Offer for a doctoral thesis

Multi-functional behaviour of complex walls made of geo- and bio-based materials

Context

The implementation of the new RE2020 environmental regulation from 1 January 2022 requires the use of low-carbon materials that improve the energy performance of buildings. One such material is clay, a natural material that has been used for thousands of years and which is enjoying a resurgence of interest in France because of its low environmental impact and the hygrothermal and acoustic comfort it provides. In fact, the embodied energy of a wall made of local clay is about twenty times lower than that of a wall made of conventional materials. From a thermal point of view, raw earth has a very high thermal conductivity (1 W/m/K), a high thermal capacity (for 2000 kg/m3 the thermal capacity is 1800 kJ/m3.°C) and a very good thermal inertia. These properties give the earth construction excellent summer comfort, but rather average winter insulation. Vegetable concrete, a bio-based material made from vegetable aggregates, a mineral binder and water, is the natural candidate to provide the necessary thermal correction to the raw earth, thanks to its very good insulating properties. Until now, plant concrete has been used mainly for its insulating properties and ability to regulate humidity (e.g. wood frame filling). The combination of raw earth/vegetable concrete would be an innovative hybrid multifunctional solution combining mechanical compatibility, preserved hygrothermal transfer dynamics and sobriety or even carbon neutrality. Scientifically, it has been shown that raw earth has a multi-physical behaviour that allows it to play both a mechanical and a hygrothermal role. Combining this with a bio-sourced concrete, which itself has coupled transfer properties, is challenging, particularly in terms of the multi-physical and technical characterisation of the interface, where many discontinuities occur.

This is the context in which the planned thesis will be carried out, with the aim of designing a low-carbon envelope wall using a combination of compacted raw earth (pisé) and bio-concrete, and evaluating its structural and energy performance. From an application point of view, the final product will be a hybrid geo- and bio-based wall solution adapted to both new construction and renovation of old buildings.

Objectives

- Identification, formulation and characterisation of the materials constituting the hybrid geo-bio solution: The aim is to formulate an optimal combination of rammed earth and vegetal concrete that can fulfil the expected mechanical and hygrothermal functions. The optimised formulations of rammed earth and vegetation concrete will be characterised separately in terms of mechanical properties, such as compressive and shear strength, and hygrothermal properties, including thermal conductivity, heat capacity, permeability and Moisture Buffer Value (MBV).

- Design of the hybrid solution and characterisation of the interface: The aim is to design assembly solutions that allow the combination of vegetal concrete with an adobe wall in new construction or as an addition in the case of rehabilitation. These solutions must guarantee that the hygroscopic character of

the clay alone is not compromised, while at the same time allowing the thermal and mechanical quality of the whole to be improved. For each of the proposed solutions, the properties at the interface are characterised in terms of mass transfer, thermal and mechanical behaviour. Optimal values for geometric texture, friction angle, cohesion, vapour transfer coefficients and heat transfer coefficients will be determined. Given the difference in pH between rammed earth and vegetation concrete, the physico-chemical interactions at the interface will also be studied.

- Determination of the influence of the implementation on the transition phase: The combination of rammed earth with vegetal concrete, be it for rehabilitation or new construction, will pass through a transitory phase during which the multiphysical properties will evolve before reaching a pseudo-permanent regime. Particular attention will be paid to the description of this phase and its kinetics according to the assembly technique used.

References :

[1] Abdulsamad, F., Revil, A., Prime, N., Gnonnoue, P. Y., Schmutz, M., Plé, O., (2020). Complex conductivity of rammed earth. Engineering Geology, 273, 105697.
[2] Amziane, S., Collet, F., (2017). Bio-aggregates based building materials: state-of-the-art report of the RILEM Technical Committee 236-BBM. Springer 23.
[3] B Contet. Characterisation of the hygrothermal behaviour of adobe - Dissertation, Ecole Nationale des Travaux Publics de l'Etat, Vaulx-en-Velin. Technical report, 2012.
[4] National Flooded Earth Project, 2021. https://projet-national-terre.univ-gustave-eiffel.fr/, accessed 18.03.22.
[5] National Low Carbon Strategy. Ministry of Ecological Transition (MTE), 5 May 2021
[6] Wadi, H., Amziane, S., Toussaint, E., Taazount, M., (2019). Lateral load-carrying capacity of hemp concrete as a natural infill material in timber frame walls. Engineering Structures, 180, (1), 264-273.

Candidate profile

The candidate should have an engineering or masters degree in materials or civil engineering. S/he should have a very good knowledge of hygrothermal transfers in materials. He/she should also show initiative and autonomy and have a strong interest in experimental work. Fluency in written and spoken English and French is essential. Experience in the field of bio- and/or geo-sourced materials would be appreciated.

Interested candidates should submit the following documents: CV, cover letter, transcripts (Master 1 and Master 2) and if possible letter of recommendation + bachelor transcript.

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Location: Institut Pascal in Clermont-Ferrand

Starting date of the thesis: October 2023

Gross annual salary: 36 000 €. Possibility to teach at Polytech Clermont, civil engineering department (max 64h/year).