Quantitative Diagnosis and Prognosis Framework for Concrete Degradation Due to Alkali-Silica Reaction

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This research is seeking to develop a probabilistic framework for health diagnosis and prognosis of aging concrete structures in nuclear power plants that are subjected to physical, chemical, environment, and mechanical degradation. The proposed framework consists of four elements: monitoring, data analytics, uncertainty quantification, and prognosis. The current work focuses on degradation caused by ASR (alkali-silica reaction). Controlled concrete specimens with reactive aggregate are prepared to develop accelerated ASR degradation. Different monitoring techniques — infrared thermography [1], digital image correlation (DIC), mechanical deformation measurements, nonlinear impact resonance acoustic spectroscopy [2] (NIRAS), and vibro-acoustic modulation [3] (VAM) — are studied for ASR diagnosis of the specimens. Both DIC and mechanical measurements record the specimen deformation caused by ASR gel expansion. Thermography is used to compare the thermal response of pristine and damaged concrete specimens and generate a 2-D map of the damage (i.e., ASR gel and cracked area), thus facilitating localization and quantification of damage. NIRAS and VAM are two separate vibration-based techniques that detect nonlinear changes in dynamic properties caused by the damage. The diagnosis results from multiple techniques are then fused using a Bayesian network, which also helps to quantify the uncertainty in the diagnosis. Prognosis of ASR degradation is then performed based on the current state of degradation obtained from diagnosis, by using a coupled thermo-hydro-mechanical-chemical (THMC) model [4] for ASR degradation. This comprehensive approach of monitoring, data analytics, and uncertainty-quantified diagnosis and prognosis will facilitate the development of a quantitative, risk-informed framework that will support continuous assessment and risk management of structural health and performance.

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References: