Development of a Nano-modified Concrete for Next Generation of Storage Systems

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ABSTRACT:

This project addresses the NE research needs in the development of a superior concrete for extended storage of used nuclear fuel.

Current challenges in extending the safe storage period of used nuclear fuel to potentially a century or longer include the development of structural materials that can withstand severe conditions for extended periods of time and retain their functionality to maintain the integrity of the fuel containment. This requires extending the service life and performance of concrete under radiation and high temperatures/gradients in addition to environmental weathering and shock loading conditions. Nanomodification of concrete through the incorporation of nano-sized particles has shown to enhance the overall performance of concrete, with higher compressive and flexural strengths, improved hydration and internal curing characteristics, early cracking resistance, and higher durability compared to conventional concrete as a result of the high reactivity of the nano-particles.

The goal of this research is to develop a superior concrete for the long-term storage of used nuclear fuel by engineering concrete at the nanoscale through the incorporation of nano-sized and nano-structured particles based on enhanced reactivity (not fiber reinforcement). The proposed project will focus on nano-silica, nano-calcium carbonate, nano-iron, nano-alumina, and nanoclay in concrete. State-of-the-art experimental chemical and mechanical characterizations across multiple length scales (nano to macro) and computational analysis will be integrated to elucidate key aspects of the performance of nano-modified concretes and their sensitivities to environmental weathering, radiation and thermal influences and the subsequent effect on the material mechanical performance. Optimum nano-particle content and combinations that demonstrate maximum synergy for superior mechanical properties and durability of concrete under relevant environments found in used nuclear fuel storage will be identified.

This project will advance a key component of nuclear waste storage systems through the inclusion of nano-engineered concrete additives to enhance the stability and longevity of nuclear waste dry storage casks. The outcomes from this project are expected to impact material effectiveness in storage applications over extended periods of time in severe radiation, thermal, and environmental conditions and to advance the state of knowledge and understanding in the field of nuclear waste storage.

The research team brings a unique combination of expertise in multiscale experimental characterization, durability testing, nanotechnology in concrete, and coupled complex multi-phenomena of degradation processes and damage modeling at different time and length scales that is needed to develop a superior, high strength, temperature and radiation resistant concrete with improved weatherability for the long-term storage of used nuclear fuel.