Multiscale Investigation of Concrete Deterioration Due to the Effect of Nuclear Radiation and Alkali-Silica Reaction

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ABSTRACT

Concrete is frequently adopted in the nuclear filed as a shielding material. Therefore it results exposed to nuclear radiations, such as neutrons and gamma rays, that can influence its structural and mechanical properties significantly [1], [2]. It has been also found that irradiation can induce and accelerate the alkali-silica reaction (ASR) of the aggregates. Moreover, small cracks generated in aggregates by the irradiation may accelerate the alkali-silica reaction [3]. Therefore for nuclear facilities suffering of structural aging, or for underground nuclear waste repositories that can be more easily exposed to wet environments, this phenomenon is worth being addressed.

ASR is one of the most important causes of deterioration in concrete structures. This deleterious chemical reaction can produce expansive stresses and so generate microcracks in concrete materials.

Originally observed by Stanton in 1940, this reaction occurs between reactive forms of silica in the aggregates, alkali and hydroxyl ions in the pore solution. Therefore, the role of the water is fundamental because a certain internal humidity is necessary for gel formation, its expansion and for the reaction to continue [4]. Moreover, ASR mechanisms are thermo-activated; that is, the higher the temperature, the faster the chemical reactions proceed [5].

In this work concrete deterioration due to the effect of nuclear radiation and alkali-silica reaction is investigated. Concrete is considered as a heterogeneous material in which cement paste, aggregates of different size and a thin layer of matrix material between these two components called interfacial transition zone (ITZ) coexist.

A F. E. fully coupled hygro-thermo-mechanical 3D research code [2] has been adopted to study the effects of nuclear radiation and alkali-silica reaction in cementitious materials. This code has been used in conjunction with a Monte Carlo code developed by CERN and the National Institute of Nuclear Physics (INFN) of Milan, Fluka [6], useful to describe the radiation field (neutron fluence and deposited energy) which in turn influences the mechanical field.

REFERENCES

[1] H.K. Hilsdorf, J. Kropp and H.J. Koch, "The effects of nuclear radiation on the mechanical properties of concrete", in: *Douglas McHenry International Symposium on Concrete and Concrete Structures. ACI SP 55-10,* Detroit, Michigan, pp. 223–251, (1978).

[2] V.A. Salomoni, C.E. Majorana, B. Pomaro, G. Xotta and F. Gramegna, "Macroscale and mesoscale analysis of concrete as a multiphase material for biological shields against nuclear radiation", *Int. J. Numer. Anal. Meth. Geomech.*, 38, pp.518-535, (2014).

[3] T. Ichikawa and T. Kimura, "Effect of Nuclear Radiation on Alkali-Silica Reaction of Concrete", *Journal of Nuclear Science and Technology,* 44(10), pp. 1281–1284, (2007).

[4] A. Steffens, K. Li and O. Coussy, "Ageing approach to water effect on alkali-silica reaction. Degradation of Structures", *Journal of Engineering Mechanics,* 129, pp. 50-59, (2003).

[5] F.J. Ulm, O. Coussy, L. Kefei, and C. Larive, "Thermo-chemo-mechanics of ASR expansion in concrete structures", *Journal of Engineering Mechanics,* 126, pp. 233-242, (2000).

[6] A. Fassò, A. Ferrari, J. Ranft, P.R. Sala, "FLUKA: a multi-particle transport code. CERN-2005-10, INFN/TC_05/11,SLAC-R-773", 2005.