Nonlinear Ultrasonic Diagnosis and Prognosis of ASR Damage in Dry Cask Storage

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ABSTRACT

The alkali-silica reaction (ASR) is a deleterious chemical process that may occur in cement-based materials such as mortars and concretes, where the hydroxyl ions in the highly alkaline pore solution attack the siloxane groups in the siliceous minerals in the aggregates. The reaction produces a crosslinked alkali-silica gel. The ASR gel swells in the presence of water. Expansion of the gel results in cracking when the swelling-induced stress exceeds the fracture toughness of the concrete. As the ASR continues, cracks may grow and eventually coalesce, which results in reduced service life and a decrease safety of concrete structures.

Since concrete is widely used as a critical structural component in dry cask storage of used nuclear fuels, ASR damage poses a significant threat to the sustainability of long term dry cask storage systems. Therefore, techniques for effectively detecting, managing and mitigating ASR damage are needed. Currently, there are no nondestructive methods to accurately detect ASR damage in existing concrete structures. The only current way of accurately assessing ASR damage is to drill a core from an existing structure, and conduct microscopy on this drilled cylindrical core. Clearly, such a practice is not applicable to dry cask storage systems. To meet these needs, this research is aimed at developing (1) a suite of nonlinear ultrasonic quantitative nondestructive evaluation (QNDE) techniques to characterize ASR damage, and (2) a physics-based model for ASR damage evolution using the QNDE data. Outcomes of this research will provide a nondestructive diagnostic tool to evaluate the extent of the ASR damage, and a prognostic tool to estimate the future reliability and safety of the concrete structures in dry cask storage systems.