Post-doctoral internship

Numerical study of DEF at the mesoscale by cohesive-volumetric approach

Thematics: Mechanics ; Chemistry; Civil engineering ; Applied mathematics
Keywords : Delayed Ettringite Formation (DEF), chemo-mechanical parameters identification, mesoscale, reactive transport
Place : Cadarache (13)
Duration : 18 months
Availability date : as soon as possible
Supervising : Céline PELISSOU and Frédéric PERALES

Description:

This post-doctoral internship of 18-months is part of the research carried out at the Institute of Radiorotection and Nuclear Safety (IRSN) concerning concrete aging in the containment buildings of nuclear power plants (extension of the operating life of nuclear reactors) conducted by the CONCRETE Consortium and as part of the European ACES project (Towards Improved Assessment of Safety Performance for LTO of nuclear Civil Engineering Structures) started in September 2020.

The internal swelling reaction (ISR), with slow kinetics, is distinguished into two types of chemical reactions: the Internal Sulfate Reaction (ISR) and the Alkali-silica Reaction (ASR). They have recently been detected on massive nuclear structures (containment, basement), such as the Gentilly-2 plant in Canada (ASR), Seabrook in the USA (ASR), or Tihange-2 in Belgium (ASR&DEF). At the mesoscale, that is to say the aggregate scale, under some environmental conditions (thermo-hydric), swelling products can occur in the pores (delayed ettringite for DEF, silico-alkaline gel for ASR) and at the interface between the paste (or cement) and can be induce structure expansion and then micro-macro cracks which can lead to the structure cracking. These swellings ultimately lead to the loss of mechanical and confinement properties (strength, permeability, sealing).

Here, the objective is to predict, by scaling up (from the microscopic scale and the cement/aggregate interface to the mesoscopic scale where the concrete microstructure is considered as a two-phase material with a matrix embedded in aggregates collection), the mechanical behavior of the concretes affected by DEF by taking into account the interfacial properties between cementitious matrix and aggregates. The numerical platform based on a cohesive-volumetric approach is XPER and is developed at IRSN. This study is a continuation of previous and ongoing works on the predictive tool development for the mechanical behavior and cracking of « degraded » concrete. Upscaling works have been done on sound model material and are currently extended to DEF model material. This work projects on the one hand a fine "experimental" DEF understanding at the interface scale and, on the other hand, handling of the chemo-mechanical modeling of cracking. This developed chemo-mechanical model makes allows to take into account, on the one hand, the reactive transport of chemical species within the porous cementitious matrix and in the cracks and, on the other hand, the created phases impact (delayed ettringite) on mechanical, diffusive and cracking behavior.

In the framework of this post-doctoral internship, the experimental data (obtained at the interface scale as part of a thesis in progress at IRSN) will be used to identify the cohesive. This model will be then applied to the prediction of delayed ettringite formation and fracture pattern at the mesoscale.

Numerical simulation will be the central point of this work. A complementarity of experimental modeling / chemo-mechanical parameters identification / numerical simulation will be developed to understand the DEF problem at the interface and material scales. This work will be divided into several parts :

- Realization of a bibliographical study on DEF pathology, on DEF models used in the literature at different scales, on cohesive zone models to understand the damage and cracking and scaling techniques (homogenization methods). Familiarization with chemo-mechanical parameters identification process (elastic, cohesive, Biot's modulus).
- Identification of cohesive parameters on model materials affected by DEF using experimental results obtained in a thesis in progress at IRSN and numerical calculations campaign with XPER tool.
- Identification of mechanical (for example the Biot modulus) and chemical parameters of the chemo-mechanical model taking into account the delayed ettringite formation and the ettringite pressure on the development and propagation of cracks in affected concrete.
- DEF simulation at mesoscale: cracking pattern prediction linked to DEF.
- Confrontation with experimental data (from WP 3.1 ACES) in terms of cracking and swelling linked to DEF.
- Writing a publication and an English report summarizing all the modeling work and confrontations between experimental data and numerical simulations.

Candidate profile : The wanted candidate must present/have the following profile: Doctoral degree in Mechanics or Civil Engineering with a strong taste for numerical simulations and a good spoken and written level in English.
Knowledge of homogenization, reactive transport, programming tools (python) and performance of mechanical laboratory tests will be appreciated.

Supervising : Send the CV, a motivation letter specifying the professional outlet envisaged after the post-doctorate, the thesis defense report joined with the two reporters reports and recommendation letter(s) from supervisors of thesis and previous stage/post-doctorate, to:

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