

Combined Quick Look and Final International Trip Report

Travel Dates: March 29, 2009 to April 3, 2009

Location: Cadarache, France

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Organization/Committee: Meeting of NUCPERF 2009, Long-term Performance of Cementitious Materials and Reinforced Concrete in Nuclear Power Plants and Waste Management Facilities. Organized by the French Atomic Energy Agency (CEA) and the Belgium Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS).

Sensitivity: Not Applicable

Desired Outcome: Participation in the workshop provided the NRC with an opportunity to exchange state-of-the-art information with worldwide experts on the long-term performance and service life of concrete structures as they apply to newer nuclear facilities and waste disposal facilities. The subjects addressed in the workshop covered technical issues important to understand the complexities of concrete performance, from laboratory testing to modeling of concrete behavior to monitoring and decommissioning. Many of these issues on materials behavior over the long term are currently under discussion within the NRC with respect to Waste Incidental to Reprocessing (WIR), newer nuclear power plants, decommissioning of reactors, low level waste (LLW) management and cement solidified waste.

Results Achieved: The travelers effectively interacted with experts from a variety of organizations on issues relevant to prediction of the long-term performance of cementitious materials. The travelers identified information sources from the workshop that will help NRC staff address issues relevant to assessing the performance of cementitious materials in nuclear applications. NRC staff participated in the workshop, in part, as a result of involvement in the collaborative Cement Barriers Partnership (CBP) and research at the National Institute of Standards and Technology (NIST) on cementitious materials performance. The CBP is a multi-agency effort to develop a state-of-the-art assessment tool to evaluate the long-term performance of cementitious materials. As a result of participation in the meeting, NRC staff has identified information sources and opportunities for collaboration with agencies outside the CBP. In addition, information presented at the workshop will be useful to incorporate into future revisions of staff guidance documents, such as NUREG-1854, the staff guidance document for review of Department of Energy waste determinations.

Discussions and Summary of Trip: David Esh (FSME) and Jacob Philip (RES) attended NUCPERF 2009 – Long-Term Performance of Cementitious Barriers and Reinforced Concrete in Nuclear Power Plants and Waste Management in Cadarache France from March 30 to April 2, 2009. The meeting was attended by experts representing over 40 organizations from 14 countries. The purpose of the meeting was to discuss the use of cementitious materials and reinforced concrete and its effectiveness and long-term performance in nuclear applications. The meeting was organized around six sessions: present and future expectations, coupled processes (thermo-hydro-chemical-mechanical), corrosion, modeling, test methods, and aging management. Many of these sessions presented information on materials behavior relevant to research and safety reviews being performed by NRC on Waste Incidental to Reprocessing (WIR), low level waste (LLW) management, and new nuclear power plants.

The opening session provided a keynote lecture by J. M. Torrenti of Laboratoire Central des Ponts et Chaussées. Dr. Torrenti provided an overview of concrete and nuclear energy research, with emphasis on applications in France. A key issue is prolonging the life of operating reactors as nuclear energy from 58 reactors at 19 sites provides roughly 80% of the electricity used in France. Areas of active research include: the mechanical behavior associated with autogenous and thermal shrinkage, prediction of cracks in massive concrete structures, measuring permeability before and after loadings, evaluating durability coupling with mechanics, measuring delayed ettringite formation and expansion effects, development of monitoring and nondestructive examination techniques, and evaluating variability in concrete properties at real sites in order to develop probabilistic assessment approaches.

Papers presented in the session on present and future expectations included two general overviews and four papers associated primarily with reinforcement corrosion. The first overview provided the progress in the cementation of radioactive wastes – activities of the International Atomic Energy Agency (IAEA) by Fred Glasser of the University of Aberdeen. The IAEA has set up a core project to investigate the behavior and performance of cementitious materials. It is intended to understand the processes that can result in the degradation of the physical and chemical characteristics of the materials. The activities involve 26 research organizations from 22 IAEA member countries. The needs of the member states are very different, resulting from the differences in maturity of their application of nuclear technologies. The presentation described the problems, approaches, and solutions being taken by IAEA member states. The second overview by A. Huerta provided the activities of the Organization for Economic Cooperation and Development/ Nuclear Energy Agency (OECD/NEA) in the fields of aging management of concrete structures. The OECA/NEA has developed a working group to advance the understanding of those aspects relevant to ensuring the integrity of structures, systems, and components using an integrated approach to design, safety, and plant life management. The presentation detailed recent activities and products of the working group, including a report titled “A Decade of CSNI Activities in the Area of Ageing of Nuclear Power Plant Concrete Structures.”

The four papers on reinforcement corrosion highlighted the emphasis of the international nuclear community on the importance of cementitious materials to provide structural integrity and hydraulic isolation. R. Francois of the Université Paul Sabatier de Toulouse (France) presented observations from a long-term monitoring program in existence since 1984. The program evaluated the influence of cracks on reinforced concrete exposed to a salt fog under cyclic wet/dry conditions. Important observations included that some cracks experienced self-healing, and the traditional approach of using a diffusion model could not explain the observed chloride profiles. G. Duffo of the Comisión Nacional de Energía Atómica (Argentina) presented work to evaluate reinforced concrete structures. Of interest was the use of embedded sensors inside the walls

during construction and the observation that pre-welded rebar showed much higher corrosion potential than unwelded rebar. P. Zuloaga of ENRESA (Spain) presented a paper on the leaching of reinforced concrete vaults for the El Cabril LLW disposal facility. The leaching of calcium from the cement was evaluated with an experimental and numerical modeling program. Of particular interest was the generation of significant quantities of condensate within the disposal system, which was unanticipated. The original safety assessment for the facility expected about 600 L/year of water to enter each disposal vault from basic hydrologic (infiltration) processes. In some vaults, as much as 400 L/year of water has been collected as a result of capillary suction of moisture into the facility and temperature differences between the facility and its environment. Natural cycling of moisture and temperature causes significant movement of water compared to pure hydrologic processes. In addition, the facility observed a rather significant change (rise) in the local water table due to the impervious surfaces of the disposal facility blocking the evaporation of moisture to the environment. These observations highlight the challenges associated with assessing the performance of real disposal systems.

Parallel sessions on Corrosion and Coupled Processes were held in the afternoon of March 31. Seven papers were presented in the session on corrosion and eight papers were presented in the session on coupled processes. In the session on corrosion, Y. Berthaud of the Laboratoire de Mécanique et Technologie (France) presented the results of modeling that were able to simulate the observed cracking patterns around rebar in cement. In addition, his group used a digital visualization technology to see small deformations in concrete members before they were visible to the naked eye. In discussion with the author, the travelers learned the techniques would likely be applicable to waste disposal systems. In the session on coupled processes Ken Snyder of the National Institute of Standards and Technology presented a paper titled "Stable Hydrated Phases in Engineered Barriers Composed of Blended Cementitious Mixtures." The objective of the paper was to identify the hydration products of varying cementitious material compositions for use in eventual numerical simulation of future performance. David Esh and Jacob Philip were co-authors of this paper.

Parallel sessions on Modeling and Test Methods were held on the morning of April 1. Each session had eight papers. O. Kari of Helsinki University of Technology presented a paper on modeling the durability of concrete for nuclear waste disposal facilities, with emphasis on the Finnish radioactive waste disposal system which has a 500 year barrier requirement. This was one of the few papers focused on simulating multiple deterioration mechanisms, including interactions terms. The author stressed the need for model validation, and expected to do coupled process experiments in the future to validate the parameterization of the model. J. Arnold of Vanderbilt University (a member of the CBP), presented a paper on the impact of mineral deposition by carbonation and dissolution on tortuosity for leaching of constituents from a cementitious waste form. Mr. Arnold summarized relationships for relative tortuosity changes from the literature, which is a key information need long-term performance simulations. The relationships in the literature show a relatively large amount of uncertainty or variability, which has direct implications to material performance modeling. The session on test methods provided papers on a variety of techniques, including ultrasonic velocity measurements, electrical migration, and a restrained ring shrinkage test.

The final session of the meeting provided eight papers on aging management. Aging management is an extremely important issue to the extension of life for older nuclear facilities. K. Philipse of AECL (Canada) presented data on strain gauges that were installed over 35 years ago and are still functioning to assess the performance of CANDU containment buildings. C. Weiss of the US Army presented information on innovative reactive vitreous coatings for

potential use in nuclear power plant construction. The coatings are designed to protect the rebar from corrosion while at the same time provide a strong bond of the rebar to the concrete. The coatings are fused to the steel at 750 to 850 C and are designed to provide protection from deleterious agents. Since reinforcement corrosion is a key degradation mechanism for structural reinforced concrete, innovative solutions should be considered that may add considerable long-term performance benefits. S. Han of the Korean Ocean Research and Development Institute presented the results of numerous measurements of carbonation depths for coastal structures. He performed an analysis of carbonation based on a reliability concept, which could be more broadly applicable to designing and evaluating cement-based systems for nuclear applications.

A summary session of the meeting was held, with the co-chairs from each session presenting the key lessons and observations from their sessions.

Pending Actions/Planned Next Steps for NRC:

Technical information from the meeting will be incorporated into products developed as part of NRC participation in the Cement Barriers Partnership as well as relevant future guidance documents for WIR, LLW, and new power reactors.

Points for Commission Consideration or Items of Interest:

None

Policy Issues: There are no outstanding policy issues based on the information presented at the meeting.

Attachments:

Meeting agenda

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