



## UNIVERSITE DE TOULOUSE – LMDC – THESIS PROPOSAL

### Investigation of the multi-physical behaviour of low-CO<sub>2</sub> materials (LC<sup>3</sup> type) in leaching environments

The construction and public works sector and the production of cementitious materials are responsible for a large amount of greenhouse gas emissions, and consumption of exhaustible resources and energy. On a global scale, cement production accounts for about 5% of CO<sub>2</sub> emissions and about 2% of energy consumption (Holban et al., 2015), associated with the transport and calcination of raw materials (limestone and clay). To reduce the negative environmental impact of concrete production, alternative low-carbon binders are being developed. Recently, there has been growing interest in the scientific community in the use of Limestone Calcined Clay Cement (LC<sup>3</sup>), which offers (i) high clinker replacement rates (Antoni et al., 2012), (ii) the use of raw materials that are widely available and accessible throughout the world and (iii) similar or enhanced mechanical characteristics to that of concrete with Portland cement produced from a similar clinker (Dhandapani et al., 2018; Sharma et al., 2021). Even though several studies have shown the potential of LC<sup>3</sup> for applications in aggressive environments such as water containing chlorides (Dhandapani et al., 2018) or sulphates (Ejbouh et al., 2022), their durability in the diversity of aggressive environments to which concrete structures are exposed has not been sufficiently characterised. Therefore, this study aims **to assess the potential use of low-CO<sub>2</sub> cementitious materials (LC<sup>3</sup> type) for applications in leaching environments** such as fresh water, natural water, agricultural effluents (agricultural infrastructures), industrial environments (AFNOR, 2022; De Belie, 1997). An innovative aspect of the subject will be the **assessment of mechanical and physical characteristics of materials during degradation**. The subject is part of the **interdisciplinary work of the Laboratory of Materials and Durability of Constructions (LMDC)** by developing innovative low-CO<sub>2</sub> materials and studying their durability concerning leaching. The thesis will focus on three main areas:

- In-depth study of the mineralogical composition and transfer properties of the materials (CEM I and LC<sup>3</sup>) as a function of the binder composition (proportion of cement, calcined clay and limestone for LC<sup>3</sup>) and water to binder ratio.
- Understanding the phenomenology of leaching attacks as a function of different leaching conditions (nature of the acid, concentration, type of renewal, pH, etc.)
- Multiphysics evaluation of the local properties (chemical, mechanical and physical) of materials undergoing degradation.

This thesis will feature a strong experimental component and a methodology based on various advanced analytical techniques for liquids and solids, such as Inductively Coupled Plasma-optical emission spectrometry and ionic chromatography, X-ray diffraction, thermogravimetric analysis, scanning electron microscopy (+ Energy-dispersive X-ray spectroscopy), Mercury Intrusion Porosimetry, microtomography, autoradiography, nuclear magnetic resonance and **microindentation** in a controlled environment.

**Start of thesis: 1 October 2024**

#### **Working conditions and location:**

The PhD student will be enrolled in a fully funded thesis (MEGEP grant) at the **Université de Toulouse** and will be based mainly in Toulouse. The supervisory team, from LMDC, INSA Toulouse, will consist of: Ass. Prof. Marie Giroudon, Prof. Alexandra Bertron, and Prof. Laurie Lacarrière.



From an academic point of view, the Laboratory of Materials and Durability of Constructions (LMDC) is highly-recognised in the field of Civil Engineering, and the training received during the thesis in cement chemistry, microstructural analysis of materials and modelling will provide a range of multi-disciplinary skills that will be of great value. The team supervising this thesis combines skills in the multiphysical behaviour of cementitious materials in aggressive environments, experimental protocols for exposing materials to these environments, and multi-scale characterisation of cementitious materials.

LMDC is the largest Civil Engineering Laboratory in France. It has a staff of 120, including 60 PhD students every year, providing a dynamic working environment and numerous opportunities for scientific exchange and stimulation. The laboratory has its own range of scientific equipment (SEM-EDS, XRD, ATG, ICP-OES, ion chromatography, etc.) and is a member of research federations (including the Fermat federation), giving its staff access to a large number of cutting-edge facilities.

Finally, the members of LMDC enjoy a very pleasant working environment next to the Canal du Midi in the city of Toulouse. Toulouse is a young and attractive city, ideally located in the middle of south-west France, offering a wide range of tourist attractions.

#### **Candidate profile and selection criteria:**

Essential: The candidate should have a strong scientific curiosity and a taste for experimental work, with the following: (i) an M2 level or master's degree (Engineering degree or university course) in Materials Science, Physical Chemistry or Civil Engineering – Students who are about to graduate can also apply, (ii) a good command of English, and (iii) significant research experience will be an important element. The future PhD student should be motivated and committed, and show initiative and autonomy. They will have various contacts with whom they will need to communicate regularly and act as an interface. They will have to present their results very regularly and report on the progress of their work to various scientific contacts. The PhD student will therefore need to demonstrate good writing skills, as well as an ability to communicate and present their work.

Desirable: An interest in exploiting data using numerical analysis tools (based on languages such as Python) will be appreciated. Knowledge of techniques for analysing the mineralogical, chemical, microstructural and/or mechanical properties of solids and their theoretical underpinnings would be a plus. Knowledge of cementitious materials would also be an advantage.

#### **How to apply?**

Please upload your CV and a supporting statement at this link (<https://filesender.renater.fr/?s=upload&vid=e4289083-fba4-4139-aa25-5943f6ba3b16>). The supporting statement should be a maximum of 700 words with (i) a statement outlining your motivation to pursue (ii) do you have any relevant research or work experience, and (iii) technical skills you've developed.

#### **Last date**

Opening of the call for applications: Immediate

Closing of the call for applications: 22/04/2024

Tentative dates of interview (preselection): 02/04/2024 to 29/04/2024

#### **Contact:**

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