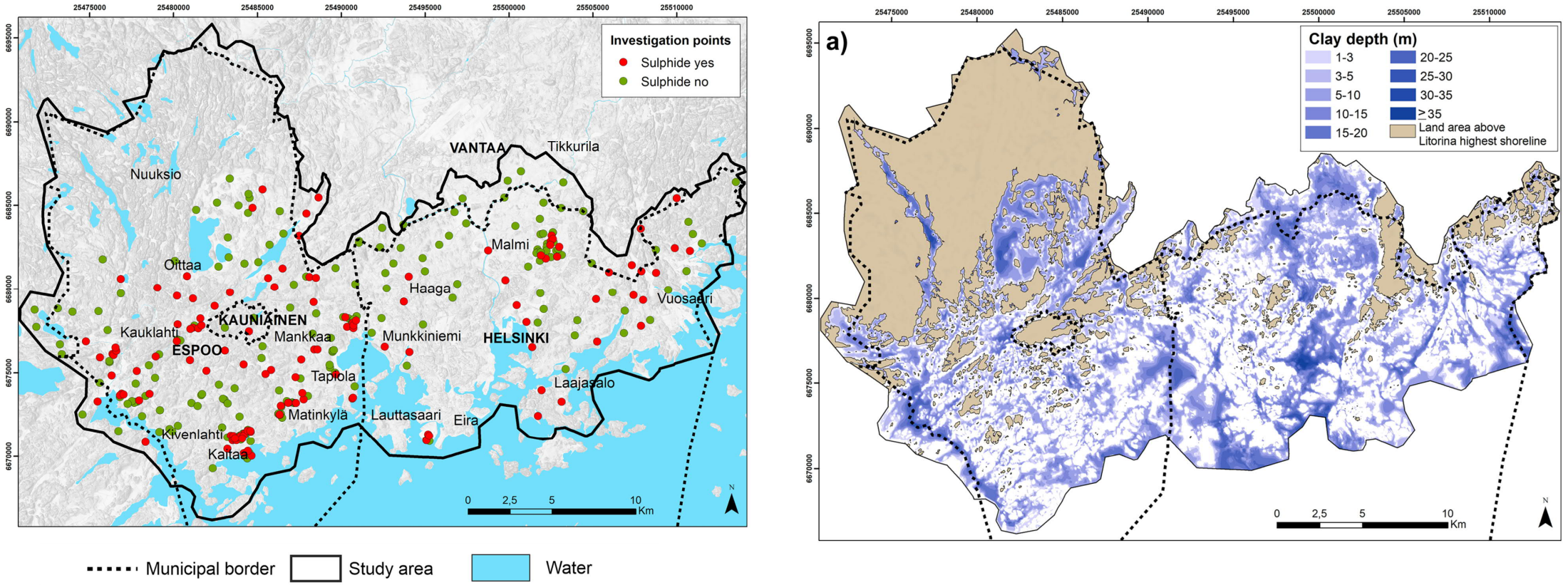
Research Interests

- Soft-Clay Stabilization
- Valorization of industry waste in geo-environment.
- Waste containment structures in mines/landfills
- Geotechnical characterisation of mine tailings
- Bio-based materials in interior construction
- Bitumen recycling by bio-based additives
- Machine learning assisted Life cycle analysis
- Rammed Earth Structures

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

Excavated waste clay: Scenario in Finland

Clay distribution in greater Helsinki Region.



Saresma et al. (2025) showcase the clay distribution in the Greater Helsinki region.

Excavated waste clay: Scenario in Finland

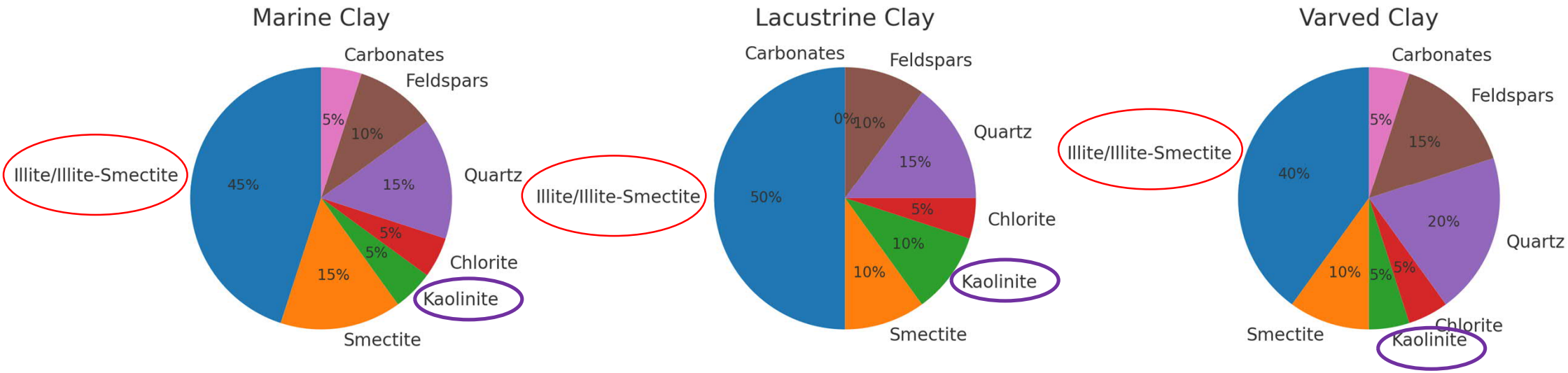
Source: KREFT-BURMAN et al. (2012)

- **20-30 Mt waste clay requires landfilling annually (Finland) (ABSOILS-2012)**
- **7 €/ton as logistics costs => 10.5 M€ annually in transporting alone (Helsinki)**

- **CO_2 emission will start imposing extra cost on construction companies**
- **The expected price is 100 €/CO_2 t by 2030**
- **Companies and cities would incur significant costs for hauling excavated soils.**

Excavated waste clay: Scenario in Finland

What kind of Clay is geologically there in Finland?



Average ChatGPT results based on the following research works*

Al-Ani, T. and Sarapää, O., 2008. Clay and clay mineralogy. Physical-chemical properties and industrial uses, pp.11-65.

Peuraniemi, V., Aario, R. and Pulkkinen, P., 1997. Mineralogy and geochemistry of the clay fraction of till in northern Finland. Sedimentary Geology, 111(1-4), pp.313-327.

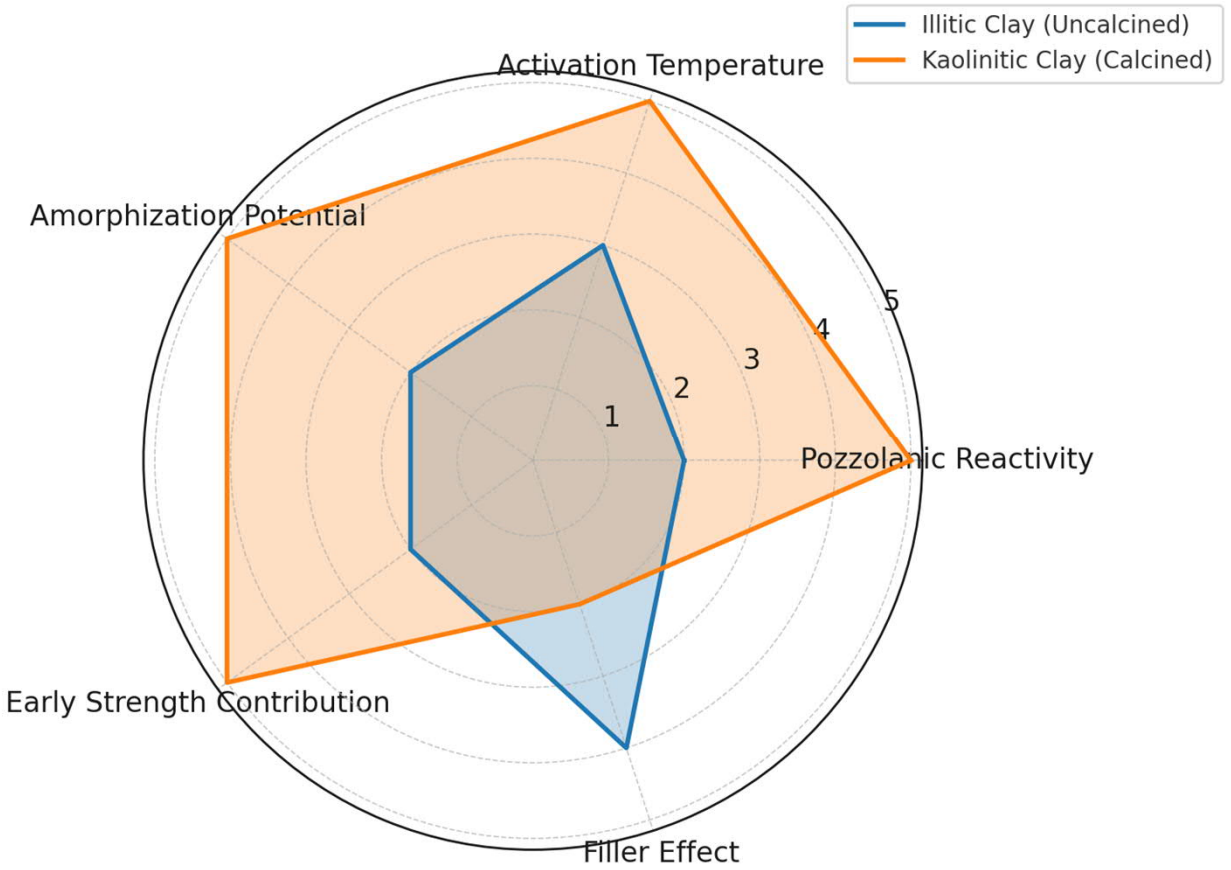
Räisänen, M.L., Tenhola, M.A.R.K.K.U. and Mäkinen, J.A.R.I., 1992. Relationship between mineralogy and the physico-chemical properties of till in central Finland. Bulletin of the Geological Society of Finland, 64(1), pp.35-58.

Pulkkinen, P., 2004. Mineralogy and geochemistry of the fine and the clay fractions of till in northern Finland. University of Oulu.

Salminen, R., Kukkonen, M., Paukola, T. and Toellikkoe, S., 1997. Chemical composition of clays in southwestern Finland. SPECIAL PAPER-GEOLOGICAL SURVEY OF FINLAND, pp.117-126.

Puranen, R., Sahala, L., Saavuori, H. and Suppala, I., 1999. Airborne electromagnetic surveys of clay areas in Finland. SPECIAL PAPER-GEOLOGICAL SURVEY OF FINLAND, pp.159-172.

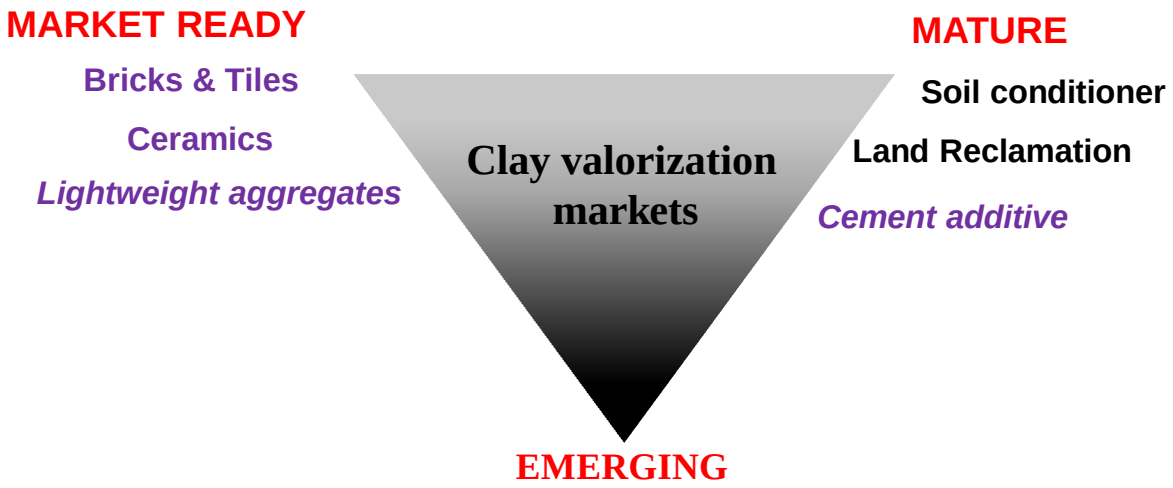
Excavated waste clay: Scenario in Finland



Compared with kaolinite, illite is less reactive because:

- Its layer structure is more stable.
- It requires higher temperatures (≈ 800–1000 °C) to activate vs. ≈ 650 °C for kaolinite.

Excavated waste clay: Scenario in Finland



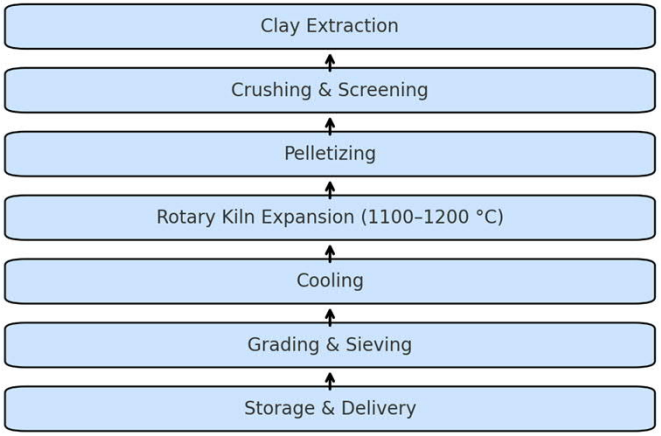
	Advanced composites	3-D printing materials	Nanomaterials	Foams
Product value	High	Moderate	High	High
Product volume	Low	Moderate	Moderate	Moderate

Consideration for emerging and market-ready markets for excavated clay utilization

- Value Vs Volume?
- Emissions & Logistics?

Excavated waste clay: Scenario in Finland

LECA Production Process from Clay in Finland

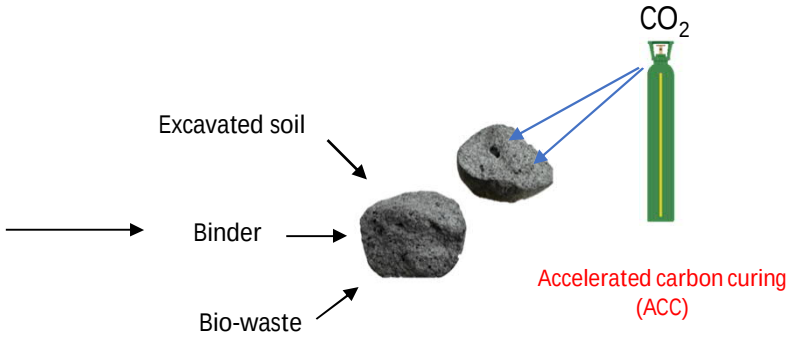


Source: https://www.leca.fi/

Spotted on my walk within Aalto!

Two current strategies and ongoing research

Construction site

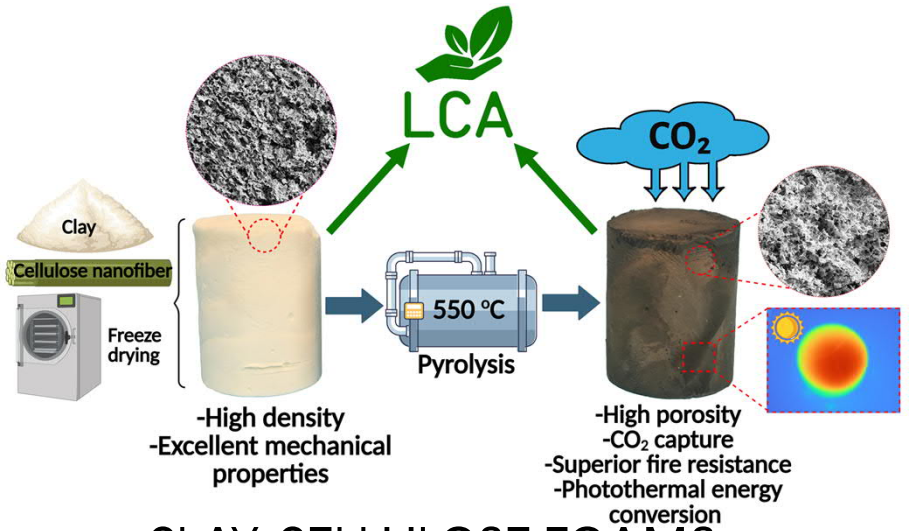


Novel engineered material

CO_2 sinks => 7.38%

SOFT CLAY AGGREGATE:
On-site development of aggregates using bio-carbons and CO_2 sequestration. (TRL3)

Hanafi et al. (2025). 1st revision (Waste Management)

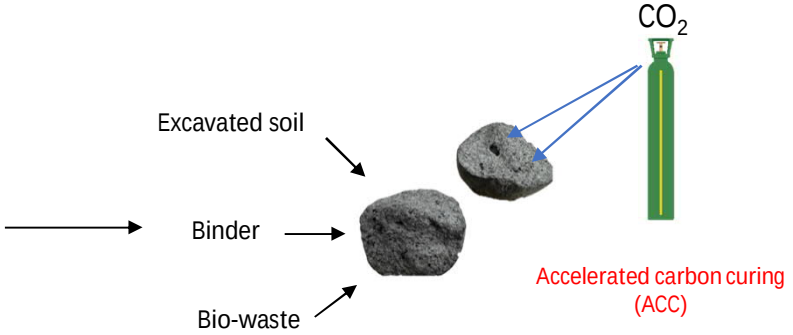


CLAY-CELLULOSE FOAMS:
High-value usage of excavated clay using bio-carbons and CO_2 sequestration. (TRL3)

Baniasadi et al. (2025). Under Review (Advanced Functional Materials)
In collaboration with AALTO CHEM

SOFT CLAY AGGREGATE:

Construction site



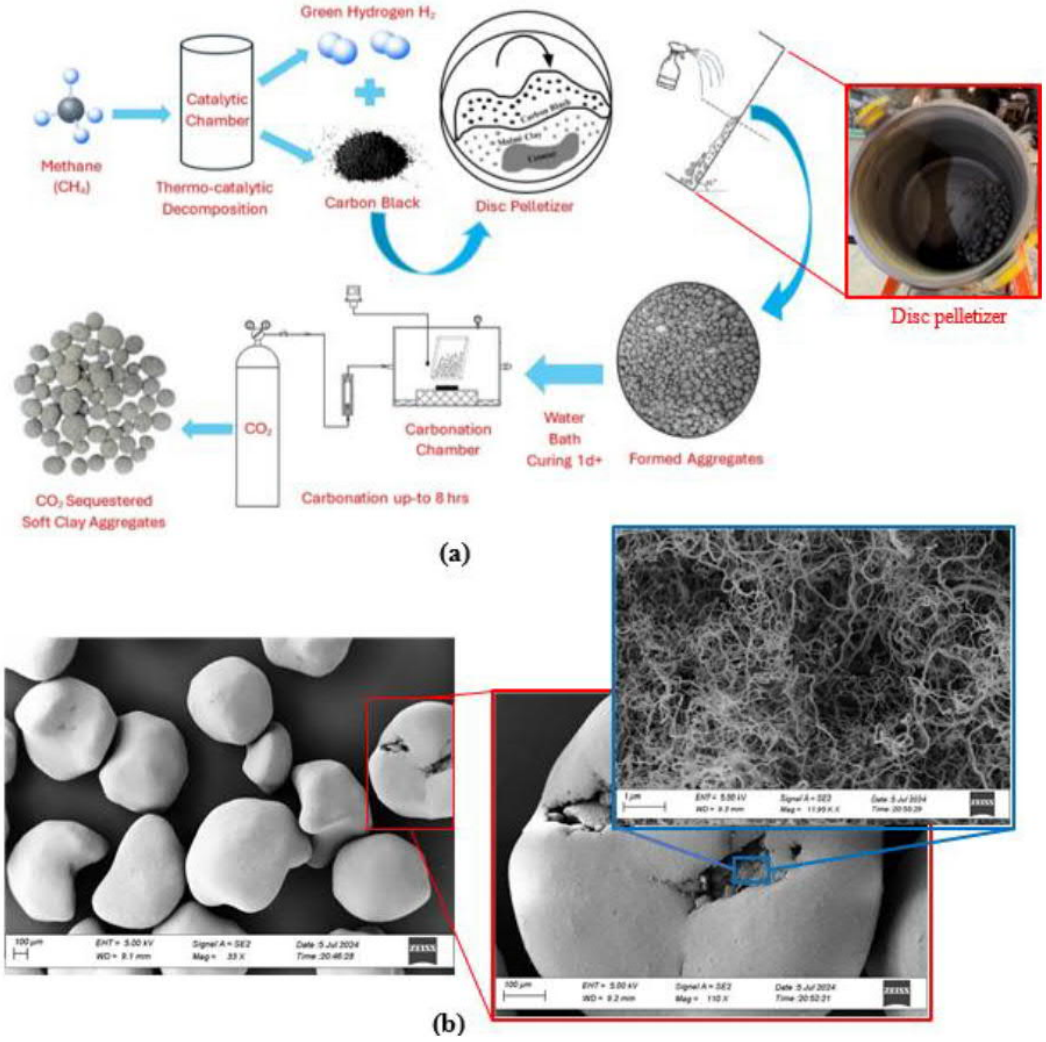
Novel engineered material

CO_2 sinks => 7.38%

- PATENT NO: (Serial number: FI 20247154)
- No calcination.
- Minimal Portland cement binder used.
- Circular binders can also be used (till now tested with 4 different binders).
- Tailormade applications.
- On-site development using bio-carbons and Accelerated CO_2 curing.

Source: Hanafi et al. (2025). 1st revision

SOFT CLAY AGGREGATE:



- Three step process.
  - ➢ Proportionate mixing
  - ➢ Pelletizing
  - ➢ Curing process

Source: Hanafi et al. (2025). 1st revision

SOFT CLAY AGGREGATE

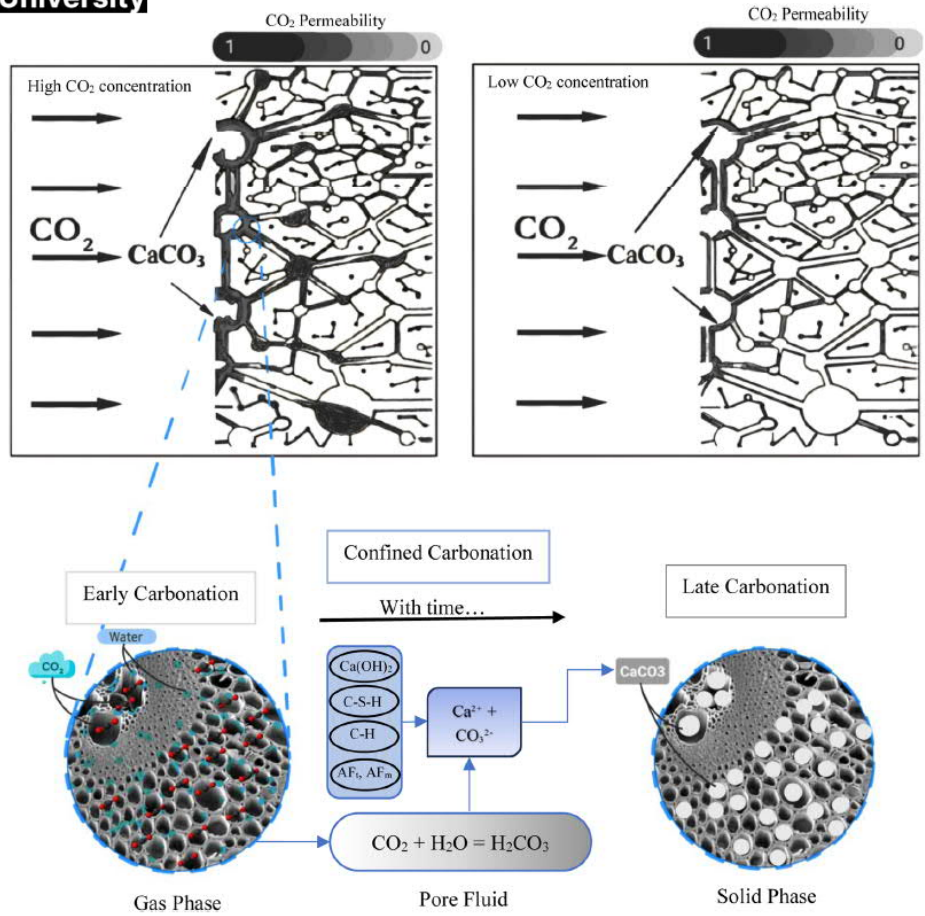
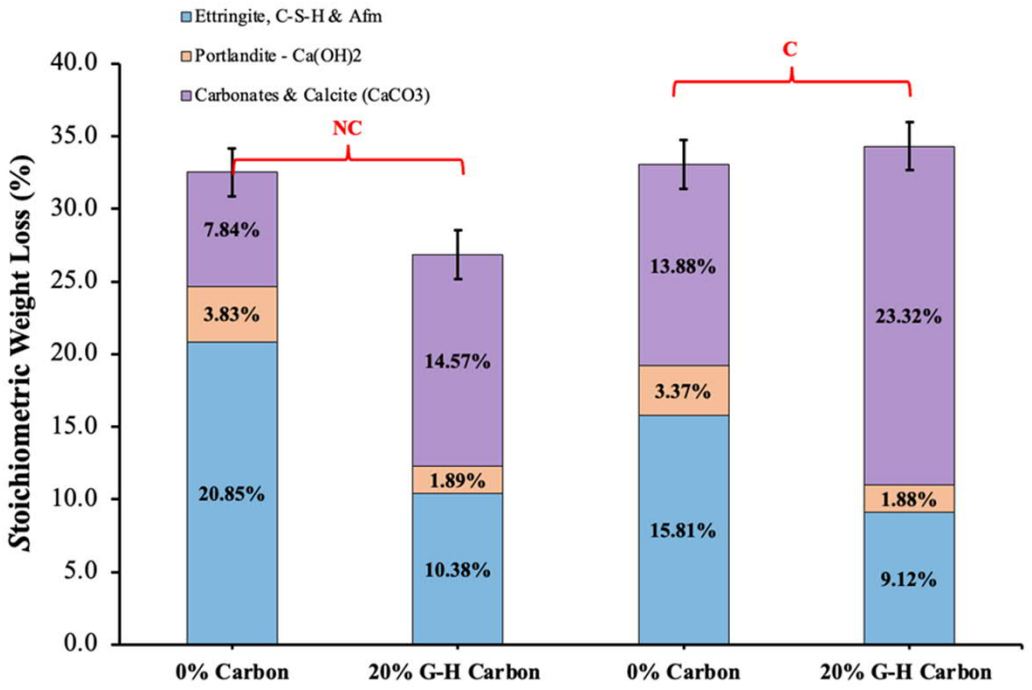


Fig. 6. Conceptual diagram indicating biochar's role in carbonation curing under high and low atmospheric CO_2 concentration.



Source: Hanafi et al. (2025). 1st revision

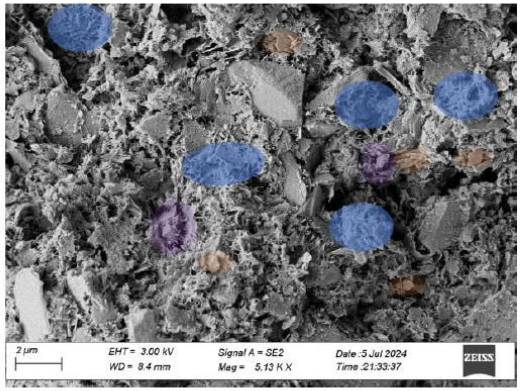
SOFT CLAY AGGREGATE

Reference SCAs without carbon

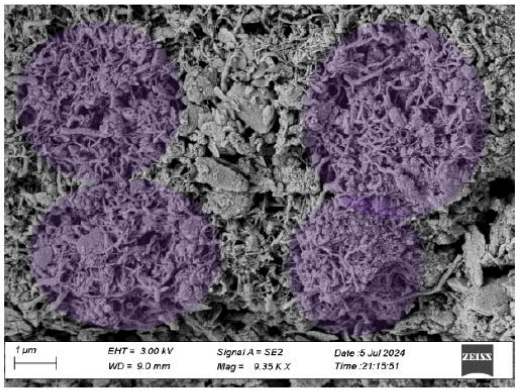
Carbonated SCAs with carbon

30 mm 10 mm

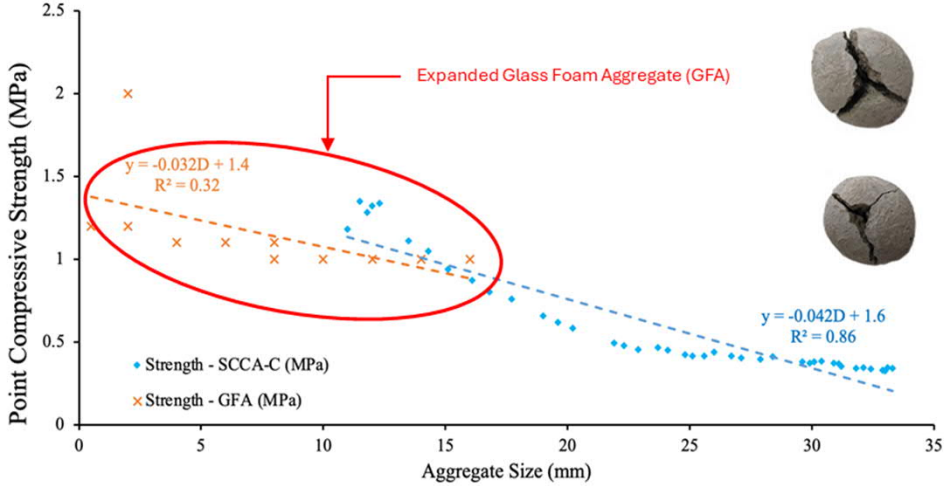
(a)



Control SCA without carbon

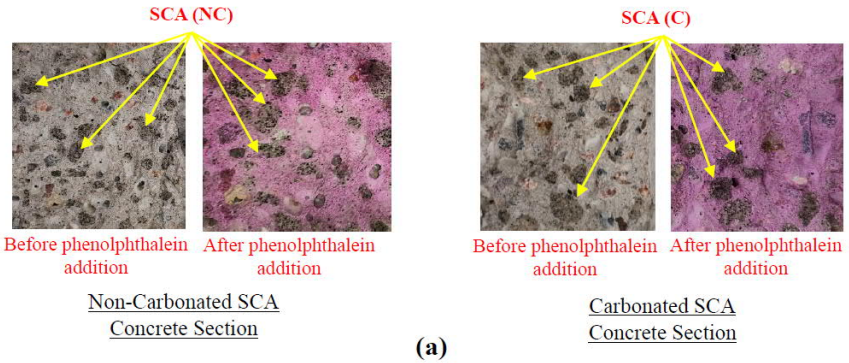


SCA-C with 20% carbon

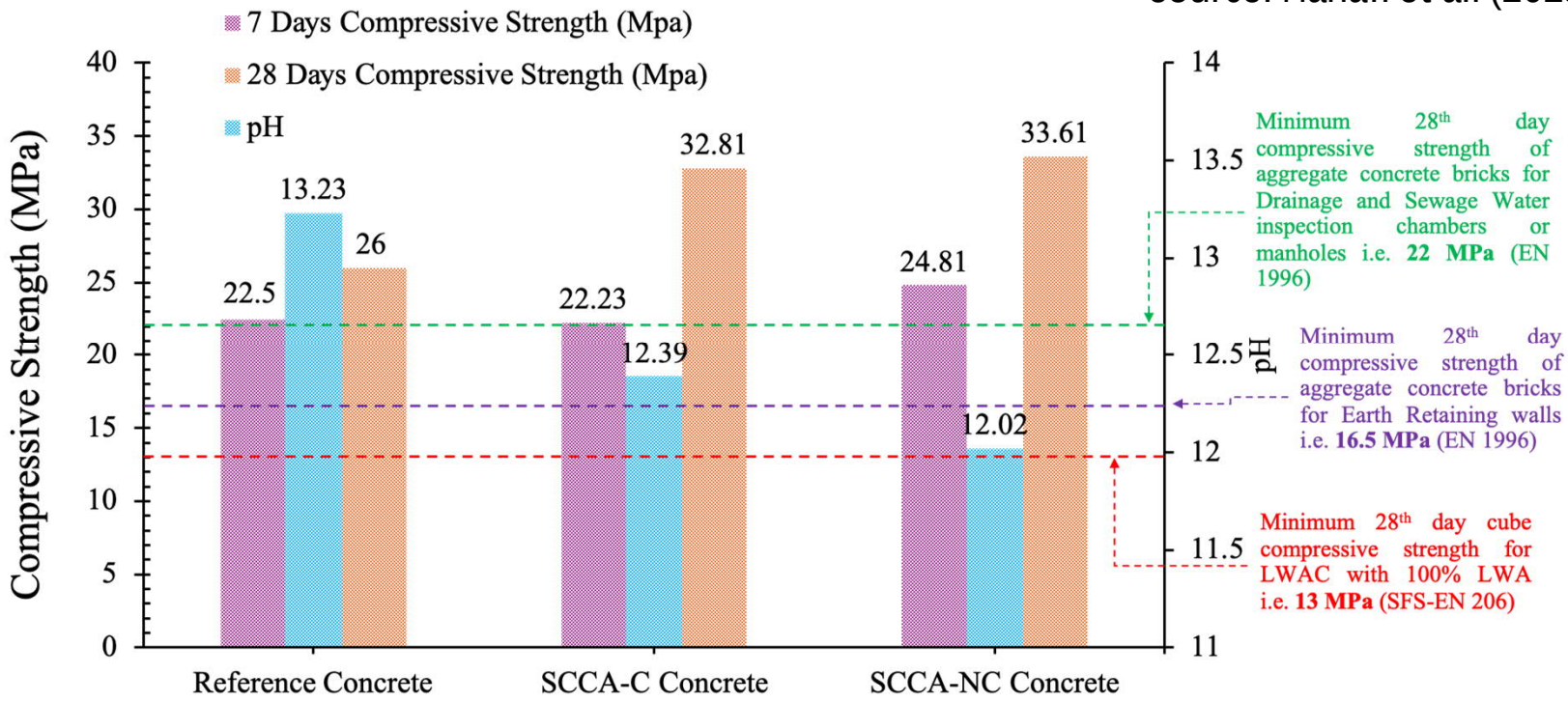


Source: Hanafi et al. (2025). 1st revision

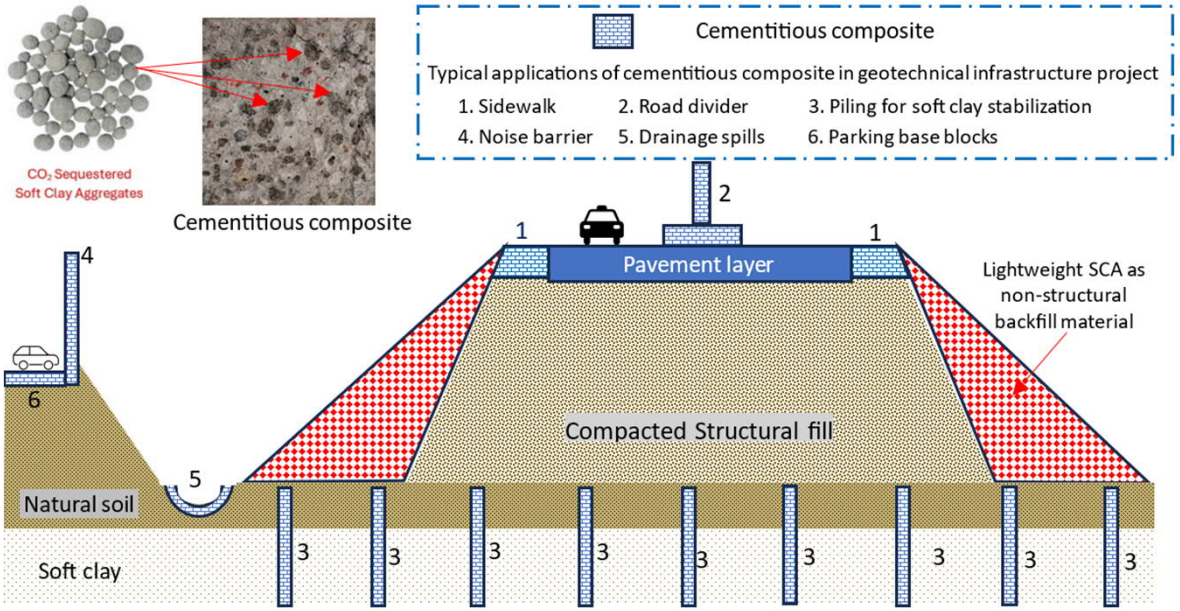
SOFT CLAY AGGREGATE



Source: Hanafi et al. (2025). 1st revision



SOFT CLAY AGGREGATE



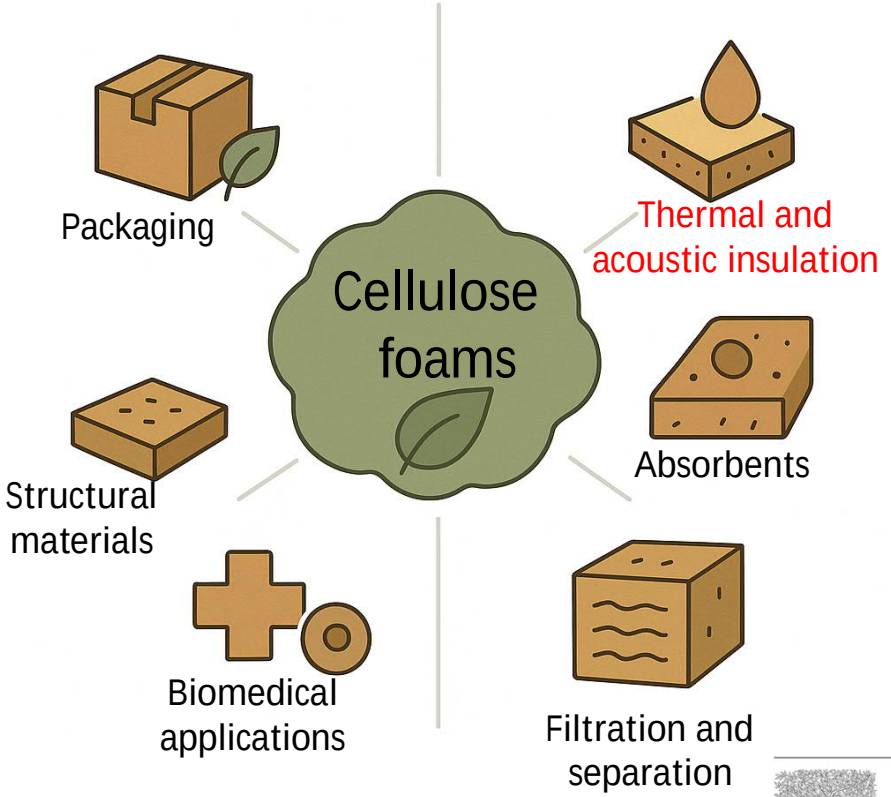
Major questions ahead that need solving?

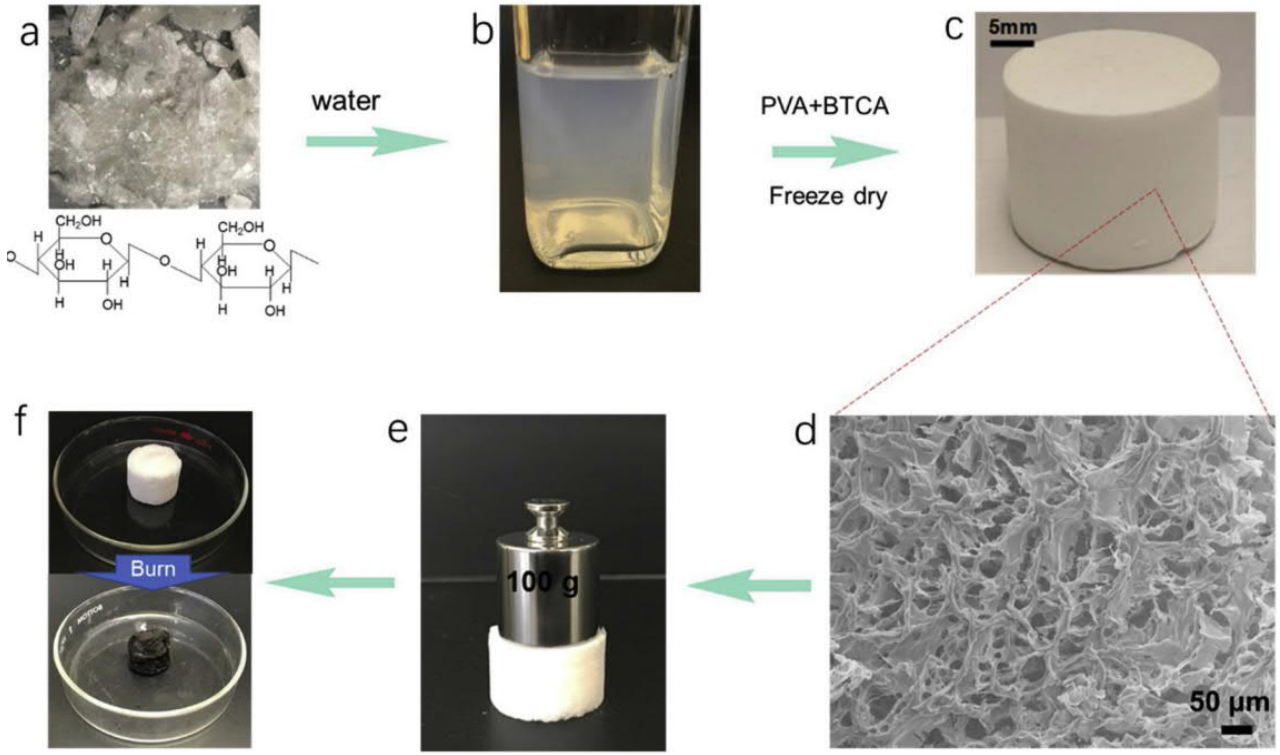
- Moisture variations in natural clay?
- Minimal Portland cement binder used.
- Biocarbon availability and costs?
- Emissions?

Hiiltä sitovat rakennusmateriaalit suomalaisista sivuvirroista (HIRAS)

Carbon-sequestering building materials from Finnish side streams (HIRAS)

CARBONATED CLAY CELLULOSE FOAMS





Source: https://doi.org/10.1016/j.carbpol.2019.04.059

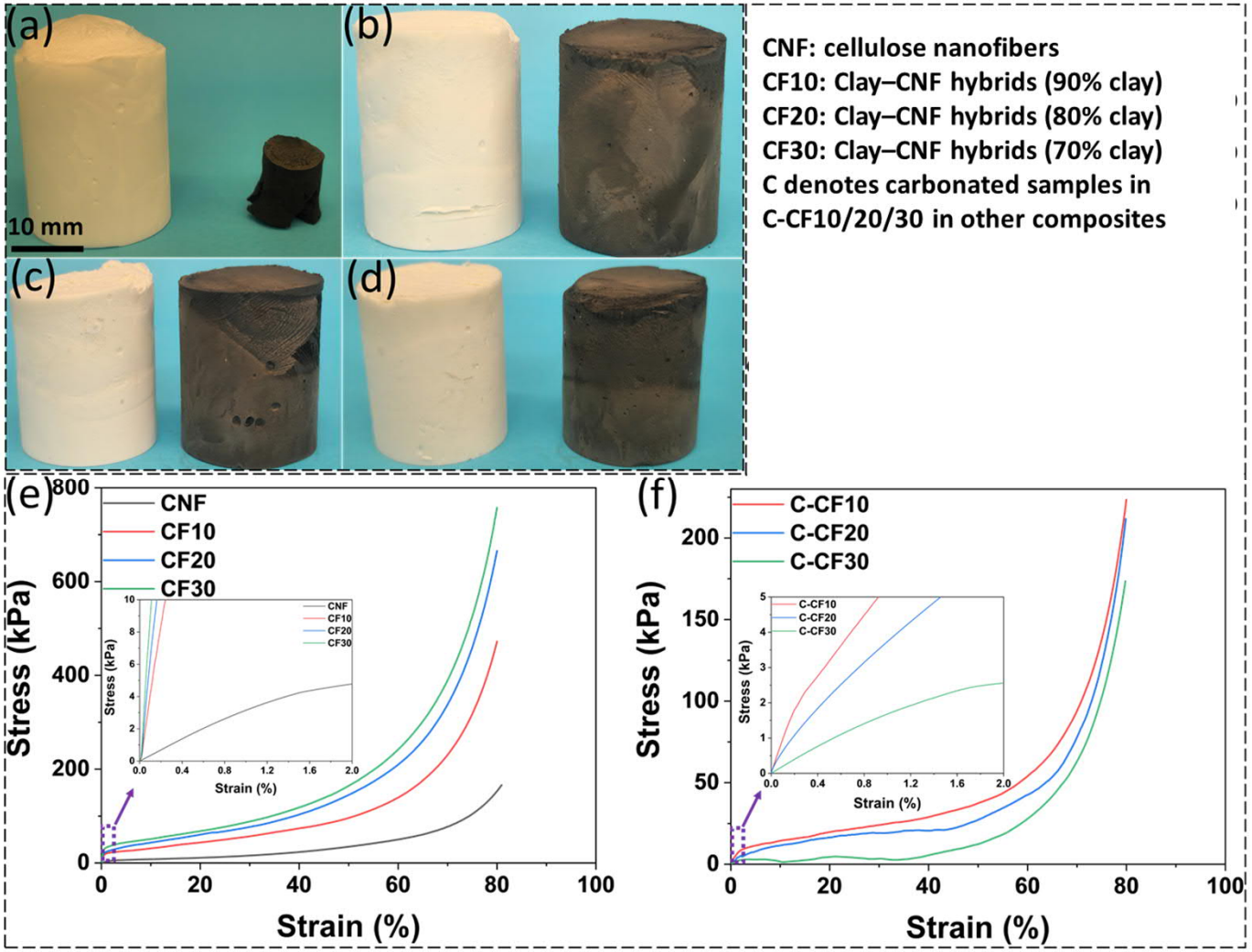
Contents lists available at ScienceDirect
Energy & Buildings
journal homepage: www.elsevier.com/locate/enb

€ 500-5000 per m^3

The economics of thermal superinsulation in buildings

Jannis Wernery [a,*], Francisco Mancebo [a], Wim J. Malfait [a], Michael O'Connor [b], Bjørn Petter Jelle [c]

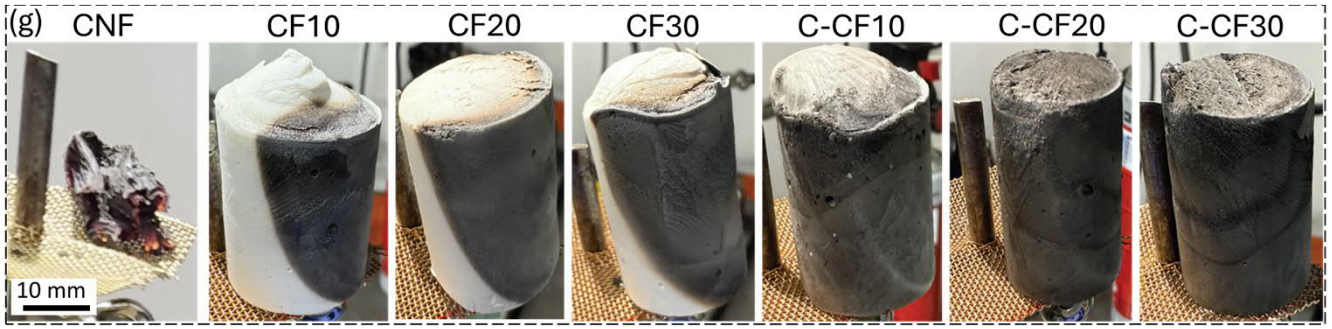
CARBONATED CLAY CELLULOSE FOAMS



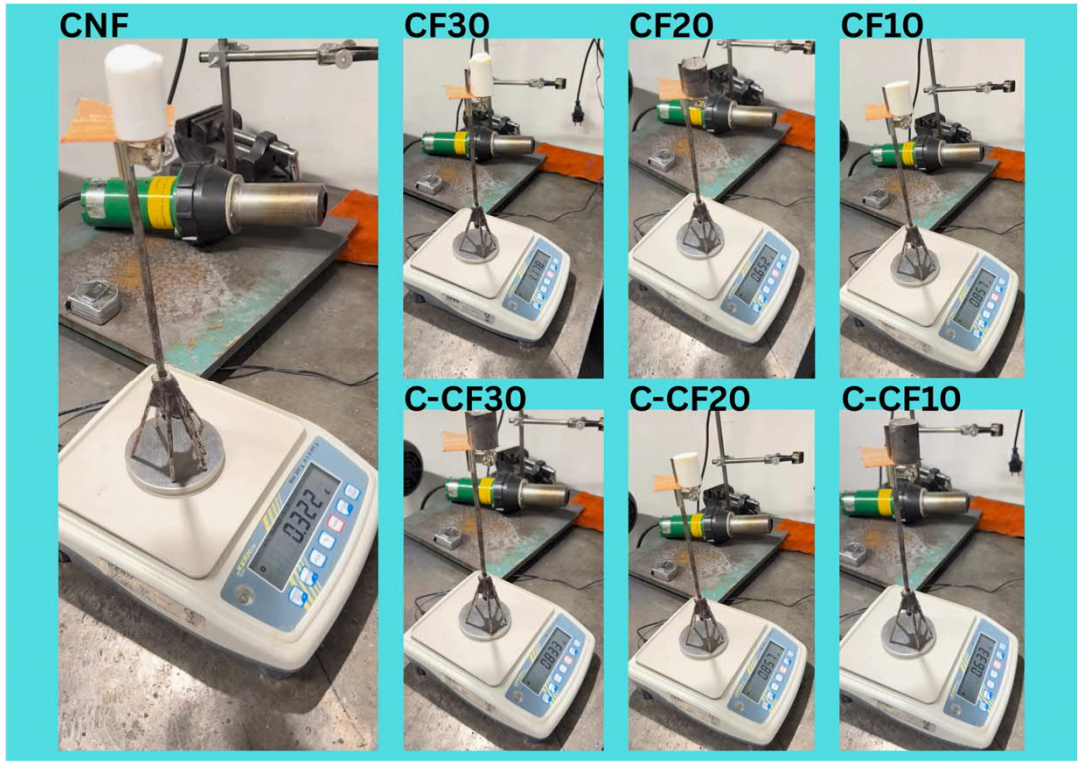
Hybrid Clay-cellulose based foams are superior to cellulose only foams in terms of mechanical performance.

Source: Baniasadi et al. (2025). Under Review

CARBONATED CLAY CELLULOSE FOAMS

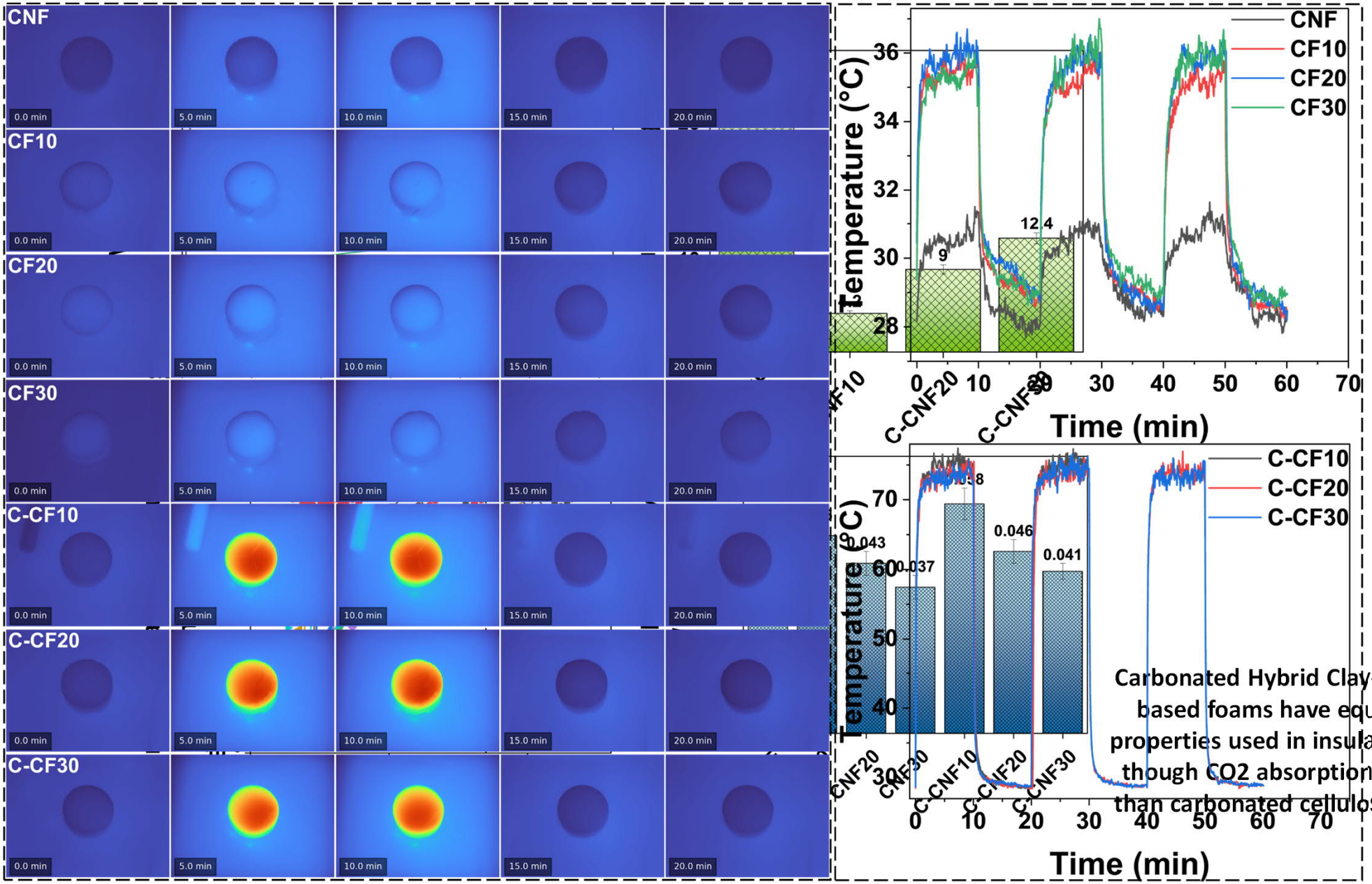


Foams at 60s after ignition



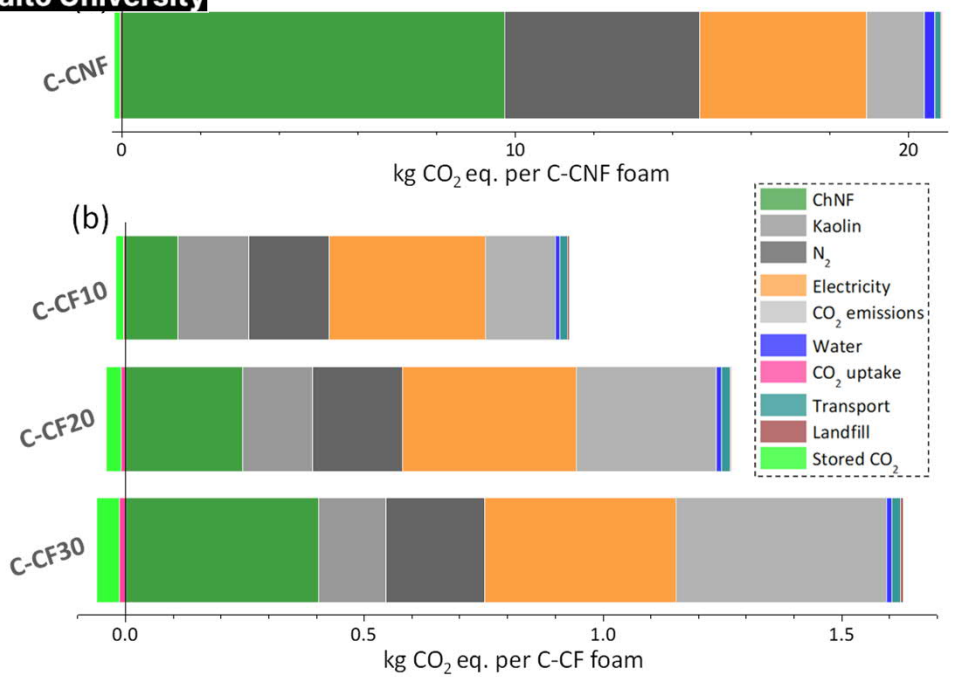
Hybrid Clay-cellulose based foams are superior to cellulose only foams in terms of flame resistance

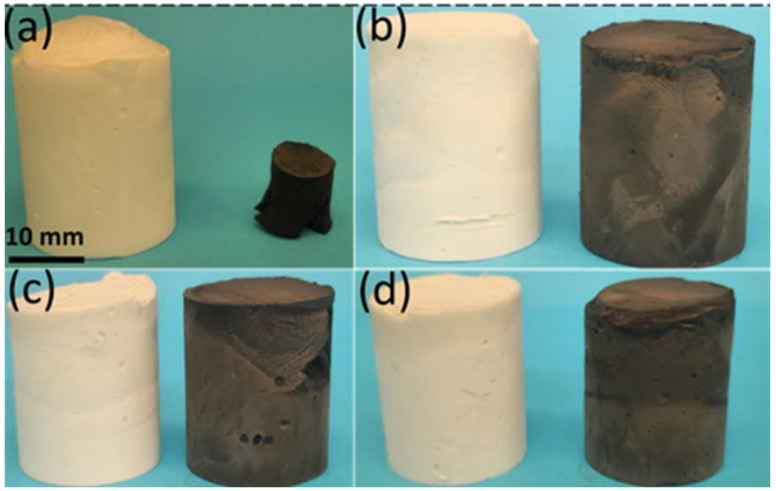
Source: Baniasadi et al. (2025). Under Review



Carbonated Hybrid Clay-cellulose based foams have equivalent properties used in insulation even though CO_2 absorption is lower than carbonated cellulose foams.

CARBONATED CLAY CELLULOSE FOAMS





Major questions ahead that need solving?

- Foam performance with Illitic clay?
- Acoustic performance?
- Biocarbon availability and costs?

Source: Baniasadi et al. (2025). Under Review

The way ahead? Towards TRL7 from TRL3

Roadblocks:

1) How to minimize cement and CO_2 intensive synthetics/practices usage in the construction sector to adhere to Finnish Building Act?

2) Clay characterisation and utility in other complimentary construction sectors. Are we ready to go beyond geotechnical domain?

3) Limited funding resources. Require more industry support in the value chain to develop robust products.

4) TRL3 is good for academicians. TRL7 and beyond is useful utilization of tax-payers money.

5) Industry scale validation and participation only possible when academia and practitioners come together.

Kiitos paljon