Description of the research work

Laboratory : LMDC (Laboratoire Matériaux et Durabilité des Constructions de Toulouse**)**

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Title:

A multiscale modelling for the prediction of vegetable fiber-mortar composites by two approaches : Mean-field homogenization (MFH) and direct finite element (FE) numerical simulations.

Abstract:

Scientific problem - Stakes

Over the past century, there has been a dramatic increase in natural resources due to the increasing population. The fastest growth from 1900 to 2005 came from construction minerals, as the most important component in the building sector, which increased by a factor of 34 times [Krausmann et al. (2009)]

From [Parliament (2014)], about half of all our extracted materials and energy consumption and about a third of our water consumption are from construction and use of buildings in the EU.

The products in the building sector, especially concrete, lead to copious greenhouse gas emissions, thus aggravating the climate change. On one hand, the toll is heavy for the building sector making up about one third of all waste in the EU. On the other hand, the increasing quantity and variety of by-products or solid wastes have prompted researchers to take a strong interest in the use of recycling/re-using materials in construction materials.

It appears that the use of concrete containing by-products can be an effective way to reduce carbon emissions and contribute to environmental protection. This type of concrete is also known as eco-friendly concrete. There are many way of recycling or reusing waste in the building materials and the impact of their incorporation in building materials is still a challenge. The research proposal is involved on the development of materials with low environmental impact : mortars incorporating vegetal fibers.

Incorporating plant aggregates in construction materials not only alleviates the scarcity of traditional mineral resources but also reduces the environmental problems caused by agricultural wastes. For some special applications, such as house thermal and acoustic insulation materials, green concrete has advantages over traditional concrete [Tran-Le et al. (2019)].

This PHD proposal is in part of the research area of the LMDC (Laboratoire Matériaux et Durabilité des Constructions) with an expertise in particular on the design and multiphysical optimization of bio-based building materials. The study will be focused on fiber-reinforced composites and follows a PHD thesis [Saad, 2018-2022] on the experiment study of its mechanical long term performances and early age behavior. The goal here is to carry on the study and propose a modelling to compare with the experiment data from [Saad, 2018-2022], predict and finally optimize new eco-friendly fiber-reinforced materials.

The following two work packages presented here are all focused on the link between the micro-structure of the new eco-friendly materials and their macro-behavior. It can be noticed that the macro performances of this materials can be affected by the fiber aspect ratio, volume fraction, orientation and interfaces.

In order to take into account the effects of the material microstructure, we propose here two approaches and then two work packages with a common multi-scale analysis. The first one is a computational multiscale simulation on a 3D RVE (Representative Volume Element) and the second one is based on the mean-field homogenization theory with a semi-analytical calculations.

Research Work Packages:

1. Work Package 1: Numerical homogenization on 3D fiber composites RVEs.

   This work package will focus on the finite element-based numerical simulations of natural fiber-reinforced mortars based on a simplified RVE: composed of natural fibers inclusions with specific interfaces embedded in a mortar matrix. The goal is to compare the compressive strength and energy absorption capacity obtained by FE simulations with experimental results from [Saad] and other publications and finally predict and optimize a new composition regarding the fibers ratio, size and orientation. This work package will be performed in collaboration with Joseph Absi from University of Limoges.

2. Work Package 2 : Micromechanical approaches to predict the mortar incorporating vegetable fibers

   Another way of prediction is to build micromechanical equations and use a semi-analytical homogenization approach based on the micromechanics theory. It appears as an effective tool for determining the overall properties of a composite material when the properties and volume fractions of its phases are known. Multi-scale models has been used to predict a wide range of cement-based materials [Fang et al. (2021), Zhang et al. (2021)], nevertheless few have been carried out to predict eco-friendly material's behavior. So, the main purpose will be to propose a set of equations obtained from micromechanics to predict the mechanical behavior using constituent eco-friendly material properties to reach the ultimate goal of optimization of its microstructure: fibers size, orientation, shape aspect ratio, ect. This work package will be performed in collaboration with Iulia Mihai from University of Cardiff.

It will therefore be interesting to compare the multi-scale theoretical modeling with FE approaches from the Work Package 1. The final objective of this first study is to establish an optimum on the quantity and the geometrical characteristics of fiber inclusions and its mechanical performances.

References

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