Contract No. and Disclaimer:

New Materials Developed To Meet Regulatory And Technical Requirements Associated With In-situ Decommissioning Of Nuclear Reactors And Associated Facilities

John K. Blankenship, Christine A. Langton, John C. Musall, and William B. Griffin

Savannah River Nuclear Solutions, Aiken, SC, john.blankenship@srs.gov
Savannah River National Laboratory (SRNL), Savannah River Nuclear Solutions, Aiken, SC, christine.langton@srnl.doe.gov
Savannah River Nuclear Solutions, Aiken, SC, john.musall@srs.gov
Savannah River Nuclear Solutions, Aiken, SC, william.griffin@srs.gov

INTRODUCTION

For the 2010 ANS Embedded Topical Meeting on Decommissioning, Decontamination and Reutilization and Technology, Savannah River National Laboratory's Mike Serrato reported initial information on the newly developed specialty grout materials necessary to satisfy all requirements associated with in-situ decommissioning of P-Reactor and R-Reactor at the U.S. Department of Energy's Savannah River Site. Since that report, both projects have been successfully completed and extensive test data on both fresh properties and cured properties has been gathered and analyzed for a total of almost 191,150 m^3 (250,000 yd^3) of new materials placed. The focus of this paper is to describe the 1) special grout mix for filling the P-Reactor vessel (RV) and 2) the new flowable structural fill materials used to fill the below grade portions of the facilities. With a wealth of data now in hand, this paper also captures the test results and reports on the performance of these new materials.

Both reactors were constructed and entered service in the early 1950s, producing weapons grade materials for the nation's defense nuclear program. R-Reactor was shut down in 1964 and the P-Reactor in 1991. In-situ decommissioning (ISD) was selected for both facilities and performed as Comprehensive Environmental Response, Compensations and Liability Act actions (an early action for P-Reactor and a removal action for R-Reactor), beginning in October 2009. The U.S. Department of Energy concept for ISD is to physically stabilize and isolate intact, structurally robust facilities that are no longer needed for their original purpose of producing (reactor facilities), processing (isotope separation facilities), or storing radioactive materials. Funding for accelerated decommissioning was provided under the American Recovery and Reinvestment Act. Decommissioning of both facilities was completed in September 2011. ISD objectives for these CERCLA actions included:

- Prevent industrial worker exposure to radioactive or hazardous contamination exceeding Principal Threat Source Material levels;
- Minimize human and ecological exposure to unacceptable risk associated with radiological and hazardous constituents that are or may be present;
- Prevent to the extent practicable the migration of radioactive or hazardous contaminants from the closed facility to the groundwater so that concentrations in groundwater do not exceed regulatory standards;
- Eliminate or control all routes of human exposure to radiological and chemical contamination; and
- Prevent animal intruder exposure to radioactive and hazardous contamination.

WORK DESCRIPTION

Approach

A systems engineering approach was used to identify functions and technical requirements of the fill materials. Laboratory testing was performed to identify candidate formulations and develop final mix designs.

General technical requirements determined to be applicable to all materials were:

- Compressive strength $\geq$ 0.34 MPa (50 psi);
- Hydraulic conductivity $\leq 10^{-5}$;
- Flowable and self-leveling; and have
- Zero bleed water.

Scale-up testing was accomplished to verify/improve upon material production and placement, as well as fresh and cured properties.

P-Reactor Vessel Fill – Calcium Sulfo-aluminate

The need for material compatibility between the grout and reactor materials imposed additional requirements. Both the P- and R-RVs contain aluminum components, which were left in place as part of the ISD closure. After estimating the amount of aluminum metal abandoned in each RV, calculations were performed to estimate the potential for exceeding 60% of the Lower Flammability Limit (LFL) as a result of hydrogen generation from corrosion of the aluminum in a caustic medium (e.g., portland cement-based grout with its pH of approximately 12.5). Results indicated the limited amount of aluminum remaining in the R-RV did not pose an LFL issue if a portland cement-based material was used to fill the vessel. However, the calculation for portland cement fill for the P-RV, which contains significantly more aluminum metal, exceeded the 60% LFL, thereby dictating development of a new near-neutral (≤ 10.5) pH fill material. Based on estimates of the amount and rate of H_2 generated as a result of corrosion of the aluminum components abandoned in place in the P-RV, a new flowable calcium sulfo-aluminate grout with integral crystalline waterproofing was designed and tested by SRNL to meet the unique material and placement requirements associated with the P-RV. A cutaway of the P-RV is shown in Figure 1.

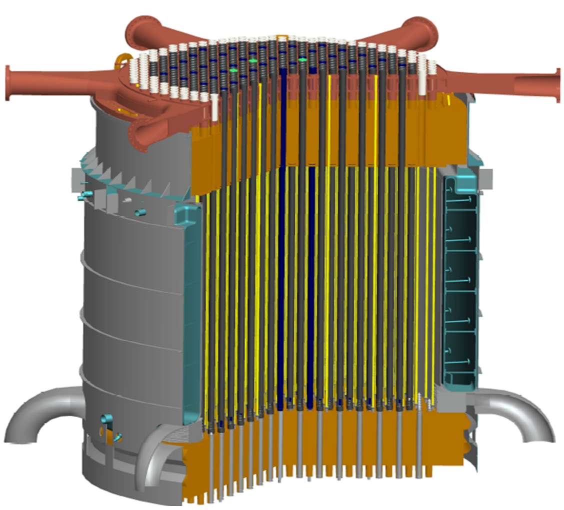

Figure 1 – Cutaway of the P-Reactor Vessel

A total of 90.2 m^3 (118 yd^3) of calcium sulfo-aluminate grout was used to fill the P-RV. The material met all requirements. Tests showed the average compressive strength at 7 days to be 6.85 MPa (994 psi) and 7.52 MPa (1090 psi) at 28 days.

Flowable Structural Fill Materials

Three grout mixes (i.e., special hybrid grouts) were developed for filling the massive below-grade voids/rooms of the P- and R-Reactor facilities. Two of the materials developed were actually used. These grouts utilize zero bleed, flowable structural fill technology developed at SRNL. Each is based on a portland cement - Class F fly ash binder and were specified for bulk filling, dry placements and underwater placements. With the exception of the near-neutral pH, requirements associated with these materials were essentially identical to those for the calcium sulfo-aluminate material used in the P-RV. The underwater mix was utilized primarily to grout the reactors' Disassembly Basins, displacing shield water upward until adequate grout was in place for shielding, after which remaining water was mechanically evaporated and grouting completed using the dry area grout formulation. The dry area formulation was also utilized for grouting of the large below grade void spaces/rooms at each reactor and grouting of the R-RV.

The material met all requirements. Overall average 7 day compressive strength for the dry area mix was 1.54 MPa (223 psi) and for the underwater mix 2.94 MPa (427 psi). Overall 28 day compressive strength for the dry area mix was 2.88 MPa (417 psi) and for the underwater mix 4.99 MPa (724 psi). A limited amount of testing was performed at 91 days, where the overall compressive strength for the dry area mix was found to be 9.40 MPa (1363 psi) and for the underwater mix 13.98 MPa (2028 psi). All compressive strength values far exceeded the 0.34 MPa (50 psi) minimum requirement.

RESULTS

The special flowable fill grouts designed for P- and R-Reactor ISD resulted in considerable labor, cost, and schedule savings versus conventional materials. The CO_2 footprints of the SRS P- and R-Reactor facilities ISD were minimized by using a small amount of cement and byproduct material to produce structural fill materials.