Modelling radiation-induced volumetric expansion in concrete

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ABSTRACT

Nowadays identifying the conditions that lead to concrete deterioration is the object of a new worldwide attention in the field of nuclear plants. The radiation damage process seems to be not well understood yet, as well as a unified approach to the practical and predictive assessment of irradiated concrete, which combines both physics and structural mechanics issues, appears to be missing. The comprehension of radiation effects on concrete was largely based on Hilsdorf and coauthors' curves compiled in 1978 [1] up to a few years ago. Recently, Field et al. [2] expanded this data collection to later experimental campaigns on neutron-irradiated concrete and mortars. Many authors [3,4] agree on the main role of aggregates in the development of neutron irradiation-induced swelling, also addressed in recent literature as radiation-induced volumetric expansion (RIVE), recently confirmed by Maruyama et al. [5]. On the other hand, the cement paste undergoes shrinkage due to (i) the radiolysis process under gamma radiation and (ii) the evaporation of pore water under radiation heat. Hence the mismatch in the volumetric change of concrete components (aggregates expansion and mortar shrinkage) may cause damage at the interface between the two phases. RIVE particularly involves siliceous aggregates. Eventually, the conversion of crystalline quartz into distorted quartz has a twofold consequence: (i) microcracking due to a differential volume change within the composite and (ii) higher reactivity to certain aggressive chemicals, e.g. calcium hydroxide responsible of alkali-silica reactions (ASR) in concrete [6].

In this work a coupled thermo-hydro-mechanical research code has been used and upgraded to model radiation damage and RIVE phenomenon on irradiated concrete by specifically taking into account the radiation field, and a validation is proposed based on the experiments reported in [3].

REFERENCES

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

[2] K. G. Field, I. Remec, and Y. Le Pape, "Radiation effects in concrete for nuclear power plants—part I: quantification of radiation exposure and radiation effects," *Nuclear Engineering and Design*, vol. 282, pp. 126–143, (2015).

[3] B. Kelly, J. Brocklehurst, D. Mottershead, and S. McNearney, "The effects of reactor radiation on concrete," in Proceedings of the 2nd Information Meeting on Prestressed Concrete and Reactor Pressure Vessels and Their Thermal Isolation, EUR-4531, pp. 237–265, Commission des Communautés Européennes, Brussels, Belgium, (1969).

[4] M. F. Elleuch, F. Dubois, and J. Rappeneau, "Effects of neutron radiation on special concretes and their components," in ACI Special Publication SP-34: Concrete for Nuclear Reactors, Paper SP34-51, pp. 1071–1108, (1972).

[5] I. Maruyama, O. Kontani, S. Sawada, O. Sato, G. Igarashi, and M. Takizawa, "Evaluation of irradiation effects on concrete structure-background and preparation of neutron irradiation test," in Proceedings of the ASME Power Conference (POWER '13), no. 98114, p. 9, Boston, (2013).

[6] T. Ichikawa and T. Kimura, "Effect of nuclear radiation on alkali-silica reaction of concrete", *Journal of Nuclear Science and Technology*, vol. 44(10), pp. 1281–1284, (2007).