Flame-retardant recyclable bio and geo-based foams

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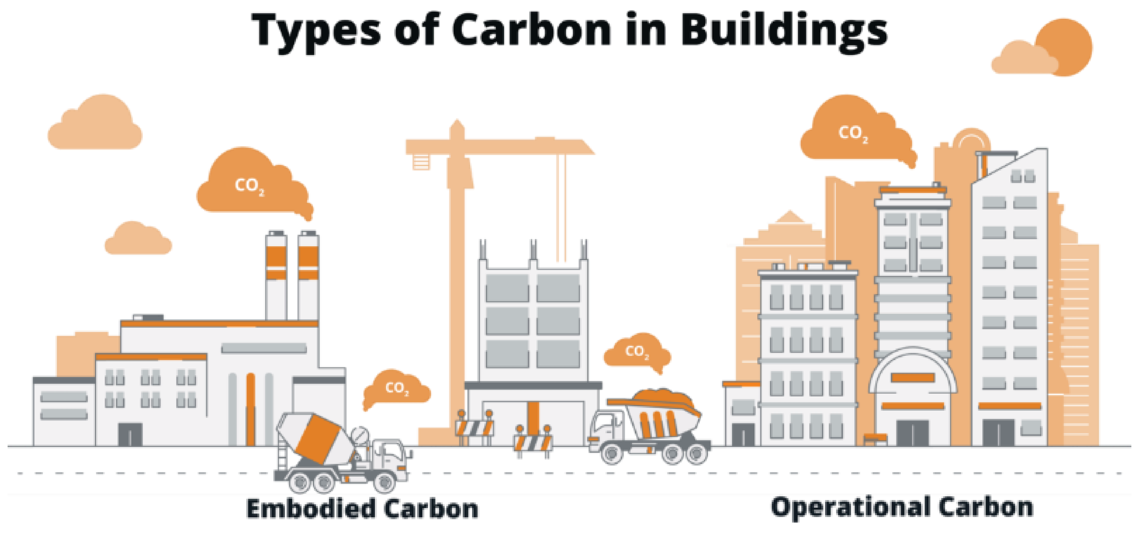
Environmental context

The design of materials for the building industry represents a sector with significant needs. Indeed, this sector represents globally **37% of the carbon footprint and 33% of energy consumption** and uses mainly non-renewable resources. It is therefore imperative that new materials are developed which are environmentally friendly. This research aims to develop 100% bio-based, geo-sourced, recyclable composites for the building industry.

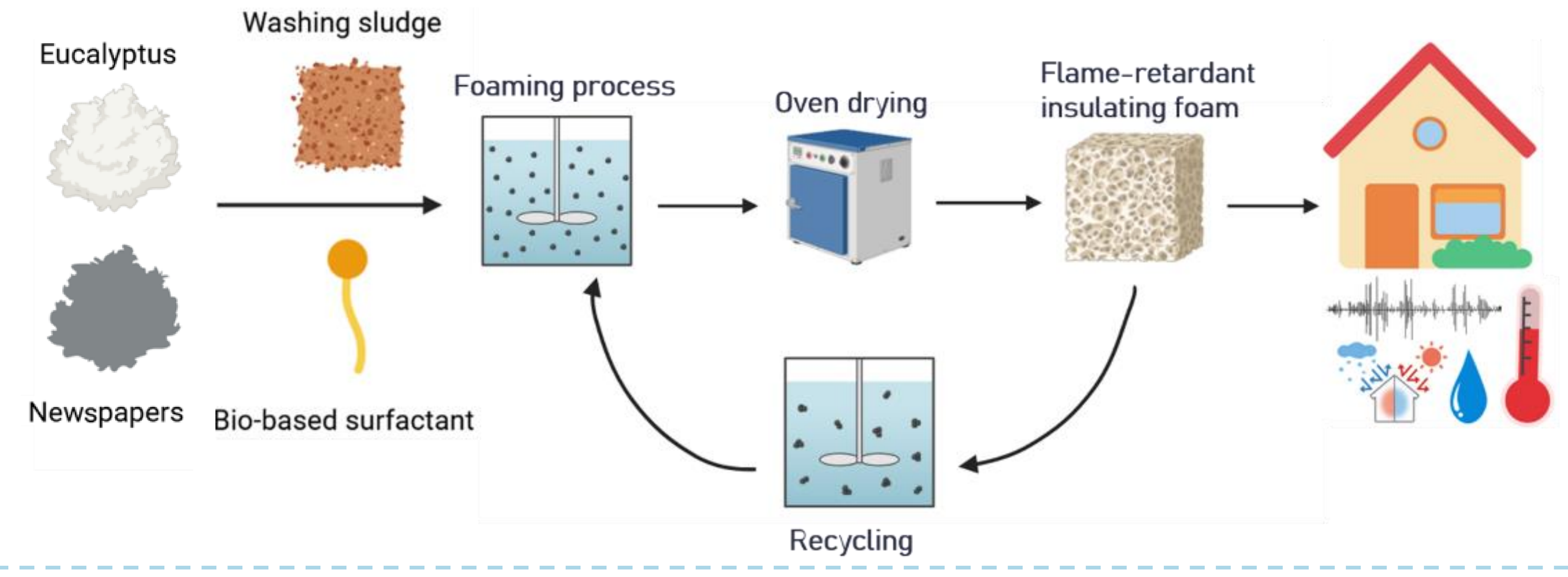
Types of Carbon in Buildings



1. Carbon Cure – 2018

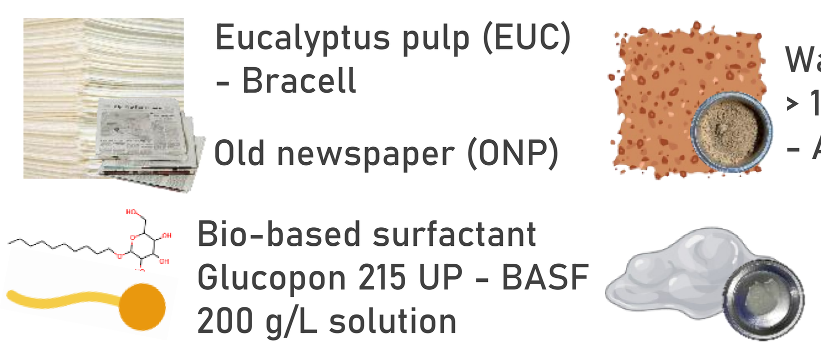
Project presentation

The DESICELL project aims to propose high-performance and **ready-to-use materials** from carefully selected resources with the lowest possible energy. The earth from **gravel washing sludge** and the fibres from **recycled paper** will be selected as raw materials. Here the focus is made on low-density materials obtained by foaming process to propose an alternative to mineral wool flame retardant materials.



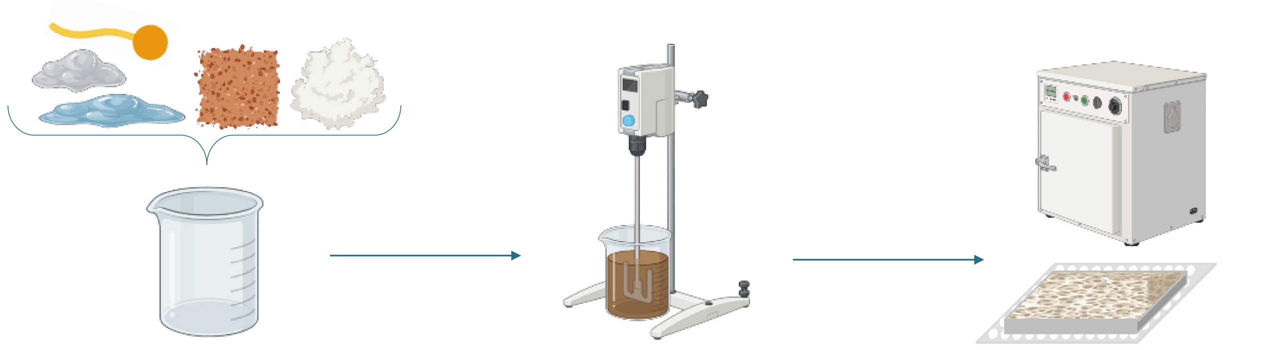
Materials and Methods

Materials



- Eucalyptus pulp (EUC) – Bracell
- Old newspaper (ONP)
- Washing sludge (earth) > 100 µm diameter silts and clay – Akterre
- Bio-based surfactant Glucopon 215 UP – BASF 200 g/L solution
- Microfibrillated cellulose (MFC) at 3wt.% – Valida, SAPPI

Foaming process



- Formulation based on fibres suspension + surfactant (+ earth + MFC)
- Turbotest VMI mixer 10 000 rpm, 15 min
- Drying in ventilated oven 40°C, 24 hours

Characterisation methods

- Roughness analysis
  Alicona profilometer
  Peak height and hole depth
- Uniaxial compression
  80% indentation
- Abrasion test
  Standard tape TESA 7475
  ImageJ for image analysis
- Fibres morphology analysis
  MorFi Neo analyser, accuracy 5 µm
  Fibres > 500 µm and fines < 50 µm
- Water uptake
  Climatic chamber
  23°C, 50 or 80% RH
- Fire resistance test
  Camping gaz and constant distance

Results and discussion

Water vapour uptake

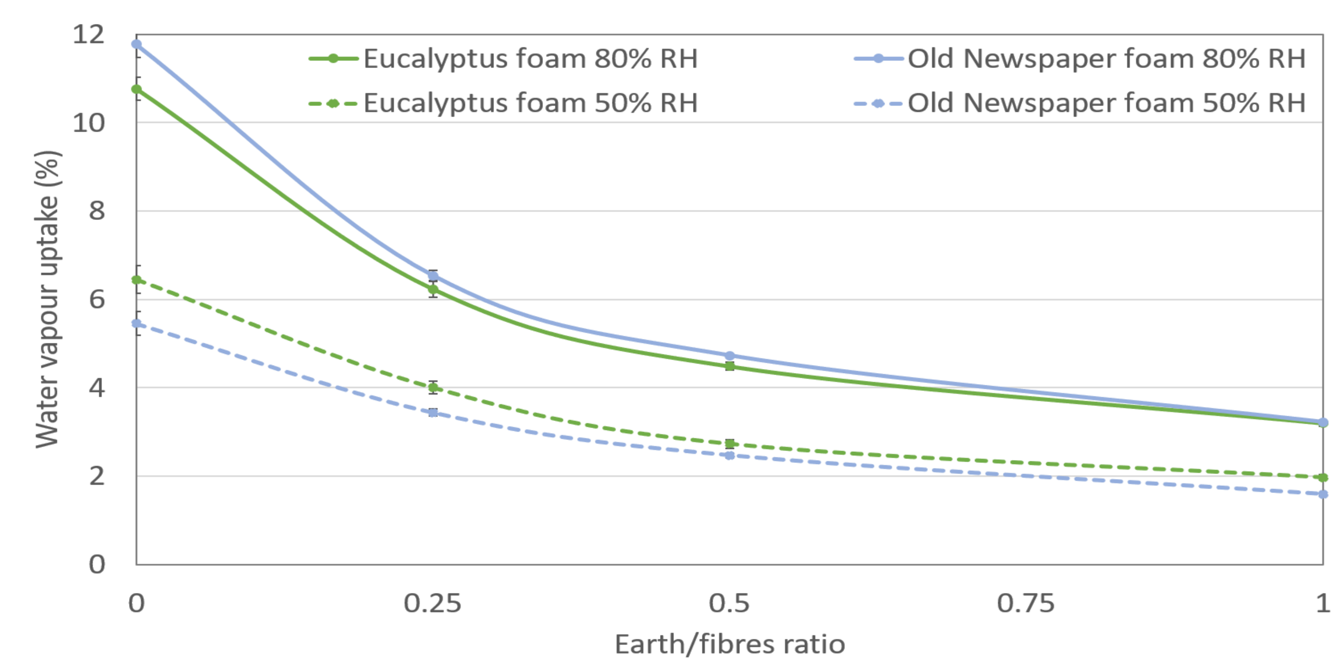


Figure 4: Water vapour uptake test on foam samples with eucalyptus or old newspaper pulp, with various earth/fibre ratios in a climatic chamber at 23°C and 50% RH or 80% RH.

- Increase of earth/fibres ratio:
  ↳ Cellulose is more hydrophilic than earth
  ↳ Decease in porosity
  ⇒ Decrease in water vapour uptake

Mechanical properties

Nomenclature: PULP earth/fibres ratio = 0; 0.25; 0.5; 1

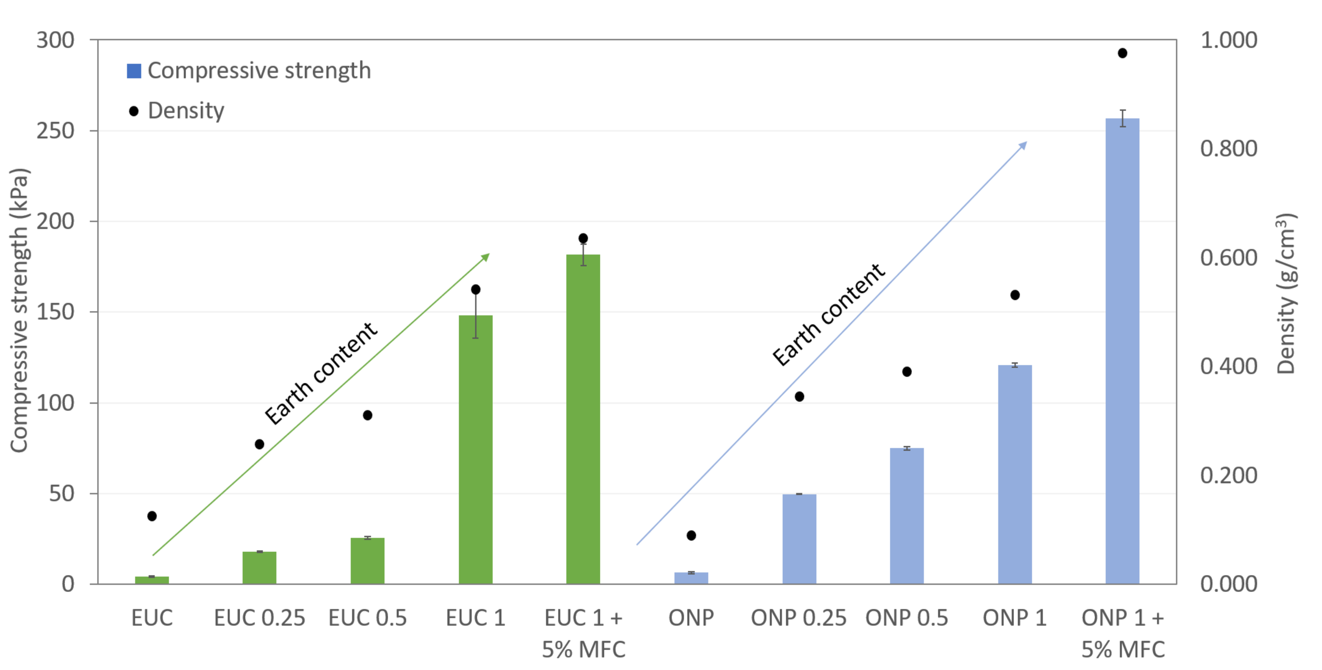
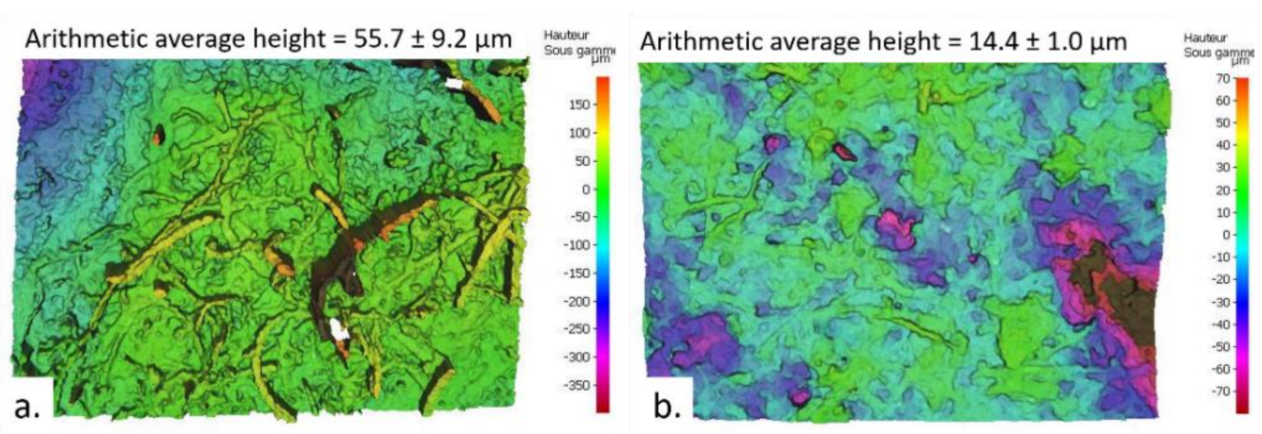


Figure 2: Compression test on foam samples with eucalyptus or old newspaper pulp, with various earth/fibre ratios and with the addition of 5% of MFC in bulk.

- Increase of earth/fibres ratio:
  ↳ Earth density (1.9 g/cm³) > cellulose fibres density (< 1.5 g/cm³)
  ⇒ Increase in compressive strength
- Microfibrillated cellulose (MFC) addition:
  ↳ High specific area increases the fibres interaction due to hydrogen bonding
  ⇒ Increase in density and mechanical properties

Surface properties and fibres morphology



c.

Pulp	Average fibres length (µm)	Fine content (million/g of pulp)
Eucalyptus	453 ± 1	53 ± 1
Old newspaper	233 ± 1	819 ± 3

Figure 1: Roughness analysis on foam samples with a. eucalyptus and b. old newspaper pulp, with an earth/fibre ratio of 1 and c. table of the fibres pulp morphology using MorFi data analysis.

- Pulp fibres length:
  ↳ Decrease in fibres length decreases the fibre's entanglement
- Pulp fine content:
  ↳ Increase in fine content increases fibres interactions
  ⇒ Decrease in porosity, roughness
  ⇒ Increase in density

Fire resistance experiments

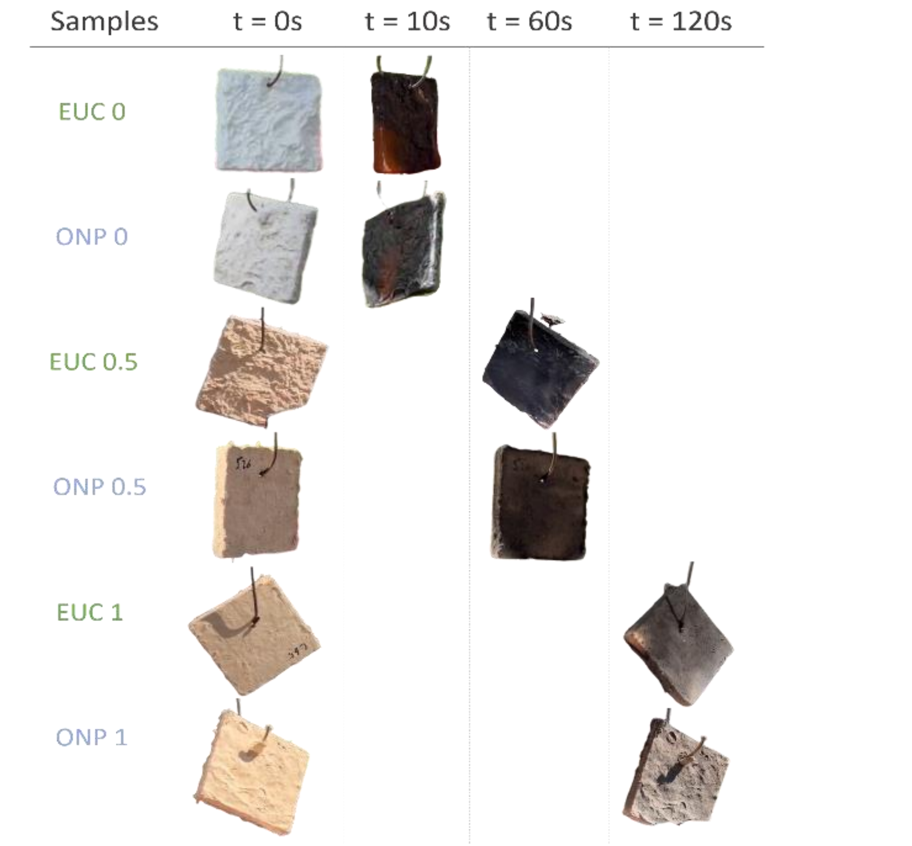
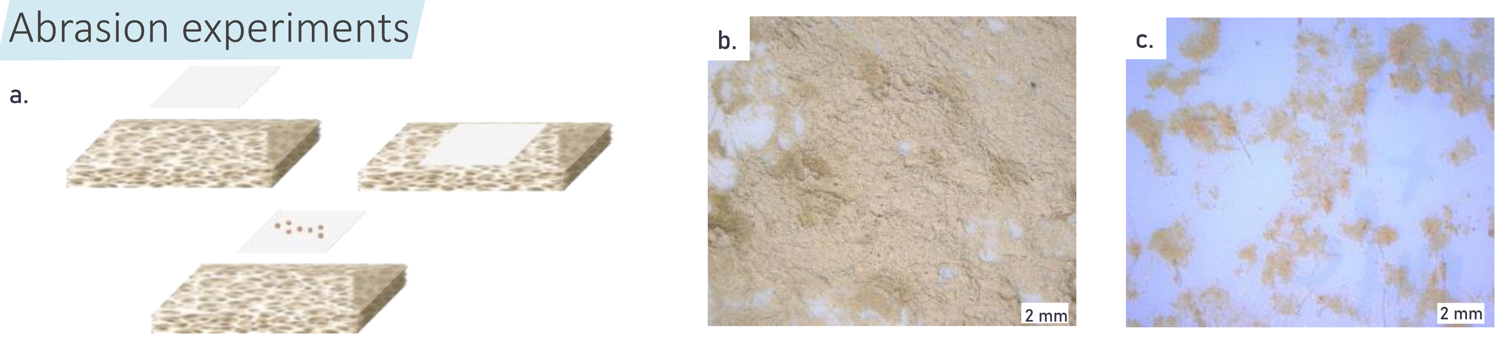


Figure 3: Fire resistance test on foam samples with eucalyptus or old newspaper pulp, with various earth/fibre ratios and their burning stages at 0, 10, 60 and 120 seconds.

- Increase of earth/fibres ratio:
  ↳ Cellulose fibres are organic
  ↳ Earth is a mineral (inorganic material)
  ⇒ Increase in fire resistance

Abrasion experiments



d.

Sample	Surface covered by earth and fibres dust (%)
ONP	99.1 ± 0.2
ONP + 5% MFC	31.9 ± 4.3

Figure 5: a. abrasion test setup, standard tape surface after abrasion: b. ONP ratio= 1, c. ONP ratio= 1 + 5% MFC in bulk, d. Percentage of foam's surface covered by dust.

- Addition of 5% MFC in bulk:
  ↳ High specific area increases fibres interactions due to hydrogen bonding
  ↳ MFC is surrounding the cellulose fibres and earth particles
  ⇒ Decrease in powdery effect of the foam surface

Conclusions

- Pulp type and fibres morphology → influence on the density and surface the roughness.
- Earth addition → increase in mechanical properties but decreases the water vapour uptake.
- Earth improves the fire resistance → substituting boron salt and flame retardant additives.
- MFC addition increases the density and network cohesion → to better mechanical properties and abrasion resistance.

Perspectives

- Investigation on the process settings (foaming speed, air volume incorporation, drying temperature).
- Shrinkage measurement → pulp type, additives, drying temperature.
- Investigate the thermal behaviour of the different.
- Investigate the acoustic insulation properties of the foams in order to substitute ceiling tiles.

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