Master training - Research project BIO UP

Host laboratories: INSA Lyon – GEOMAS (EA 7495) / MATEIS (UMR 5510)

Expected date: February to July 2024

Plant-based concretes
Characterization of the vegetable particle / binder interface

1 Context

This master training as part of the national project BIO-UP (2022- 2026), which gathers different industrials and public partners. In its report published on November 24, 2020, the French High Council for Climate highlighted France's lagging behind in terms of energy-efficient building renovation. It underlines the importance of achieving efficient buildings in periods of cold as well as of high heat and humidity in order to adapt them to climate disruption. These conclusions will be included in future national environmental regulations ("RE2020") which will require the reduction of the carbon impact of buildings, the ongoing improvement of their energy performance, and the guarantee of acceptable temperature during hot summers. To meet these challenges, biobased materials, produced from biomass, are being increasingly used on a massive scale in the construction sector (figures 1 and 2). From an environmental point of view, they allow the storage of CO_2 during their entire lifetime thanks to the mechanism of photosynthesis. In addition, their high porosity and chemical composition give them high hygrothermal and acoustic insulation properties. Therefore, these materials are key alternatives to traditional construction materials for the energy-efficiency renovation of existing buildings. Currently, the market for biobased concrete is showing more than 15% annual growth in volume according to industrialists. They account for 10% of the insulation market and a doubling is expected within five years, according to the French trade union association of biobased construction companies (AICB). Up to now, biobased construction materials are mostly used for their insulating properties than for structural purposes due to their low strengths.

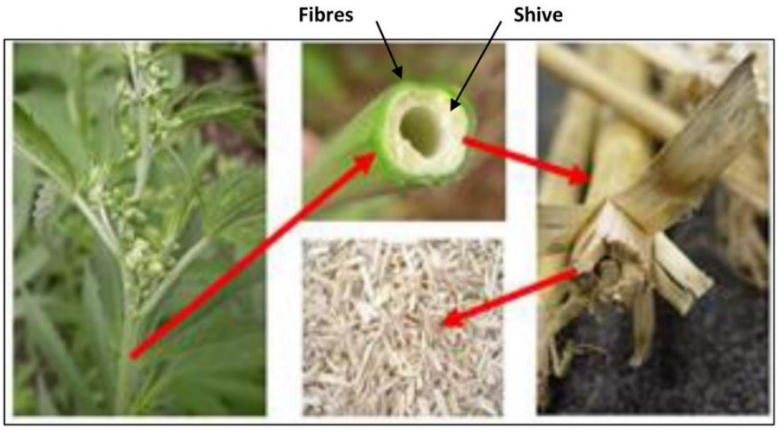

Figure 1: hemp stalks [Nguyen, 2010; Tran Le et al., 2010]

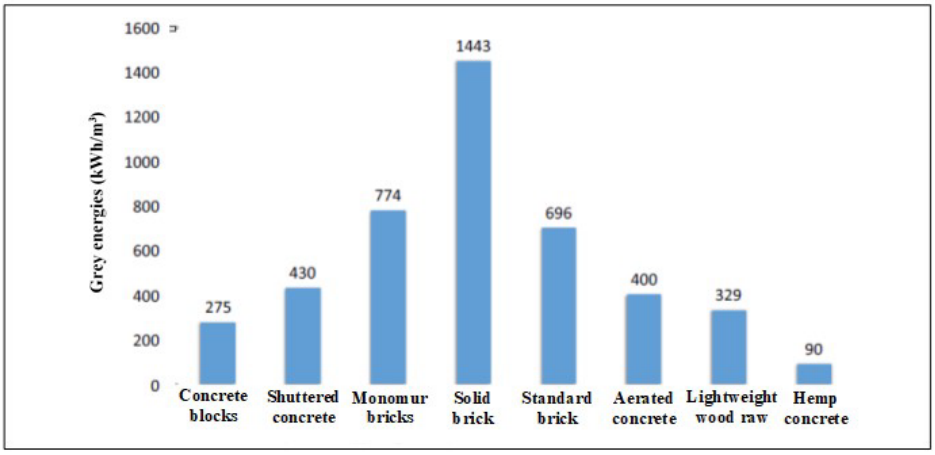

Figure 2: grey energies for some commonly used building materials [Tran, 2010]

2 Topic

Low adhesion of the cementitious matrix on the vegetal particles, as well as poor hydration of the cement are the main causes of these poor mechanical performances, which limits a large-scale production of plant-based composites. In fact, vegetal particles have a high capacity to absorb water limiting the hydration of cement. In addition, vegetal particles have the ability to fix ions, like calcium, avoiding the formation of cement hydrates. To limit these phenomena, it is possible to treat the vegetal particles, by mechanical or thermal actions, in order to modify their surface and reduce their capture capacity (FNDT, EDTA, NaOH), or to change the cementitious matrix (from Portland cement to plaster or ettringite binder). The assessment of the better compatibility between a binder and a plant with a simple and reliable experimental test remains an issue.

The research project focuses on the experiment evaluation of the Interaction Transition Zone (ITZ) between the cement and vegetal for different couple cement/ vegetal particles [Diquélou et al., 2015] [Jalabert, 2010] [C. Julliot, 2021] [Corvalan and F. Diebolt, 2023]. The protocol [Delhomme et al., 2023] consists in studying the surrounding area of the vegetal particles poured (Figure 2) in a cement matrix by visual observations (image analysis, microscopy) and microstructural characterization (X-Ray Diffraction, Fourier Transform Infrared Spectroscopy…).

Figure 2: Hemp pellet cast in cement paste after cement setting.

This project will therefore be carried out in these following stages:

- Literature review on cement, plant particles, ITZ (Master thesis, publication),
- Experimental tests with different binders (Prompt cement, pozzolanic cement CEM IV/A (P), LC3 based on a blend of limestone and clay calcined and cement CEM II/C (Q-LL), a cement sulfo-aluminate cement) and vegetal particles (hemp, rapeseed, miscanthus, bamboo)
- Microstructural (XRD, FTIR, infrared microscopy) and chemical characterisations of ITZ (image analysis, micromechanical characterizations).
- Impact of the couple binder/ vegetal particles on hydration process at the interface.

3 Output

- Master thesis
- Summary of work in publication (roughly 8 pages) and poster format.
- Presentations

4 References

Corvalan L., and Diebolt F. (2023). Characterization of the transition zone between hemp fibers and a binder. Master Thesis (PIRD), INSA Lyon.

Delhomme F, Prud'homme E, Julliot C, Guillot T, Amziane S, Marceau S (2022) Effect of hemp on cement hydration: experimental characterization of the Interfacial Transition Zone. Results in Chemistry, 4, 100440.

Diquélou Y., Gourlay E., Arnaud L., Kurek B. (2015). Impact of hemp shiv on cement setting and hardening: Influence of the extracted components from the aggregates and study of the interfaces with the inorganic matrix, Cement & Concrete Composites, 55:112-121

Jallabert, L. (2020). Evaluation of the microwave impact on the adhesion between hemp fibers and a binder. Master Thesis (PIRD), INSA Lyon.

Julliot, C. (2021). Effect of hemp on cement hydration Experimental characterisation of the Interfacial Transition Zone. Master Thesis (PIRD), INSA Lyon.

Nguyen (2010). Contribution à l'étude de la formulation et du procédé de fabrication d'éléments de construction en béton de chanvre. Thèse de Doctorat - Université de Bretagne Sud.

Tran Le, A. D., Maalouf, C., Mai, T. H., Wurtz, E., & Collet, F. (2010). Transient hygrothermal behaviour of a hemp concrete building envelope. Energy & Buildings, 42, 1797–1806.

Application and contacts

The training will be supervised by Elodie Prud'Homme (MATEIS/INSA Lyon) and Fabien Delhomme (GEOMAS/INSA Lyon).

All interested applicants should send their CV with a letter of motivation and a transcript of their M1 and M2 grades to Elodie Prud'Homme (elodie.prudhomme@insa-lyon.fr) and Fabien Delhomme (fabien.delhomme@insa-lyon.fr).

Gratuities: about 600 € per month