

Research Related to Concrete Technology at USNRC



CSNI-NEA Working Group on Integrity and Aging of
Components and Structures-Concrete Subgroup Meeting
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Research/Recent Activities Related to Concrete Technology

- Experience with Concrete Modeling with LS-DYNA
- Research related to Transportation Casks
- State-of-the-art Reactor Consequence Analysis (SOAR-CA) Project
- Revision of Regulatory Guides
- High Temperature Effects on Concrete
- Research on Cementitious Materials
- NRC/DOE Workshop on U.S. Nuclear Power Plant Life Extension R&D, Life Beyond 60, February 2008
- Future Potential Research for Concrete in NPPs

Experience with Concrete Modeling with LS-DYNA

- NRC staff is currently involved in analysis of new and existing nuclear power concrete structures subjected to impact from large objects at different speeds.
- The analysis is being performed using LS-DYNA code
- The code has been benchmarked for these kinds of problems using the results of impact tests performed on concrete panels
- Winfrith Model (Material 84)
 - Input: density, E_c , f'_c , f_t , fracture energy, aggregate size
 - Only uses reduced integration solid elements (hourglassing)
 - Fairly robust for impact and blast analysis
 - Used successfully for drop analysis and aircraft impact

Research Related to Transportation Cask Drop Tests

- NRC is currently performing structural analysis of the CONSTOR spent nuclear fuel transportation cask
- The cask is manufactured in Germany and a full-scale model of the cask was tested to IAEA requirements
- A fully instrumented CONSTOR cask was dropped from a height of 30 feet and results of the test were recorded by German Federal Institute for Materials Research and Testing (BAM).
- The cask overpack is a sandwich panel with steel plates on the outside and in-filled with concrete

Research Related to Transportation Cask Drop Tests (cont.)

- NRC staff is performing confirmatory analysis of this cask drop test using LS-DYNA code
- Results of the analysis will be compared with test data to determine magnitude of uncertainty in the computer results
- NRC staff has plans to analyze full scale and scale models of Mitsubishi Heavy Industries (MHI) transportation casks. The results will be compared with drop test data to be provided by BAM
- This analysis will also determine the effect of scale in the finite element analysis

Research Related to Transportation Cask Impact Tests (cont.)

- NRC plans to perform computer simulation of a train locomotive impact on the CONSTOR and MHI transportation casks
- The staff will compare the response of the CONSTOR and MHI casks determined by computer simulation during a regulatory drop test and a realistic severe train accident scenario

State-of-the-art Reactor Consequence Analyses (SOAR-CA) Project

- Objective is to determine “loss of function” of selected containments in terms of “leak rate vs. pressure” using a simplified approach for beyond design internal pressures
- This approach is based on the lessons learned and data collected from the 20 years of analytical research and scale model tests sponsored by the NRC at Sandia National Laboratories
- The containment leakage rate at high internal pressures have been determined for representative PWR, BWR and Ice Condenser containments
- The containment performance so determined is currently used for severe accident analysis of nuclear power plants

Revision of USNRC Regulatory Guides

- NRC has revised several Regulatory Guides (RGs) in preparation for review of new reactor license applications
- RG 1.136 is for design limits, loading combinations, materials, construction, and testing of concrete containments
- Revision 3 of RG 1.136 endorses the ASME Section III, Div. 2, Code, 2001 with 2003 addenda

Revision of Regulatory Guides (cont.)

- The revised RG 1.136 includes requirements for:
 - Wedges and anchor nuts for protection of prestressing materials from low-temperature effects
 - Time-dependant loss of prestress levels in the containment tendons
 - Permanent corrosion protection systems in construction specifications
 - Another major topic included in the revision to RG 1.136 is:
 - New guidelines for the Ultimate Capacity of Concrete Containments

Revision of Regulatory Guides (cont.)

- A new RG on containment performance assessment is under preparation to provide guidance for use in analyzing and designing concrete containment to meet current design basis and beyond design basis loading events
- Another new RG on seismic margin assessment is under preparation to meet the safety goal for the nuclear power plant including concrete structures
- Update of RG 1.107:
 - Qualification of portland cement grout as the corrosion inhibitor for prestressing tendons in prestressed concrete containment structures
 - Endorses the ASME Section III, Div. 2, Code
 - Endorses ASTM standards for the specific grouted tendon program

High Temperature Effects on Concrete

- Assess literature and data on thermal loading of concrete
- Investigate effects of long-term thermal loadings at moderate temperature level
 - Physical and mechanical properties
 - Analytical methods for structural response
- Acceptance criteria for current and future condition assessments

Research on Cementitious Materials

- NRC will be working with DOE, NIST, Simco Technologies (Canada), ECN (Energy Research Centre of the Netherlands) and Vanderbilt University, on cementitious materials performance
- The objective is to help develop a reasonable and credible set of simulation tools to predict the coupled thermo-hydro-mechanical-chemical (THMC) performance of cementitious materials
- Research will focus on cementitious materials used at nuclear power plants (NPP) and nuclear waste facilities over extended time frames (e.g., up to 100 years for operating nuclear facilities and >1000 years for radioactive waste facilities)

NRC/DOE Workshop on Life Extension R&D, Life Beyond 60, Feb 2008

- Participants included NRC, utilities, consultants, and academia
- Sessions included:
 - Industry Perspective on Future Industry Needs for Continued Operation Beyond 60 Years
 - Long-Term Reliability of Systems, Structures, and Components
 - Management of Age-Related Materials Degradation Issues
 - Determination of New Technologies, Tools, and Applications for Diagnostics and Monitoring
 - Wrap-up Plenary Session

NRC/DOE Workshop on Life Extension R&D, Life Beyond 60, Feb 2008 (cont.)

- Presentations on Concrete included:
 - “Research needs for concrete structures beyond a 60-year lifetime” by Charles Hofmayer, Brookhaven National Laboratory
 - Concrete materials and structures – Aging and life beyond 40 years, 60 years, ...” by Dan Naus, Oak Ridge National Laboratory
- Conference proceedings available at:
<http://www.energetics.com/nrcdoefeb08/>

Future Potential Research For Concrete In NPPs

- Update design approach from prescriptive to performance-based concrete materials design
- Establish concrete performance criteria
- Develop standard tests and procedures to verify compliance with criteria
- Characterize cements and admixtures (e.g., Fly ash, slag, silica fume)
- Develop monitoring, maintenance and repair strategies
- Perform computational modeling of concrete degradation

Future Potential Research For Concrete In NPPs (cont.)

- Integration with Seismic Research
 - Soil-structure interaction modeling with degraded structural elements
 - Structural health monitoring applications
 - Seismic re-assessment of existing plants
 - Post-earthquake "as-is" condition assessment
 - Performance of concrete structures in Kashiwazaki-Kariwa Nuclear Power Plant Facilities during July 16, 2007 earthquake