PhD Thesis Proposal

Subject: Durability of Alkali Activated Materials

Key-words: Mineral Additions, Chemical Activation, Delayed deformations, Carbonation, Chloride diffusion, Corrosion, Experimentation, Civil Engineering

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

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

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Other tutor: Ass. Pr. 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 decarbonization. Indeed, this process consumes important amounts of energy and releases a significant amount of carbon dioxide. 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 is often adopted for structures subjected to slightly aggressive or extreme environmental conditions.

The proposed research work focuses on the behavior of materials with 100% mineral additions, the alkali-activated materials. More specifically, the main objective of the PhD consists in studying and understanding, by means of an important experimental campaign, the durability of alkali-activated materials under aggressive environmental conditions. These materials combine generally an alkali metal source with a solid silicate powder. Two types of silica powder will be investigated: Blast-Furnace Slag (BFS) and Fly Ash (FA), activated by chemical activators, alkali sources including alkali hydroxides, silicates, carbonates, sulfates, aluminates or oxides.

The experimental campaign will first focus on the activation process of BFS and FA to design mono- and bi-additions mixtures. Very few data are available in the literature for sulfate and potassium activations. To assess the activation system efficacy, several parameters will be studied: hydration/polymerization kinetics by means of calorimetry, nature of the new products and content of anhydrous compounds by means of SEM observations, XRD analysis and selective dissolution methods, and mechanical properties (strength, Young modulus).

Secondly, the experimental campaign will focus on the corrosion risk of alkali activated materials, one of the predominant pathologies of reinforced concrete. Corrosion causes disorders in concrete structures leading sometimes to partial structure failure, and has a

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significant cost for the contracting authority. The key role of concrete coating is to ensure a sufficient cover depth and alkalinity to hold the steel in passive state. The loss of passivation usually takes place due to the penetration of aggressive species such as chloride, and/or the loss of alkalinity by processes such as carbonation.

No standards are available today to assess the chloride penetration and carbonation of alkali activated materials. The application of traditional methods to investigate these pathologies is difficult and requires caution, especially the interpretation of the results. A novel methodology has thus to be developed to determine the chloride penetration and carbonation resistance of alkali activated materials. As the kinetics of these pathologies is slow, accelerating it is necessary to obtain results in acceptable time limits. For the chloride penetration, two ways will be investigated: chloride spray and migration tests under electric field. The pore structure and the pore solution will be experimentally characterized and the interaction between chloride and paste products will be analyzed using SEM and XRD. These analyses will allow checking if chemical binding of chlorides is available into alkali-activated materials, and the formation of crystalline chloride compounds. Concerning carbonation, tests will be performed in a climatic chamber to pilot relative humidity, temperature and CO_2 concentrations. During these tests, we will focus on three points: products stability in environment rich in CO_2, effect of activation process on carbonation, and the influence of the storing conditions (RH, Temperature) during the accelerated tests on the alkali activated materials performances and cracking risk. Finally, the corrosion initialization process will be monitored on reinforced concrete specimens under aggressive environmental conditions (CO_2, Cl^-) using the impedance spectrometry technic. The proposed experimental campaign will provide innovative information on the corrosion risk of alkali activated materials, on their resistance to the penetration of aggressive agents, as well as on the conditions needed to initialize corrosion (chloride concentration e.g.).

Required Skills : Experience in Civil Engineering, a strong taste for laboratory experimentation, material science.

References :

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