Research Related to Concrete Technology at USNRC

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Syed Ali, Senior Technical Advisor for Civil/Structural Issues
Office of Nuclear Regulatory Research, USNRC

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Topics

- Status of Aircraft Impact Rule and Assessment Methodology
- Modeling of Concrete Behavior under Impact Loads
- Research Related to Transportation Casks
- Degraded Containment Research
- Revision of USNRC Regulatory Guides
- High Temperature Effects on Concrete
- Confirmatory Review of Design of Modular Composite Structures
- Future Potential Research for Concrete in NPPs

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Aircraft Impact Rule and Assessment Methodology

Status of RG 1.217/NEI 07-13

- AIA Rule effective July 13, 2009
- Draft Regulatory Guide (DG-1176/RG 1.217) endorsing NEI 07-13, "Methodology for Performing Aircraft Impact Assessments for New Plant Designs" issued for public comment on July 10, 2009
- Nonpublic version will contain safeguard information (SGI) aircraft impact parameters
- AIA Methodology presented to ACRS Sub-Committee on December 1, 2009
- AIA Methodology presented to ACRS Full Committee on February 4, 2010
- NEI 07-13 being revised to address ACRS comments
- AIA inspection plan and procedure developed

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Aircraft Impact Rule and Assessment Methodology (Contd)

AIA Rule Requirements

- Impact of a large, commercial aircraft is a beyond-design-basis event
- Applicants must perform rigorous aircraft impact assessment
- AIA methods should be based on realistic assumptions
- Applicants must incorporate design features to show facility can withstand aircraft impact with reduced use of operator action
- Resulting design must ensure that:
  - Either the reactor core remains cooled or the containment remains intact, <u>and</u>
  - Either spent fuel cooling or spent fuel pool integrity is maintained

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Aircraft Impact Rule and Assessment Methodology (Contd)

AIA Overview

- NEI 07-13, "*Methodology for Performing Aircraft Impact Assessments for New Plant Designs*" developed by NEI and reviewed by the NRC staff
- Considered insights gained from NRC and industry assessments of operating and new reactor designs
- Staff engaged the industry in technical discussions and exchanges during the guidance development

Aircraft Impact Rule and Assessment Methodology (Contd)

AIA Scope

- Provides an acceptable methodology to assess the effects of a large commercial aircraft impact on new reactors design
- Methodology addresses:
  - Threat definition
  - Riera loading function
  - Structural/Physical damage analysis methodology
  - Shock damage methodology
  - Fire damage methodology
  - Enhanced design features
  - Documentation and quality requirements

Aircraft Impact Rule and Assessment Methodology (Contd)

AIA Scope (Contd)

- Methodology in NEI 07-13 is a combination of analysis and rule sets
  - Structural analysis for assessing containment & spent fuel pool integrity (local and global effects)
  - Rule sets for assessing fire and shock effects
  - Rule sets for assessing physical damage to buildings other than containment and spent fuel pool structures
  - Use of finite element analysis where rule sets do not apply

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Modeling of Concrete for Impact Loads

- NRC participates in a multiple partner, international experimental research program, called IMPACT, carried out by the Technical Research Center of Finland (VTT).
- The IMPACT program uses small and medium scale tests to collect data on the behavior of reinforced and prestressed concrete slabs subjected to missile impacts.
- IMPACT also collects data on the behavior of various types of missiles (soft and hard) and their loads on structural components.
- NRC uses the test data to benchmark codes that the staff and its contractors utilize to analyze concrete components of nuclear power plants subject to impact loads.

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Modeling of Concrete for Impact Loads (Contd)

- Current NRC analyses use the LSDYNA code and the Winfrith concrete model with strain rate effects (LSDYNA material 84).
- The testing and related analysis address various parameters and effects including:
  - Soft and hard missiles,
  - Hydrodynamic impact loads,
  - Impact speed,
  - Transverse reinforcement type (stirrups and T-headed bars) and amount, and
  - Global and local failure/damage modes of the slabs such as flexure and punching shear.

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Research Related to Transportation Cask Impacts

- NRC is currently analyzing full scale and 1:2.5 scale regulatory drop tests of spent nuclear fuel transportation (SNFT) casks using LSDYNA.
  - Expected benefits of the computer modeling are to reaffirm the staff and industry practices for the design and review of SNFT casks.
- Analysis of a full scale CONSTOR® cask manufactured by Germany's GNS
  - Germany's Federal Institute for Materials Research and Testing (BAM) tested a CONSTOR® cask for a 30-foot regulatory side drop.
  - The cylindrical container of this cask consists of two co-axial steel cylinders with a specially designed concrete infill for radiation shielding (high density aggregate).

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Research Related to Transportation Cask Impacts (Contd)

- Full-scale and scale analyses of the MSF type cask of Mitsubishi Heavy Industries (MHI)
  - BAM tested full-scale and scale models of the MSF cask under a variety of regulatory drop tests.
- Thus far computer modeling results for the CONSTOR® cask are consistent with the test data.
  - The analysis uses the Winfrith concrete model.
- The staff is constructing LSDYNA models of the full scale and scale MHI transportation casks.
  - The study will compare analysis results to the drop test data.
  - The study will use analysis and test data to investigate scale effects.

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Degraded Containment Research

- NRC-sponsored research has been studying the effects of degradation in several types of containments in a risk-informed manner.
- The study integrated structural analysis results with pre-existing probabilistic risk assessment (PRA) models (NUREG-1150) for severe accident conditions.
- It used structural analysis to develop fragility curves for concrete containments with and without cases of hypothetical liner degradation.
- Analysis showed that local liner corrosion typically affects the probability of developing a leak with little effect on the global rupture pressure.

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Degraded Containment Research (Contd)

- The study calculated changes in Large Early Release Frequency (LERF) using PRA models reported in NUREG-1150 in order to use Regulatory Guide (RG) 1.174 procedures for risk-informed acceptability.
- PRA analyses showed little increase, no increase, or even decreases in LERF due to local corrosion.
- Analyses indicated that early leaks from hypothetical liner corrosion increased Small Early Release Frequency (SERF) but these are not addressed in RG 1.174.
- The study is investigating other potential metrics, e.g., consequences, to assess containment degradation in a risk-informed manner.

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Revision of USNRC Regulatory Guides

- RG 1.216 (formerly DG-1203) on containment structural integrity evaluation for internal pressure loadings above design-basis pressure is currently being reviewed by NRO for final concurrence. An ACRS briefing is projected for the end of March 2010. Final RG is expected to be publicly available by the end of April 2010.
- Update of RG 1.107 [draft final rev. by 6/2010]:
  - Guide describes quality standards for 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.

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Revision of USNRC Regulatory Guides (Contd)

- A new RG on containment structural integrity evaluation for internal pressure loadings above design-basis pressure is close to completion. This RG will provide guidance on methods that the staff considers acceptable for containment structural integrity evaluations related to: internal pressure capacity above design-basis pressure, combustible gas control and Commission's performance goal for the prevention and mitigation of severe accidents.
- A new RG on implementation of PRA-based seismic margin assessments is under preparation. This RG will provide guidance on a technically acceptable approach that satisfies 10 CFR 52.47(a)(27) and 52.79(a)(46) and is consistent with the staff requirement memorandum on SECY-93-087.

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High Temperature Effects on Concrete

- Objective of this activity is to prepare a state-of-the art report that addresses the available methods and provides guidance for estimating the thermal response of reinforced concrete structures to thermal loadings. Topics include the review of the following:
  - National and international codes and standards for analysis and response of reinforced concrete structures to thermal loadings,
  - USNRC guidelines outlined in documents such as the Standard Review Plan as they pertain to proposed advanced reactor designs,
  - Thermal loading data on concrete behavior and pertinent structural features testing from published sources that can be used for validation of analytical methods,
  - Analytical models to address elevated temperature effects on concrete strength and stiffness, concrete spalling and its effect on structural response, concrete-steel reinforcement bond, and concrete creep and shrinkage.

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Confirmatory Review of Design of Modular Composite Structures

- Modular composite construction consisting of concrete with steel faceplates (SC) is being proposed for safety-related structures of new reactor designs.
  - This construction technique is outside the scope of current US design guides and specifications such as ACI 349, ACI 318, AISC N690 and AISC 360. Review of the design requires special scrutiny and case-by-case guidance.
- As part of a confirmatory review, outside experts are informing the NRC staff of the adequacy and sufficiency of the technical bases of the design and analysis methodology, construction method and inspection method being proposed for a seismic category I SC structure of a new reactor design.

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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
- Perform computational modeling of concrete degradation
- Long term research related to the development of US standards, including harmonization with international standards, for the design of seismic category I SC structures

Future Potential Research For Concrete In NPPs (Contd)

- Integration with Seismic Research
  - Base-Isolation for NPP Structures and Components
  - Soil-structure interaction modeling with degraded structural elements
  - Structural health monitoring applications
  - Seismic assessment of degraded conditions
  - Post-earthquake "as-is" condition assessment
  - Performance of concrete structures in Kashiwazaki-Kariwa Nuclear Power Plant Facilities during July 16, 2007 earthquake