Coupled hygrothermal, electrochemical, and mechanical modelling for deterioration prediction in reinforced cementitious materials

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ABSTRACT

Deterioration of the civil infrastructure (bridges, tunnels, roads, and buildings) together with increasing functional requirements (*e.g.* traffic load and intensity) present major challenges to society in most developed countries. A major part of the infrastructure is built from concrete and costs for maintenance, renovation, and renewing are growing and by now taking up a major part of concrete structure investments. While engineering tools and methods are well developed for the structural design of new structures, tools for assessing current and predicting the future condition of reinforced concrete structures are less advanced. Existing prediction tools are largely empirical, and thus limited in their ability to predict the performance of new material, structural, or maintenance solutions. As such, the inability to reliably assess the long-term future ramifications of today's design decisions poses a major obstacle for the design of reinforced concrete structures. A primary reason for the lack of reliable modelling tools is that deterioration mechanisms are highly complex, involve numerous coupled physical phenomena that must be evaluated across a range of scales, and often cut across several academic disciplines and faculties.

In this paper a coupled hygrothermal, electrochemical, and mechanical modelling approach for the deterioration prediction in cementitious materials is briefly outlined. Deterioration prediction is thereby based on coupled modelling of (*i*) chemical processes including among others transport of heat and matter as well as phase assemblage on the nano and micro scale [1], (*ii*) corrosion of steel including electrochemical processes at the reinforcement surface [2], and (*iii*) material performance including corrosion- and load-induced damages on the meso and macro scale [3]. The individual FEM models are fully coupled, *i.e.* information, such as such as corrosion current density, damage state of concrete cover, *etc.*, are constantly exchanged between the models. To demonstrate the potential use of the developed model, a numerical example is presented, that illustrates chemical processes, the formation of corrosion cells as well as propagation of corrosion, and corrosion-induced damage in a reinforced concrete structure.

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