INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES RENNES

PhD Thesis Proposal

Subject: Creep of construction materials with a low environmental impact

Key-words: Cementitious materials, Mineral Additions, Creep, Shrinkage, Experimentation, Civil Engineering

Laboratory: Laboratoire de Génie Civil et Génie Mécanique (LGCGM)

Location: Institut National des Sciences Appliquées de Rennes (INSA Rennes)

PhD thesis director: Darquennes Aveline

Other tutor: Hannawi Kinda

Description of the thesis subject:

Because of the environmental impact, it is crucial for the cement industry to reduce the carbon dioxide emitted during limestone decarbonisation. Indeed, this process consumes important amounts of energy and releases significant carbon dioxide content. One of the solutions proposed in the construction industry is the partial or total substitution of cement or clinker by secondary materials such as mineral additions (e.g. blast-furnace slag, fly ash, and limestone filler). This solution is more respectful of the environment and used in numerous applications such as structures subjected to slightly aggressive or extreme environmental conditions. However, some of these civil engineering structures presented cracking due to their delayed deformations such as shrinkage and creep. Thus, a good knowledge of the creep behavior of these materials is essential to broaden their scope, seeing that this parameter affects seriously the material cracking sensitivity and the losses of prestressing.

The main objective of the present PhD consists in studying and understanding the mechanisms driving the different types of creep (basic, thermal and total) by means of an important experimental campaign. The main mechanisms responsible for creep of traditional cementitious materials are currently related to C-S-H and water movements, cracking, capillary depressions, etc. But these different theories present a lack of consensus today, in particularly for the new developing materials containing a high content of mineral additions, such as geopolymers and alkali-activated materials.

To understand in-deep the mechanisms responsible of creep and the effect of mineral additions, multi-scale approaches would be adopted:

1) From paste to concrete: to simplify initially the study and to make it progressively more complex taking into account the effect of the aggregates and the Interfacial Transition Zone (ITZ);
2) From mono-to ternary mineral additions substitution: to determine clearly the role of the addition types, their hydration products and their coupling.

The last part of the experimental campaign will focus on mixtures without cement like chemically activated materials. This experimental campaign will require the development of original tests to monitor the thermal and tensile creeps. Based on the experimental results, rheological models and numerical codes proposed by standards would be adapted to predict the creep deformations of these friendly environmental materials.

The PhD doctoral student will also participate to inter-laboratory meetings, scientific exchanges and experiments within the framework of the European COST action CA 15 202 - SARCOS, *Self-healing As preventive Repair of COncrete Structures* (2016-2020).

Required Skills : Experience in the field of Civil Engineering, A strong taste for laboratory experimentation, Knowledge in mechanical experimentation.

References :

(1) Darquennes, A., Staquet, S., Delplancke-Ogletree, M.-P., Espion, B., 2011, "Effect of autogenous deformation on the cracking risk of slag cement concretes", *Cement and Concrete Composites*, 33, pp.368-379.
(2) Hilaire, A., Benboudjema, F., Darquennes, A., Berthaud, Y., Nahas, G., 2014, "Modeling basic creep in concrete at early-age under compressive and tensile loading", Nuclear Engineering and Design, 269, pp. 222-230.
(3) Darquennes, A., Rozière, E., Khokhar, M.I. , Turcry, Ph. , Loukili, A. , Grondin, F., 2012, "Long-term deformations and cracking risk of concrete with high content of mineral additions", Materials and Structures, 45, pp.1705-1716.
(4) Darquennes, A., Benboudjema, F., 2018, "Behavior of activated ternary binders under autogenous condition", 2nd International Workshop on Durability and Sustainability of Concrete Structures (DSCS), Moscou, Russie, 6-7 June.

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