RESEARCH NOTES

Results: Influence of radiation on concrete expansion, dissolution, and leaching behavior

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Confidentiality: Public

1. Introduction and background

The FiR 1 research reactor, located in Espoo, Finland, ceased operation in 2015. This has prompted several studies related to its decommissioning. The focus of the current such study is to evaluate the leaching of radionuclides from concrete, as may occur during disposal of decommissioning waste, or in concrete altered by radiation in-situ when used as a containment barrier for high level waste. The resistance of concrete to such leaching has been a subject of recent research interest, but more detailed evaluation of radionuclide retention in the cement-based matrix of concrete remains necessary to evaluate instances where the dissolution is the limiting factor for contaminant release (relative to transport). Based on the findings of a literature review from a previous stage of the KYT project, VTT's Structural Materials team has analyzed a series of ongoing experiments to elucidate the extent of leaching for the FiR 1 concrete in order to provide a foundation for future work on active concrete. Interestingly, no leaching of active isotopes was measured (i.e., below detection limit). Similarities in calcium dissolution suggest limited structural changes in the cement hydration product phases due to radiation. Outcomes provide an improved basis for updating the leaching models prevalent in the literature, as well as for interpreting results of monitoring in waste repository structures.

2. Preliminary results and discussion

Concrete cores used in the project were extracted from the lower section of the shield concrete by wet drilling, with the lengths of each core segment shown for reference in Figure 1(a). For illustrative purposes, an approximation of the simulated radiation dose along the length of each core (cumulative over its 55-year service life)[2] is shown in Figure 1(b).

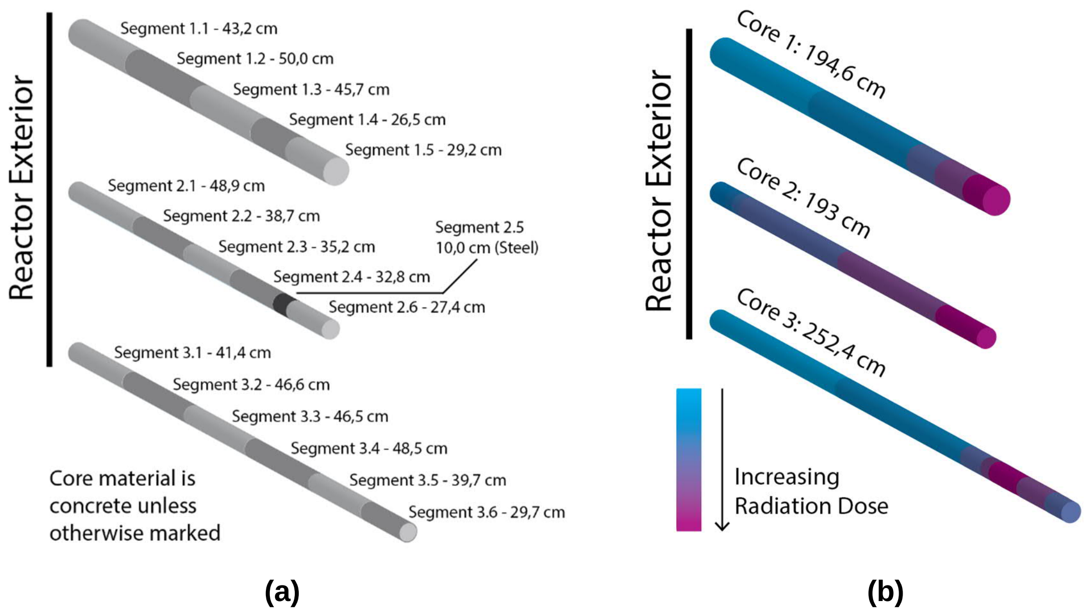

Figure 1: (a) Dimensions of the segments from each of the three concrete cores extracted from the FiR 1 research reactor shield, and **(b)** simulated radiation dose along each core.

Segments of core 3 were subdivided into 1:1 aspect ratio portions, and held at 38°C RH = 100% for residual expansion testing. Ongoing non-destructive testing was also carried out using ultrasonic pulse transducers, wherein pulse velocity was expected to relate loosely to mechanical damage, i.e., due to slower propagation of sound waves by increasingly indirect paths when traveling around cracks, air voids, etc. A similar procedure was used to that developed earlier during the project (36 unique pulse propagation paths), and the general trend of pulse velocity being slightly lower at the exterior and interior edges of the concrete was maintained throughout the duration of the current experiment (illustrated in Figure 2 (a) for the segments of core 1). Axial expansion was measured between fixed reference disks placed in pairs at increments of 120° around the circumference of each segment. Expansion was fairly uniform across exterior segments, and stabilized after several weeks of measurement (currently at 40 weeks, with no additional expansion). The innermost segment initially expanded, but then again appeared to contract, possibly due to an easier relaxation of internal stress due to radiation damage (Figure 2 (b)). The hypothesized greater expansion of inner segments due to increased alkali reactivity of the siliceous aggregates was not yet evidenced, which tentatively suggests that the impact of radiation at the low doses to which this concrete was exposed primarily has a small effect during exposure, but not an ongoing one after. This is commensurate with the limited degree of amorphization and alkali-silica reaction (ASR) observed during previous SEM measurements. Selected samples were also analyzed for air and capillary porosity before the start of measurements, with no appreciable difference observed between different positions along the core. Generally speaking, this supports the idea that the FiR1 reactor's shield concrete does not undergo substantially more deterioration due to its past exposure to radiation; however ongoing damage over time in long-term disposal scenarios, with continued long-term gamma radiation, remains a distinct possibility.

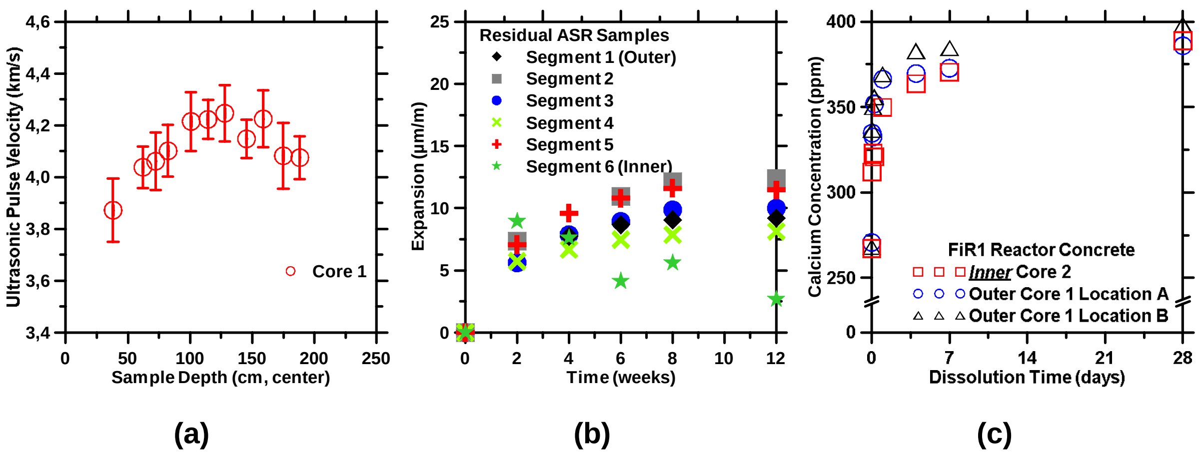

Figure 2: (a) Ultrasonic pulse velocity test results as a function of depth from the exterior of the concrete for core 1 (representative), **(b)** residual expansion data for segments of core 3 (numbered 1-6 from the surface to the interior), and **(c)** calcium concentration during dissolution experiments, for powders collected from the outer portions of core 1 and 3, compared with the inner portion of core 2 (e.g., lowest and highest radiation dose).

Dissolution experiments, conducted using suspended powders in simulated groundwater (305,4 Na; 92,22 ppm Mg; 9,17 ppm K; 267,12 ppm Ca) at 25°C collected from the outer portions of core 1 and 3, and the inner portion of core 2, were conducted over the course of one month. Analogous leaching experiments are also ongoing. Preliminary results from the accelerated dissolution tests also support that the cement phases are not made inherently more reactive as a result of past radiation exposure, with negligible difference between the most and least irradiated samples (similar to observations from expansion and ultrasound testing for the aggregate phases). Additionally, no active isotopes were detected in any accelerated dissolution solution from the irradiated powder (inner core 2), indicating the likely safety of long-term disposal of this material with respect to radionuclide release.