Multiscale and Multiphysical Testing-Modeling of Inorganic Microfiber-Reinforced Engineered Barrier Materials (IMEBM) for Enhancing Repository Performance

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Program: Spent Fuel and Waste Disposition: FC-4.1 Disposal

ABSTRACT:

This project seeks to develop inorganic microfiber-reinforced engineered barrier materials (IMEBM) that are less permeable and more resistant to desiccation, cracking, and chemical degradation over a long period of time in the challenging geological environment of high-level radioactive waste repositories. Our ***central hypothesis*** is that inorganic microfiber-reinforced bentonite can vastly reduce shrinkage cracks by generating frictional and tensile resistance within IMEBMs and control the saturation process better by increasing the affinity of water to bentonite through fiber filaments over a long period of time. To test this hypothesis, this project will pursue the following **research objectives**: (1) Develop and conduct an experimental program to identify the fundamental thermo-, hydro-, chemical, mechanical and geometrical characteristics of IMEBM constituents (bentonite and fibers) and their interaction in multiple length scales (nm to cm) with the geological environment of the repository, (2) Develop and run multiscale-multiphysics computational models to simulate the laboratory testing program, and (3) Integrate the experimentation with computational modeling to validate-calibrate the model and to propose an optimal set of variables for designing an improved engineered barrier material. This validated-calibrated model and the integrated database of the improved performance of IMEBM will be our ultimate ***deliverable***. They will serve as an invaluable tool for determining the individual design parameter of IMEBMs, leading to the development of more optimized IMEBMs that will out-perform the current bentonite-only practice substantially. Thus, upon the conclusion of this project, we will be able to identify core variables and propose applicable IMEBMs for practical application over a long period of time.

This research will fill a critical knowledge gap on the limited capability of traditional engineered barrier systems in three main aspects: desiccation cracking, permeability, and long-term durability. The resulting novel IMEBM will serve to significantly alleviate the concern of cracking and consequently guarantee greater confidence for the permanent isolation of used nuclear fuel. Our research outcomes will lead to viable design strategies and technologies for the safe and long-term disposal of spent nuclear fuel and enable sustainable fuel cycles. The fundamental understanding and resulting IMEBM will improve nuclear waste management and support the enhanced safety and security of nuclear-generated electricity in the United States.