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MULTISCALE EVALUATION OF CONCRETE DEGRADATION DUE TO ALKALI SILICA REACTION

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The paper addresses environmental degradation mechanisms in concrete materials with focus on alkali silica reaction (ASR). In this study, concrete will be considered as a highly heterogeneous three-phase material that distinguishes among the roles of cement paste, aggregates of different size and the interfacial transition zone (ITZ), a thin layer of matrix material bonding the two constituents.

ASR, first observed by Stanton in 1940 [1], is a deleterious chemical reaction that occurs between reactive forms of silica in the aggregates and alkali and hydroxyl ions in the aqueous pore solution. This produces an amorphous gel, which expands in presence of water and creates an increasing internal pressure resulting into formation of microcracks, and consequently in a drastic reduction of the mechanical properties of the concrete composite.

Even though the ASR reaction process is complicated and consists of several stages, it may be simplified into two-stages: In the first stage, the silica is dissolved from the aggregates forming an amorphous gel and precipitates; In the second stage the gel expands due to absorption of free water. With regard to this chemical process, environmental effects such as temperature and relative humidity play a critical role. In fact, the role of water is fundamental because a certain level of internal humidity is required for dissolution, reaction, and formation of the amorphous gel and precipitates. The gel expansion is governed by water imbibition, and the pore water is necessary for persistent progress of the reaction [2], [3]. Moreover ASR mechanisms are thermo-activated; that is, the higher the temperature, the faster is the chemical reactions. This kinetic effect of temperature on ASR results from the thermo-activation of the dissolution of reactive silica at the aggregate-cement interface and the reaction product formation [4].

In the present work the short and long-term performance of spent nuclear fuel storage casks subjected to different degradation mechanisms will be investigated due to mechanical, thermal, hygral and chemical alkali-aggregate reactions. To this end, meso-scale predictions of ASR effects are obtained through the use of a coupled thermo-hygro-mechanical finite element code [5], that will be used to determine the degradation of the mechanical strength values in compression, tension and shear after 1yr, 20, 40 and 60 and 300 years of creep and shrinkage and ASR exposure. Subsequently the reduced strength and ductility values will be used to characterize the environmental aging effects of the concrete properties for the macro-scale prediction of the short- and long-term performance of dry storage casks based on a novel coupled Damage-Plasticity Model.

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