



**U.S. Department of Energy**

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## **Concrete Materials with Ultra-High Damage Resistance and Self-Sensing Capacity For Extended Nuclear Fuel Storage Systems**

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### **ABSTRACT**

The long-term durability and safety of the concrete structures for spent fuel pools and dry casks are key factors for extended storage of spent nuclear fuel (SNF). Two major issues must be addressed: First, concrete is an inherently brittle material, and is susceptible to cracking, deterioration and fracture under combined thermo-chemo-hydro-mechanical effects as well as extreme hazard events. Second, current structural health monitoring (SHM) approaches rely on visual inspection or discrete sensors that cannot reliably identify spatially distributed damage such as cracking and corrosion.

To address these challenges, the proposed research combines nano-, micro- and composite technologies, computational mechanics and SHM methods to develop and model a new class of multifunctional concrete materials, which possess intrinsic damage tolerance and self-sensing capacity for extended SNF storage systems. The novelty of multifunctional concrete materials is two-fold: *First*, it serves as a major material component for the SNF pool, dry cask shielding and foundation pad with greatly improved resistance to cracking, reinforcement corrosion, and other common deterioration mechanisms under service conditions, and prevention from fracture failure under extreme events (e.g., impact and earthquake). This will be achieved by designing multiple levels of protection mechanisms into the material (i.e., ultra-high ductility that provides thousands of times greater fracture energy than concrete and normal fiber reinforced concrete (FRC); intrinsic cracking control, electrochemical properties modification, reduced chemical and radionuclide transport properties, and crack-healing properties). *Second*, it offers capacity for distributed and direct sensing of cracking, strain, and corrosion wherever the material is located. This will be achieved by establishing the changes in electrical properties due to mechanical and electrochemical stimulus.

The proposed effort is delineated into four interconnected thrusts: (1) self-sensing strain hardening material development based on micromechanics and nanotechnologies, (2) Durability characterization under individual and combined thermo-chemo-hydro-mechanical effects, (3) Fully coupled mathematical modeling and robust computational framework development, and (4) Service life prediction and life-cycle assessment. The proposed research scope and research team of five members with diverse technical backgrounds have a single goal in mind – seamless integration in the material development and characterization, coupled deterioration processes modeling, durability and radiation testing, and life cycle assessment – to realize a new class of multifunctional concrete materials for very long-term (greater than 120 years) nuclear fuel storage systems.