Research Needs for Concrete Structures Beyond a 60-Year Lifetime

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Some Past Studies that Address Aging Degradation of RC Concrete Structures at NPPs

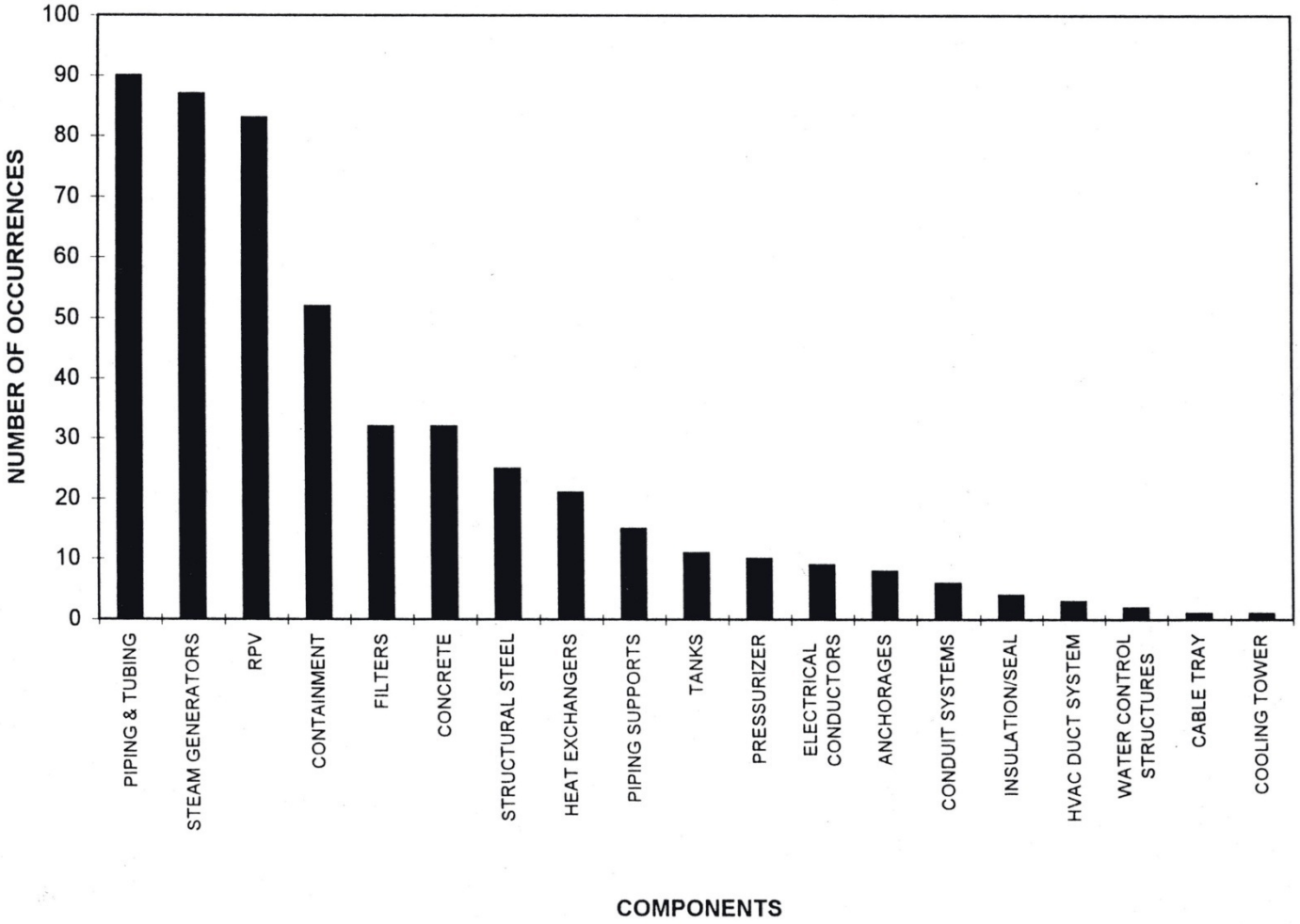
- NUREG-1522, "Assessment of In-service Conditions of Safety-Related Nuclear Plant Structures"
- NUREG/CR-6679, "Assessment of Age-Related Degradation of Structures and Passive Components for U.S. Nuclear Power Plants"
- NUREG/CR-6715, "Probability-Based Evaluation of Degraded Reinforced Concrete Components in Nuclear Power Plants"
- NUREG-1801, Vol. 1 and 2, "Generic Aging Lessons Learned (GALL) Report"
- Other Studies will be discussed by Dan Naus in Session 3

Assessment of Age-Related Degradation of Structures and Passive Components for U.S. Nuclear Power Plants

- Reviewed 18 categories of structures and passive components (SCs)
- Collected and evaluated aging degradation data from NPPs
- Developed computerized database
- Analyzed data - performed trending evaluation
- Performed scoping study -

  Identified 5 SCs requiring detailed research in Phase II
  - Reinforced concrete members
  - Buried piping
  - Anchorages
  - Steel tanks
  - Masonry walls

PASSIVE STRUCTURES AND COMPONENTS - DEGRADATION OCCURRENCES DISTRIBUTION BY COMPONENTS/SUBCOMPONENTS



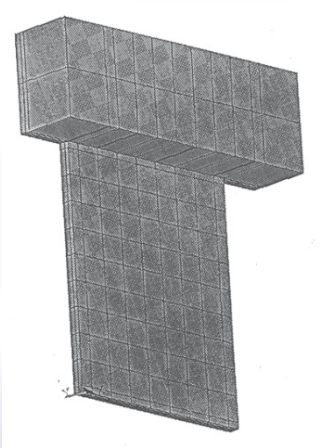
Performance of Concrete Structures at Operating Plants

- **Overall the Performance of Concrete Structures at Operating Plants has been Good**
- **However, there are Reported Instances of Degradation, such as**
  - **Cracking, spalling and other forms of deterioration of auxiliary building and secondary containment walls and slabs**
  - **Cracking of exterior concrete walls of intake structures and concrete beams supporting service water pumps**
  - **Instances of rebar corrosion**
  - **Degradation of tendon galleries of prestressed concrete containments**
  - **Water leakage and seepage in underground structures**
  - **Cracks and other deterioration of masonry-wall joints**

Probability-Based Evaluation of Degraded Reinforced Concrete Components in Nuclear Power Plants

- Evaluation of condition assessment techniques
- Evaluation of degraded SCs
  e.g., Reinforced concrete shear walls
  - Benchmark analytical method
  - Design representative member
  - Define limit state/capacity
  - Develop structural statistics for member
  - Perform fragility analysis
  - Assess effects of reduced fragilities on plant risk
- Develop probability-based degradation acceptance criteria

Naturally Aged Shear Wall Specimens



Finite Element Computer Model

Probability-Based Acceptance Limits for Degraded Reinforced Concrete Structures

- **NUREG/CR-6715 developed probability-based acceptance limits for use as a tool for making risk-informed decisions regarding reinforced concrete members. Crack width limits were developed for:**
  - **Flexural members considering loss of steel area and concrete spalling**
  - **Flexural members without concrete spalling**
  - **Flexural members with concrete spalling and no loss of steel area**
  - **Precluding shear failure in flexural members**
  - **Shear walls considering loss of steel area and concrete spalling**

- **Acceptance limits are for use in determining whether more detailed inspections and evaluations are warranted, but not for use as a "design basis" for acceptance of a degraded condition or for NRC licensing activities**

NRC Requirements/Guidance Applicable to the Management of Aging of Concrete Structures

- 10 CFR 50.55a, Code and Standards, which references ASME Section XI, Rules for In-service Inspection of NPP Components, Subsection IWL, Requirements for Class CC Concrete Components
- 10CFR 50.65, Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants
- NRC Regulatory Guide 1.160, Rev.2, Monitoring the Effectiveness of Maintenance at Nuclear Power plants
- License Renewal Aging Management Programs Described in NUREG 1801
  - ASME Section XI, Subsection IWL
  - 10CFR 50, Appendix J
  - Structures Monitoring Program
  - RG 1.127, Inspection of Water-Control Structures Associated with NPPs
  - Masonry Wall Program

Industry Guidance Applicable to the Management of Aging of Concrete Structures

- NUMARC 90-6, Class I Structures License Renewal Industry Report (Also NUMARC 90-1 and 90-10 for PWR and BWR Containment Structures)
- NEI 96-03, Guideline for Monitoring the Condition of Structures at Nuclear Power Plants
- ACI 349.3R, Evaluation of Existing Nuclear Safety-Related Concrete Structures
- ACI 201.1R, 201.2R, 207.3R, 222R, 224R, 224.1R and 311.4R, Related to condition surveys, durability, evaluation of existing structures, cause and control of corrosion of metals in concrete, control and repair of cracking, and concrete inspection
- ASME Section XI, Rules for In-service Inspection of NPP Components, Subsection IWL, Requirements for Class CC Concrete Components

Issues to Consider for Further Research

- **Develop an Operating Experience database for each operating NPP and for each class of operating NPPs**
  - **Use current structure of NUREG-1801 to organize the information**
  - **Information from the License Renewal process would be one source of such information**
  - **Database for each NPP should include all significant events and conditions that have occurred since the beginning of construction**
  - **Augment initial data base to include subsequent significant operating experience**
  - **NRC staff could rely on the up-to-date, plant-specific database, to focus its technical evaluations on renewing an operating license beyond 60 years**

Issues to Consider for Further Research

- **Initiate and maintain an Operating Experience database for each new-generation NPP and for each class of new-generation NPPs**
  - **One additional element for new plants is the licensee's ability to accurately track, from initial operation, the plant performance against design-basis TLAAs**
  - **If each plant prepared an annual report, the information could be added to the database.**
  - **Adverse trends could be identified and appropriate actions taken. This information would also be invaluable for making future license renewal decisions.**

- **Improve analytical methods to assess fragility and impact on safety that takes into account the effects of aging**

Issues to Consider for Further Research

- **Develop improved and more specific acceptance criteria for concrete degradation on both a deterministic and probabilistic basis**

- **Improve condition assessment methods and inspection tools to assess potential degradation of concrete structures, especially in inaccessible areas.**

- **Study long term effects on concrete material properties due to extended exposure to high temperatures and/or radiation**