Recent and Planned Developments and Updates in Codes and Standards, Part 2

- **Moderator:** Madhumita Sircar, Senior Structural Engineer, RES/DE/SGSEB

- **Panelists/Speakers:**
  - Christy Williams (NRIC)
  - Ronald Janowiak (AISC)
  - Andrew Whittaker (ASCE)
  - John McLean (ASME)
  - Carlos Cantarero-Leal (ACI)

NRIC Program & ACT Overview

September 28, 2022

Christy Williams
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NRIC DOE program, launched in FY'2020

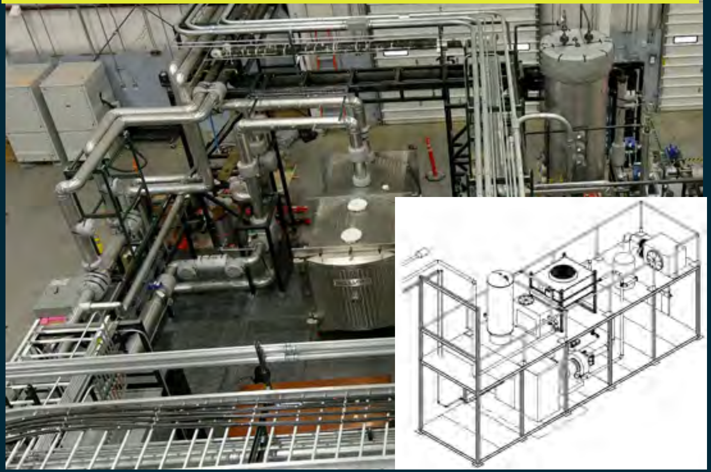
NRIC Enables Nuclear Reactor Demonstrations

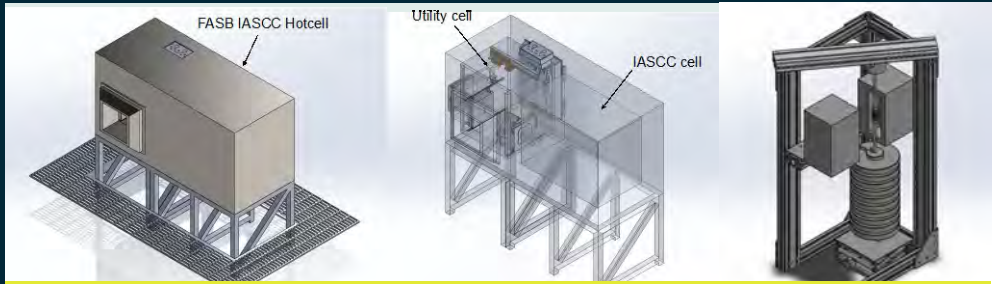
- Authorized by the Nuclear Energy Innovation Capabilities Act (NEICA)
- Partner with industry to bridge the gap between research and commercial deployment
- Leverage national lab expertise and infrastructure

NRIC INL

NRIC Experimental Test Beds

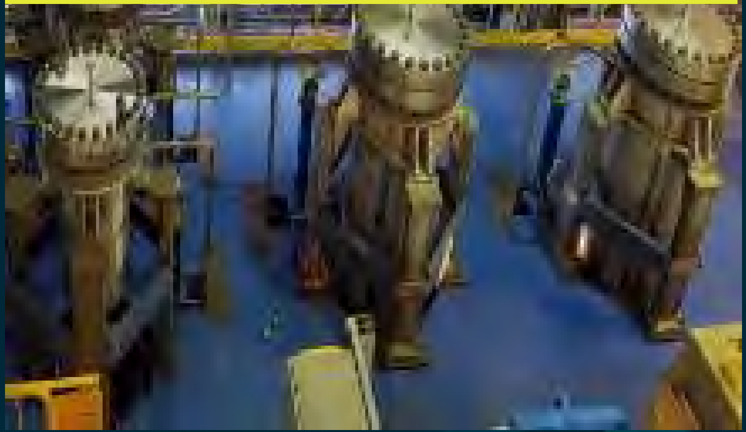
Helium Component Test Facility
[*2022*]



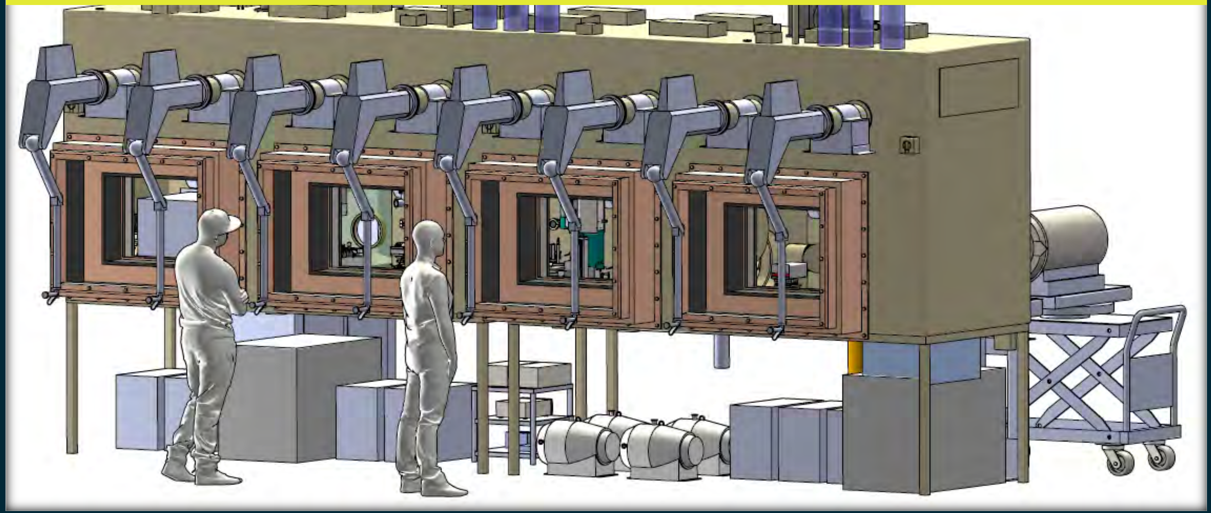


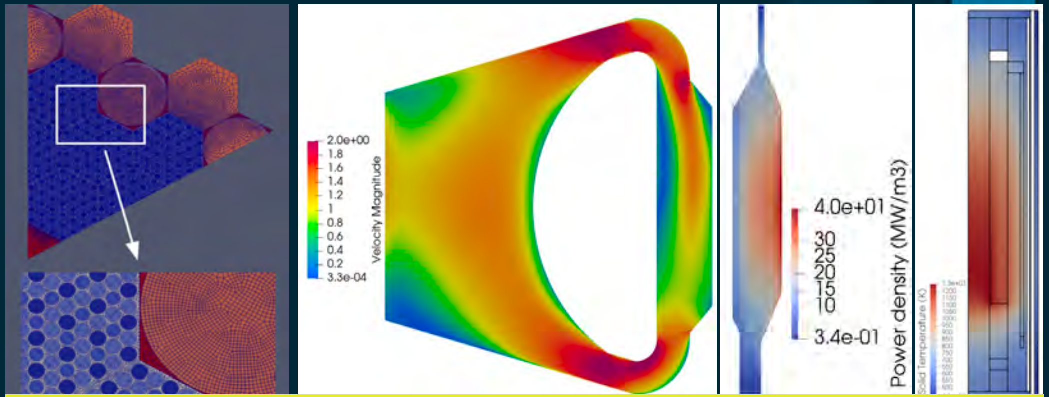
In-HotCell Thermal Creep Frame [*2022*]

Mechanisms Engineering Test Lab
(METL) [Operating]



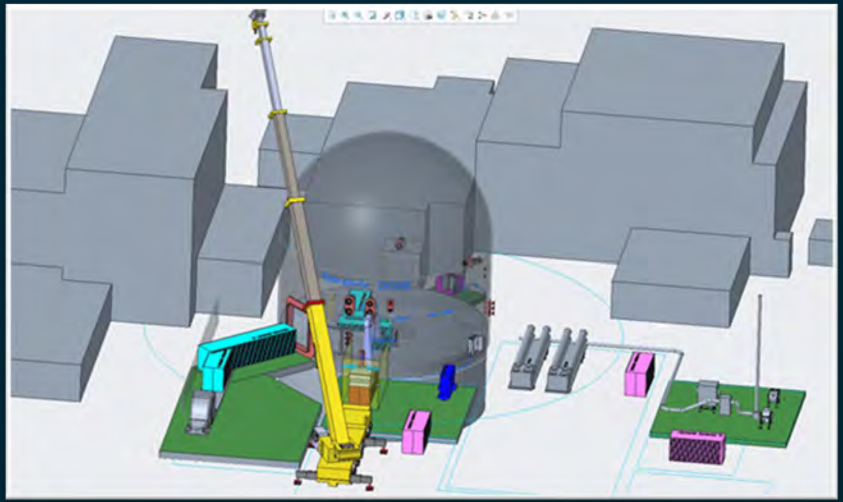
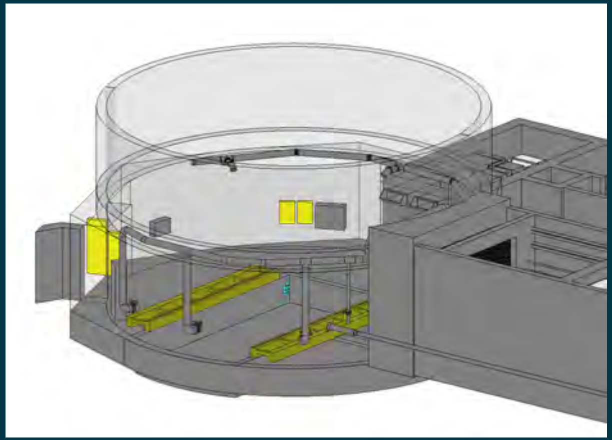
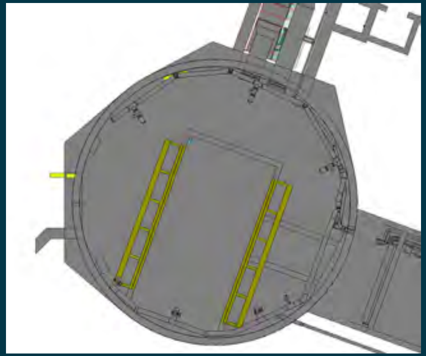
Molten Salt Thermophysical Examination Capabilities (MSTEC)
[*2024*]





Virtual Test Bed [Launched 2020]



Demonstration Test Beds In Development

- Enable continuing innovation by refurbishing and leveraging existing infrastructure for multiple demonstration projects
- Conceptual design planned for completion in early FY22 (DOME completed Dec '21)
- Prelim/Final design planned for FY22, pending DOE decisions
- DOME construction RFP late 2022 budget permitting

NRIC Advanced Construction Technology (ACT) Initiative

- Objectives:
  - Significantly Reduce Costs and Schedule for Nuclear Power Builds
  - Demonstrate, in partnership with industry, technologies to enable commercial advanced nuclear by 2030
- Progress:
  - Expressions of Interest requested – Summer 2020
  - Request for Proposals issued - Aug 2020
  - Proposals received - Nov 2020
  - Selected GEH Team – Spring 2021
  - Awarded GEH project – Dec 2021
  - Kickoff meeting – Jan 2022
  - 30% Design May 2022
  - Site Selection Sept 2022
  - 60% Design Sept 2022

ACT Team Members & Role

- General Electric Hitachi Nuclear Energy (GEH) - Team Lead
  - EPRI – Digital Twin, and NDE techniques
    - University of North Carolina @ Charlotte (UNCC) – Digital Twin
    - Nuclear Advanced Manufacturing Research Centre (NAMRC) – Advanced Sensor
  - Modular Walling Systems Holdings Limited (MWS) – Steel Brick ™
  - Purdue University – Steel-Concrete Composite prototype testing
  - Black & Veatch – Boring Technology, Construction of Demonstration, Decommissioning Plan, Scaling Prototype, & Site Selection
  - Tennessee Valley Authority (TVA) – Industry Partner

NRC Collaboration

- Congress recognized the importance of agency coordination in the Nuclear Energy Innovation Capabilities Act
- DOE/NRC MOU to "coordinate DOE and NRC technical readiness and sharing of technical expertise and knowledge on advanced nuclear reactor technologies and nuclear energy innovation, including reactor concepts demonstrations, through the [NRIC]."
  - NRIC Rotations

Fred Sock
Office of Nuclear Regulatory Research

Allen Fetter
Office of Nuclear Reactor Regulation

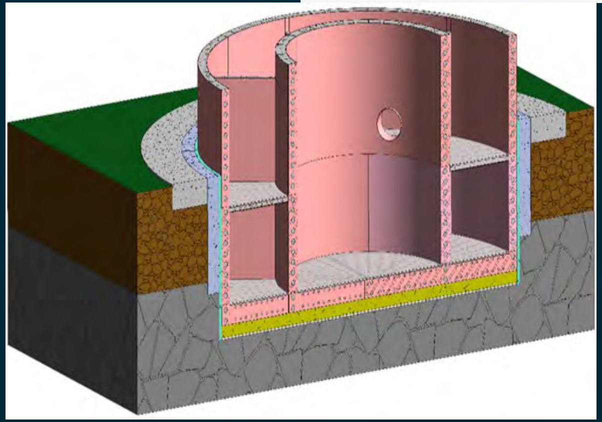
- Monthly Coordination Calls – DOE/NRC/NRIC

ACT Project Structure

- Phase 1: Detailed Design –
  - Detail and optimize the design of the scaled structure to be constructed, tested, monitored, commissioned, and decommissioned in Phase 2
  - ~12 Months – Start date Jan 27, 2022
  - Final Design - Jan 2023
  - $8.35M total cost; 70% NRIC/DOE; 30% GEH Team
- Phase 2: Construction –
  - Fabricate Steel Brick™ panels, sink the shaft, construct the scaled structure, deploy the sensors and Digital Twin, test the structure, collect data, and decommission the structure at the end of the phase
  - ~ 3 years; subject to availability of funds and successful completion of Phase 1

ACT Demonstrations Technologies

1. Vertical shaft excavation techniques
2. Steel Bricks™ system, next generation SC modules, for Seismic Category 1 structures including containments and novel techniques to integrate the modules into the basemat to avoid conventional structural attachment problems (e.g., AP1000 construction at Vogtle).
3. State-of-the-art Digital Twin replica of the structure to integrate sensor data, artificial intelligence, machine learning, and data analytics
4. Advanced condition and performance monitoring techniques for implementing construction and in-service surveillance programs to address 10 CFR 50.65 Regulatory Inspection and Monitoring requirements as part of the Reliability Integrity Management (RIM) plan



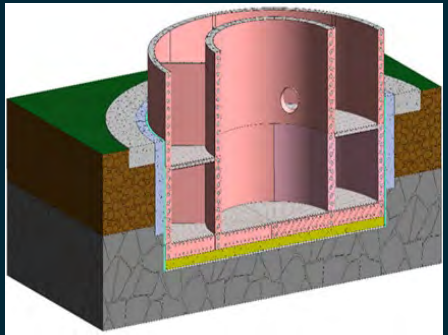
NRIC INL

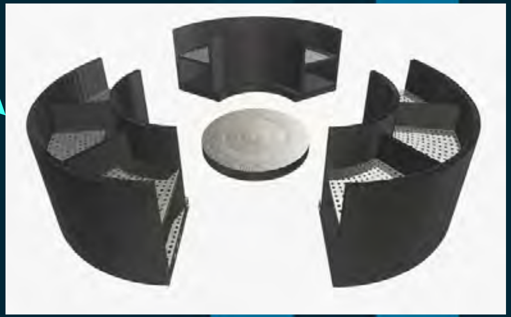
Vertical Shaft Construction

- Leverages best practices from the construction industry
  - to reduce costs associated with excavation, inspections, and testing of safety-related backfill.
- Conceptual design for scaled structure for demonstration
  - Outer diameter 16 meters
  - Shaft depth 5 meters
  - Height above grade 2 meters
  - Commercial roof will keep structure weather tight
- Potential to reduce the amount of excavation and engineered backfill needed by 1 million cubic feet
- B&V is the lead on selection of boring technology, scaled structure and site selection

Steel Brick™ System Prototype and Scaled Structure – Phase I

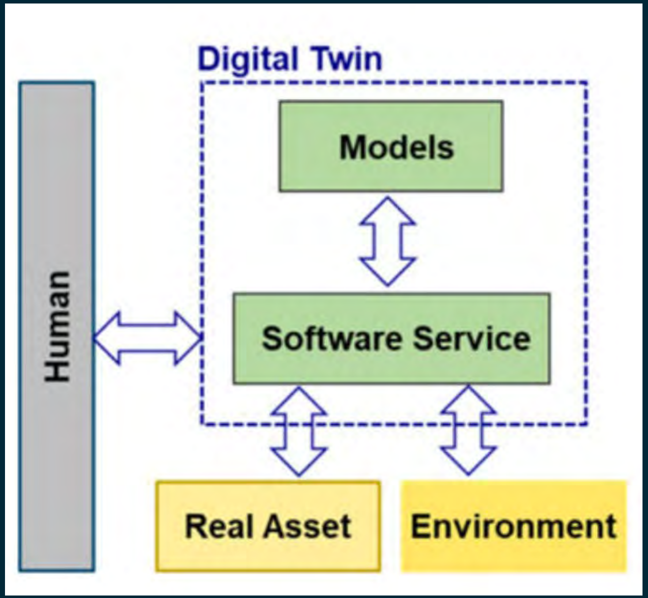
- Prototype testing of representative MWS Steel Bricks™ panels will be performed in Phase 1 to expand the current fabrication knowledge that is based on rectangular structures to cylindrical structures. The prototyping will demonstrate the strength of the critical splices and connections, generate data necessary for regulatory acceptance of the modules for containment application
- Prototype testing will be performed at the Purdue University. A Mini Digital Twin will be deployed by EPRI and UNCC to collect data and validate sensor types and locations determined by NAMRC
- The prototype testing will establish Design-Basis (DB) and Beyond-Design-Basis (BDB) structural performance of Steel Bricks™ modules, including:
    - Accident thermal and pressure loading representing containment conditions
    - Combined seismic + accident thermal loading
    - Basemat modules under shear loading and interaction with soil support
    - Strength of cylindrical shaft-to-basemat connections



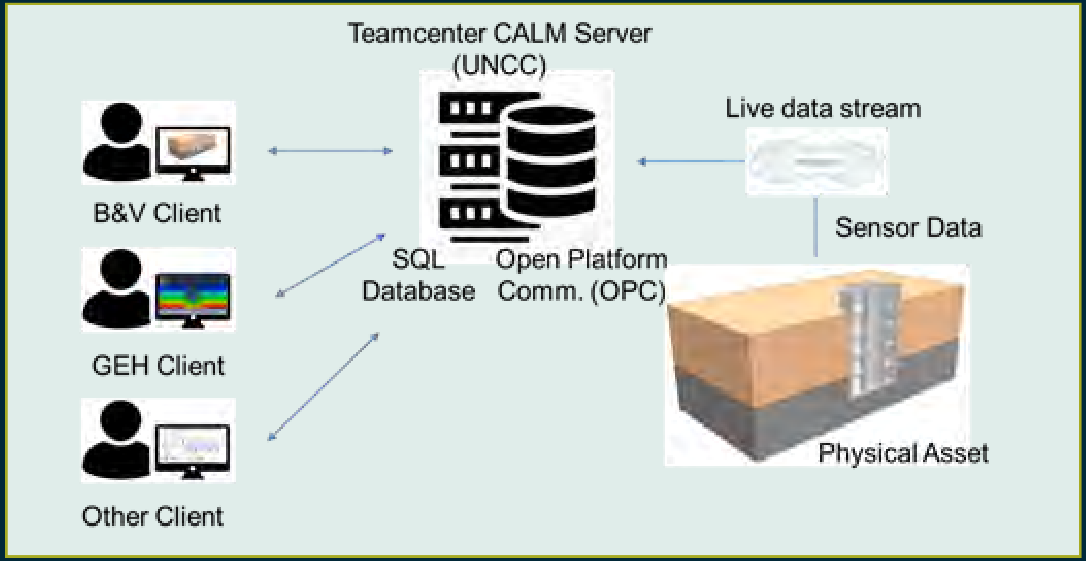


Digital Twin

Digital Twin in NRIC is defined as a general service architecture for cyberphysical manufacturing and fabrication systems comprised of multiple models and software services that interact with the real asset



The Digital Twin Concept



Data Flows in the Digital Twin

This project will demonstrate several of the benefits of the Digital Twin. Data from real assets will be streamed to a central database. This information will be combined with multiple models to allow all team members to pull critical design information throughout all stages of the project, from initial component fabrication to decommissioning.

Reliability & Integrity Management Program

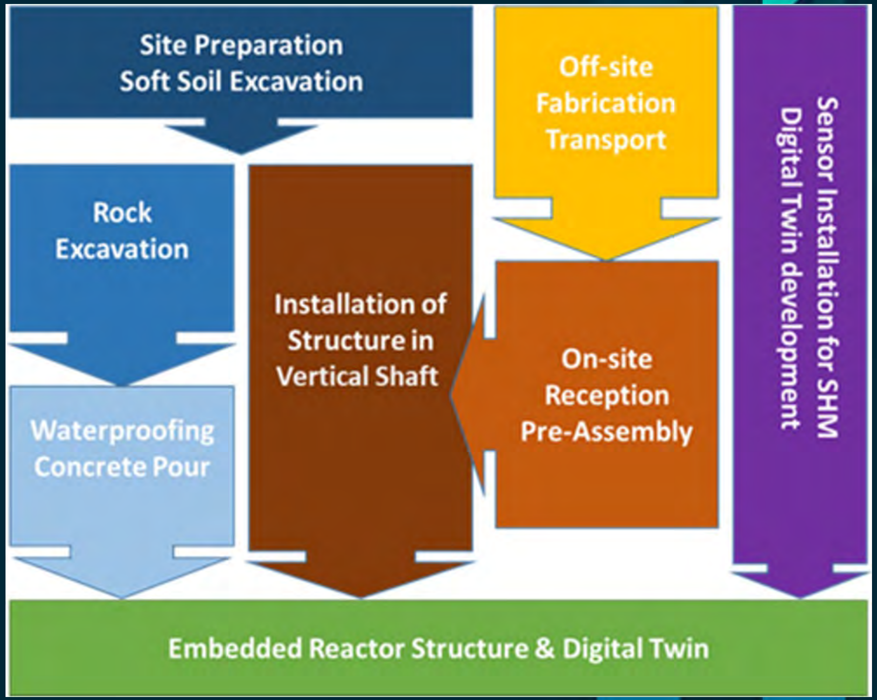
- Inspection and monitoring of the exposed rock surfaces and foundation of the excavated shaft including soil/rock movement during construction using advanced techniques such as LIDAR and INSAR, following the guidance of RG 1.132 and NUREG/CR-5738, Appendix A and B to satisfy the requirements of the NRC Inspection Manual 88131 (Geotechnical/Foundation)
- Benchmarking inspections and a testing program for construction and in-service condition monitoring of steel-concrete composite structures consistent with NRC Inspection Manual requirements to ensure that construction requirements have been adequately satisfied and to ensure any changes during the operational life of the plant are bounded by the design.

Phase 1 activities will be focused on selecting the monitoring techniques and outlining the program. The techniques will be implemented in Phase 2. Lessons learned will be generated and inputs generated for Reliability and Integrity Management (RIM) program

Putting it all together

- Vertical shaft construction leverages best practices from the tunneling industry to potentially reduce the amount of excavation and engineered backfill needed by 1 million cubic feet for typical build
- Steel Bricks™ provide substantial structural improvement over standard SC Composite Construction and can be constructed in factory while excavation is occurring
- Digital Twin/sensor system allows for continuous monitoring over life of plant

1) **Preparation of Site**
2) **Excavation of the shaft**
3) **Placement of the mud mat/foundation**
4) **Assembly of the fabricated Steel Brick ™ technology panel from offsite fabrication**
5) **Lower panels into shaft**
6) **Install Sensors for Digital Twin**
7) **Embedded Reactor Structure & Digital Twin**



Thank you

AISC “Specification for Safety-Related Steel Structures for Nuclear Facilities”

Planned Updated Code Provisions for Steel-Plate Composite Construction for the New Edition of the AISC N690

Ronald Janowiak, PE, SE, FACI
Chair – AISC Committee on Nuclear Facilities Design

September 28, 2022

Objective

- Describe the AISC N690 committee's ongoing role in supporting the nuclear industry's structural steel related needs as interest and number of design activities keeps growing
- Provide specification-related updates that are underway for the current N690 revision cycle
- Describe other synergetic steel-plate composite (SC) related activities that were catalyzed because of N690 committee's work
- The content of this presentation will focus on planned 2024 revision to the N690 specification, i.e. they have not yet been officially approved by AISC

Background

- The AISC N690 specification is a “dependent” specification
  - N690 only provides the additions and exceptions to AISC’s main building specification: AISC 360
  - N690 also captures seismic-unique provisions from AISC’s seismic specification: AISC 341

How the industry guides AISC N690 committee's work?

- The committee's diverse membership of practitioners consisting of engineers, fabricators, researchers, and constructors share recent experience at committee meetings.
- Especially, the SC SMEs/researchers from Purdue University, Bechtel, University of Alabama, and Auburn University consider industry trends, new research information, and inputs from EPRI/NRC/industry/N690 committee members to determine updates that can be implemented in the current revision cycle
- The SC updates will reflect industry/NRC feedback and new research findings, and they will also remove/relax certain conservative requirements
- The following slides cover most, but not all of the planned changes

Acknowledgements: AISC, NRC, Dr. Hasan Charkas (Electric Power Research Institute), Reactor Suppliers, SC Practitioners / Fabricators, Dr. Kai Zhang (Bechtel), Prof. Amit Varma and Dr. Jungil Seo (Purdue University), Prof. Kadir Sener (Auburn University), and Prof. Saahas Bhardwaj (University of Alabama). A special thanks to Dr. Sanj Malushte for using his recent NASCC presentation as input to today's presentation.

SC related Updates for Current N690 Revision Cycle

List of Clarifications and Elimination/Relaxation of Certain Limitations

- *Emphasize that the provisions apply to SC slabs and foundations* – This was previously implied, but most provisions only referred to "SC Walls"
- *Remove the 5-ft maximum thickness requirement* – This provision was based on desire to be conservative and deemed lack of data
- *Remove restrictions on maximum concrete strength* – This too was done out of abundance of caution; however, this aspect will now be implicitly deferred to ACI 349 (which stipulates no upper limit)

SC related Updates for Current N690 Revision Cycle

List of Clarifications and Elimination/Relaxation of Certain Limitations

- *Permit use of higher strength faceplates* – Yield strength up to 80-ksi will be permitted if the material elongation is at least 15%
- *Revise the general provision for CJP weld requirement at faceplate seams* – The language will become consistent with relevant AISC 341 provisions
- *Specify a new requirement for maximum tie-bar spacing* (in lieu of the current requirement for minimum tie-bar strength) – Adopt the language from relevant AISC 341 provisions
- *Modify interaction check for interfacial and out-of-plane shear using square interaction* – This change recognizes that the tie-bars with ductile failure modes satisfy von Mises yield criterion

SC related Updates for Current N690 Revision Cycle

List of Clarifications and Elimination/Relaxation of Certain Limitations

- *Clarify the meaning of "openings/penetrations"* – User note will clarify that the penetration related detailing requirements do not apply to small holes in individual faceplates for fasteners / dowels
- *Allow simpler detailing requirements for "very small" penetrations* – Only a sleeve needed for penetrations with effective diameter smaller than 6-inch or ¼ of the slab / wall thickness; no capacity reduction and penetration is ignored in analysis
- *Provide option for use of analysis method for "small openings" with free edge*
- *Permit smaller flange for "small openings" in the connection region*

SC related Updates for Current N690 Revision Cycle

<u>List of New/Revised Provisions based on Recent Research</u>

- *Permit concrete contribution to out-of-plane shear strength to be based on 2SQRT(f'_c)* – Recent research confirmed the current equation based on 1.5SQRT(f'c) is conservative
- *Revise nominal flexure strength equation to allow ~10% increase* – Recent research indicates that Poisson effect causes additional moment capacity
- *Permit relaxed compactness requirement for faceplates in interior region* – Recent research shown that ~20% larger spacing of tie-bars/headed shear connectors is acceptable in regions away from connections/boundaries

SC related Updates for Current N690 Revision Cycle

List of New/Revised Provisions based on Recent Research

- *Provide equation for higher in-plane shear strength in the Commentary* – Recent research shows that concrete contributes 20-30% more capacity after faceplates yield (this may be useful for beyond-design-basis evaluations)
- *Provide provisions / guidance for connections with lap splicing of reinforcing bars with SC wall faceplates* – Data from recent SC connection research will be used to provide relevant guidance / provisions

SC related Updates for Current N690 Revision Cycle

List of Changes based on Industry Trends/Needs

- *Specify limits for accident and service temperature exposures* – Uniform temperature increase and through-thickness gradient limits to be specified for accident and normal operation conditions; possible mitigation measures to be covered in the Commentary

Other Synergetic SC Related Industry Developments

- *Advent of SpeedCore and related lateral force resisting systems for commercial applications* – The latest editions of AISC 341 / AISC 360 standards contain significant new provisions/updates to permit SC-based innovative structural systems!
- *Ballot currently underway for SC Containment Vessel (SCCV) Code Case in ASME Section III Division 2 Committee* – This is a huge leap for use of SC construction in the nuclear power industry! This development is supported by significant new research in the US, Japan, and South Korea

Summary

- Working with the industry, regulators, and EPRI, the AISC N690 committee has been responsive to the industry's emerging needs and new/revised code provisions are being introduced
- Synergetic developments outside of the AISC committee have been made possible because of AISC's vision and early leadership in this field of SC construction
- Modular SC construction is increasingly becoming the preferred method for nuclear power plants (and hopefully for nuclear facilities in general)

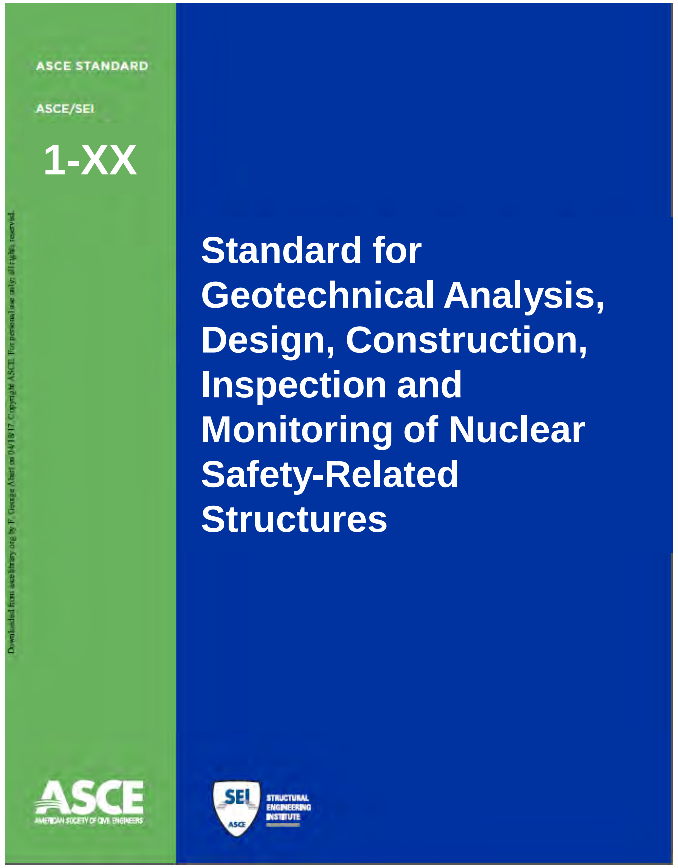
ASCE 1, 4, and 43

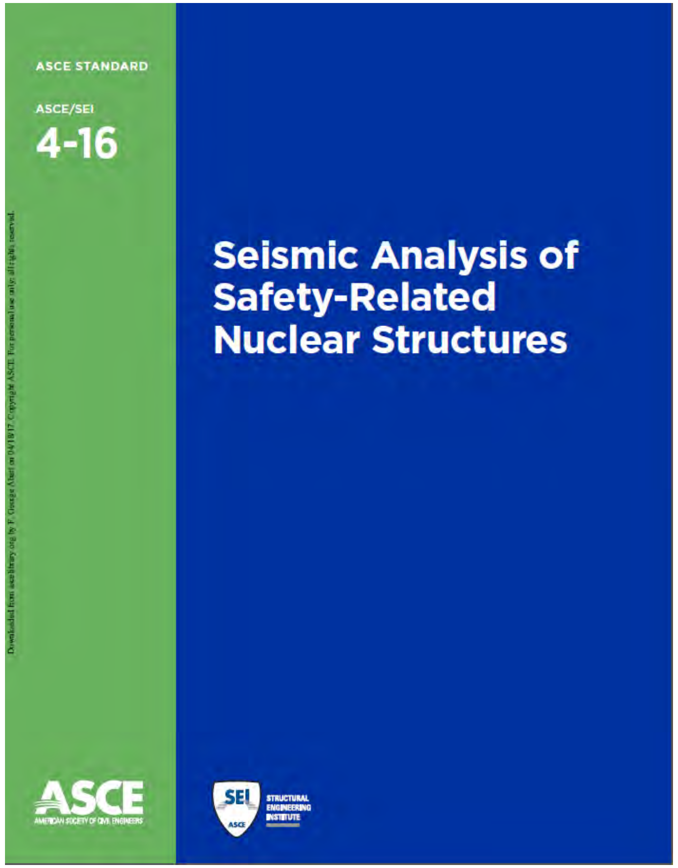
What the next year will bring

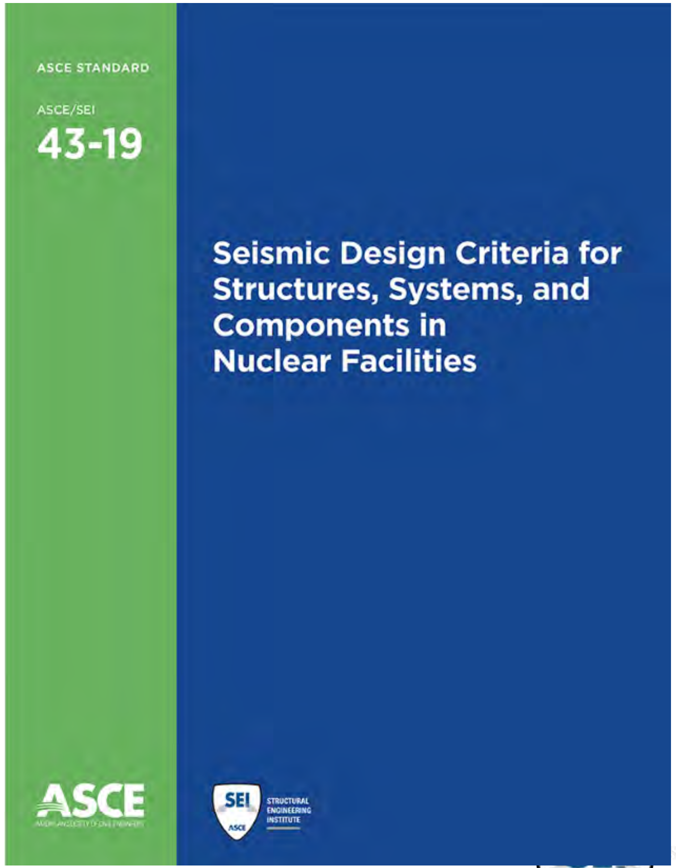
Andrew Whittaker, Ph.D., P.E., S.E., F.ASCE, F.SEI
Chair, ASCE Nuclear Standards Committee
Brian McDonald, Ph.D., P.E., S.E., F.ASCE
Chair, ASCE DANS Committee

STRUCTURAL ENGINEERING INSTITUTE

ASCE NUCLEAR STANDARDS

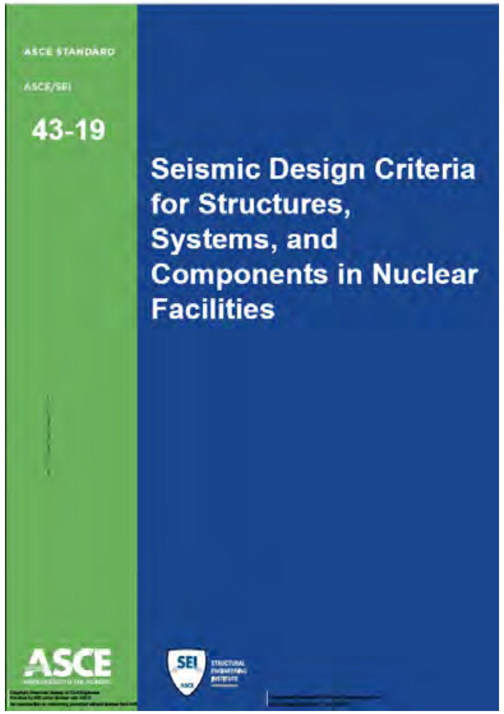






TODAY

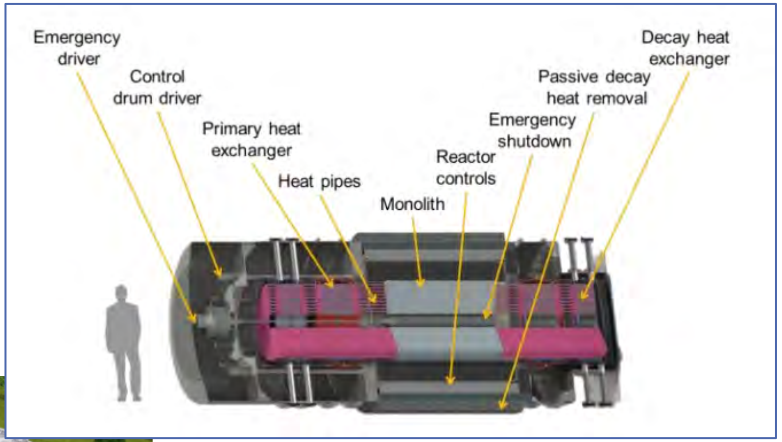
- Scope of ASCE nuclear standards
  - DOE facilities
  - Nuclear power plants
    - Large light water reactors
    - Advanced reactors
    - Microreactors and nuclear batteries
- Integration with ANS and ASME standards
- DANS planned action on ASCE 4
- Risk-based design of seismic isolation systems
- Acknowledgments



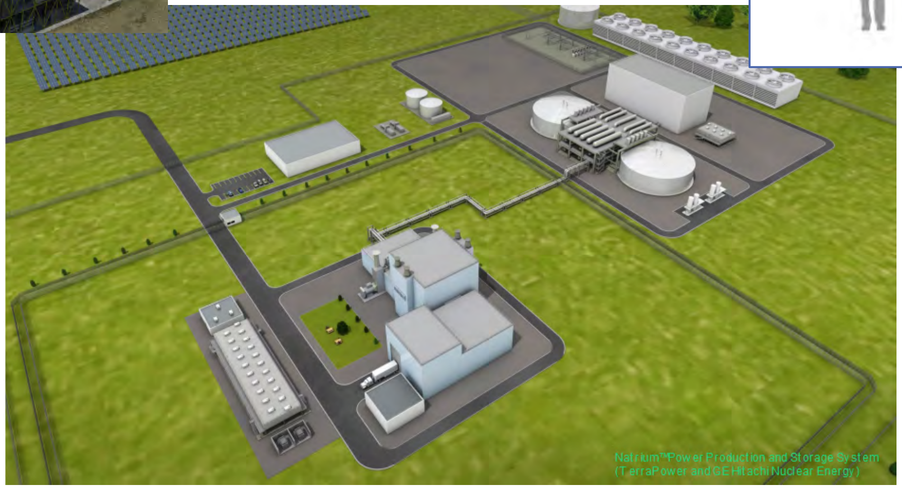
ORIGINAL TARGET OF ASCE 4

FUTURE +APPLICATIONS OF ASCE 4

Lucid Catalyst

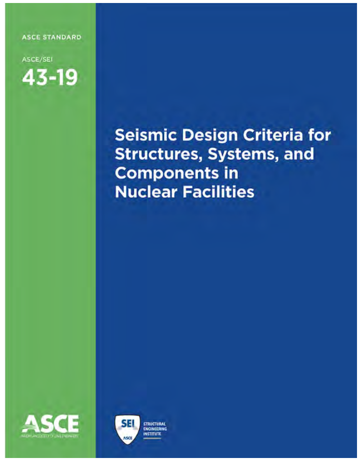


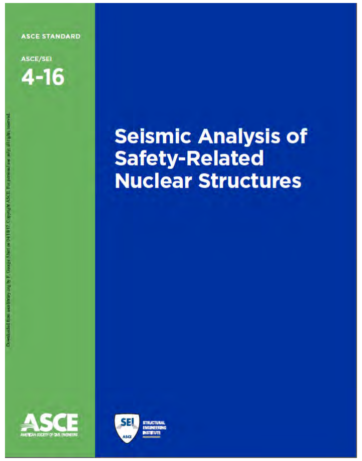
WEC

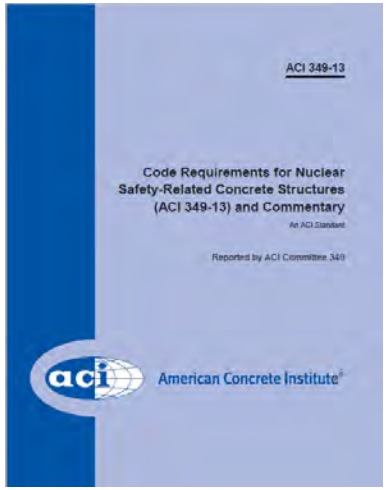


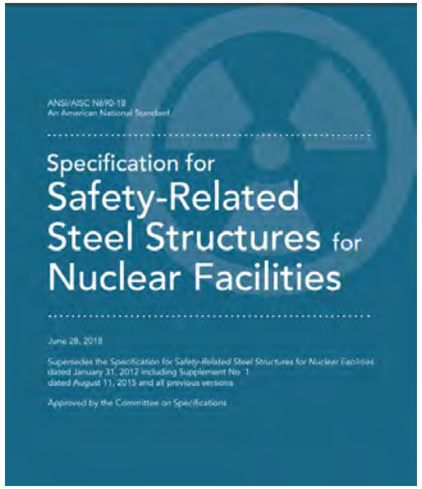
TerraPower and GEH

SDO INTEGRATION









BIG IDEAS FOR ASCE 4: 2022-2023

- Guiding principles
  - Recognize ASCE standards represent *minimum requirements*
  - Support planned merger of ASCE 4 (analysis) and ASCE 43 (design)
  - Eliminate language and commentary that stifle innovation
  - Eliminate content in the domain of others SDOs
    - Risk assessment (ANS), piping systems and supports (ASME), storage tanks (API)
  - Eliminate legacy content not used by industry
  - Focus solely on content specific to nuclear
    - Point to other ASCE standards (e.g., ASCE 7, 41) wherever possible
  - Ensure that ASCE 4 supports DOE best practice
    - Ground motion, nonlinear dynamic analysis, modeling, SSI analysis
  - Reorganize chapters to follow the design process

BIG IDEAS FOR ASCE 4: 2022-2023

Table 1-1. Summary of Earthquake Design Provisions.

	Seismic Design Category			
	2	3	4	5
Target performance goal, P_F	4×10^{-4}	1×10^{-4}	4×10^{-5}	1×10^{-5}
DBE response spectrum or acceleration time series	SF × UHRS; Chapter 2 in this standard			
Damping for structural evaluation	Section 3.3.3			
Analysis methods for structures	ASCE 4 and Chapter 3 in this standard			
Analysis methods for systems and components	In-structure response spectra; ASCE 4 and Chapter 8 in this standard			
Load factor	1.0			
Inelastic energy absorption factors	Table 5-1 and/or Table 8-1 in this standard			
Material strength	Minimum specified value			
Component design strength	Design strength according to materials standards unless exceptions are made in this standard			
QA program	Chapter 10 in this standard			
Independent peer review	Chapter 10 in this standard			

Table 1-2. Deformation and Damage by Limit State.

Limit State	Expected Deformation	Expected Damage
A	Large permanent distortion, short of collapse	Significant
B	Moderate permanent distortion	Generally repairable
C	Limited permanent distortion	Minimal
D	Essentially elastic behavior	Negligible

Source: Adapted from ANS 2.26 (ANS 2017).

Building Performance Levels and Ranges

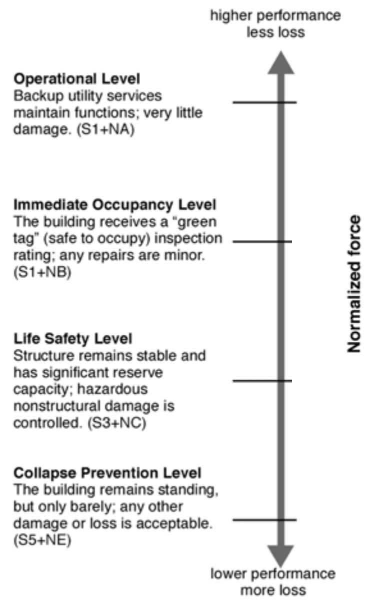
Performance Level: the intended post-earthquake condition of a building; a well-defined point on a scale measuring how much loss is caused by earthquake damage. In addition to casualties, loss may be in terms of property and operational capability.

Performance Range: a range or band of performance, rather than a discrete level.

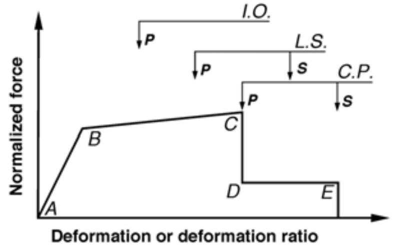
Designations of Performance Levels and Ranges: Performance is separated into descriptions of damage of structural and nonstructural systems; structural designations are S-1 through S-5 and nonstructural designations are N-A through N-D.

Building Performance Level: The combination of a Structural Performance Level and a Nonstructural Performance Level to form a complete description of an overall damage level.

Rehabilitation Objective: The combination of a Performance Level or Range with Seismic Demand Criteria.

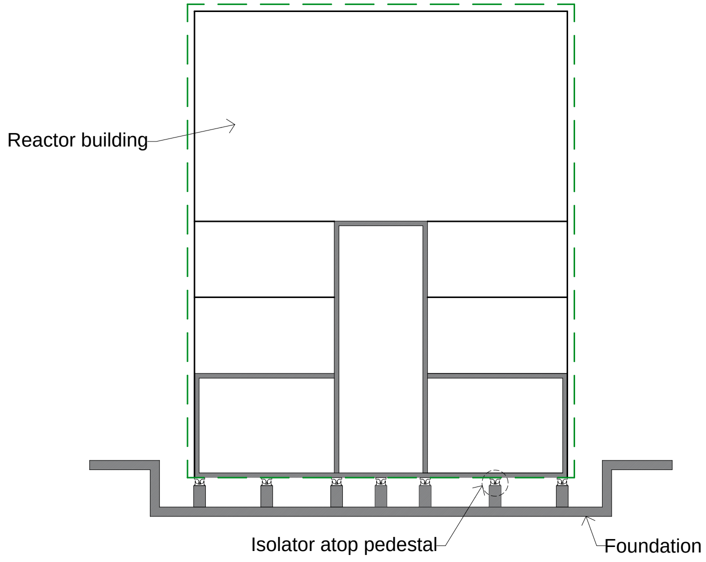


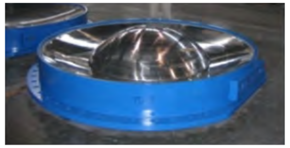
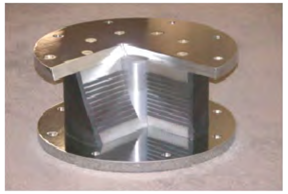
FEMA 273, 1997



SEISMIC ISOLATION

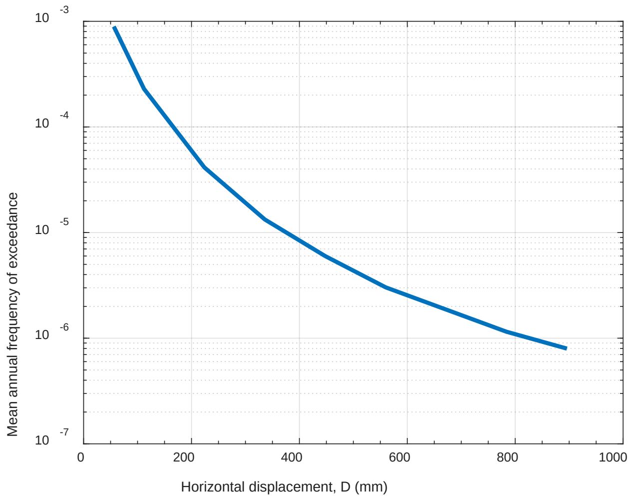
- Chapter 12 of ASCE 4-16
  - Being revised, expanded scope
    - 3D isolation systems, advanced and micro-reactors
  - Supported by NUREG/CRs 7253, 7254, 7255
    - Laser-focused on large light water reactors
- ARPA-E funded research
- DOE-funded topical report in production

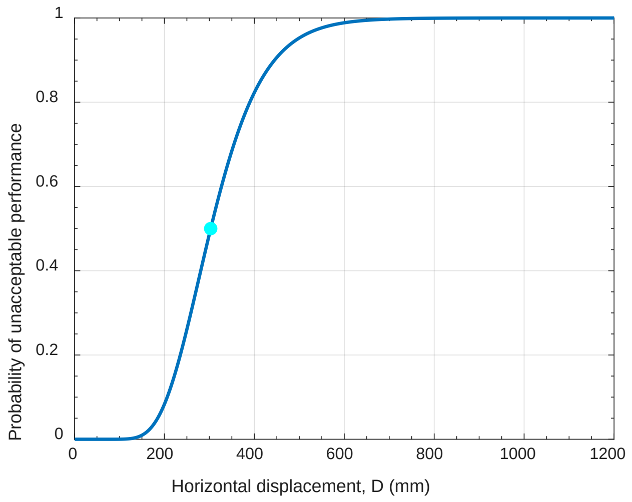


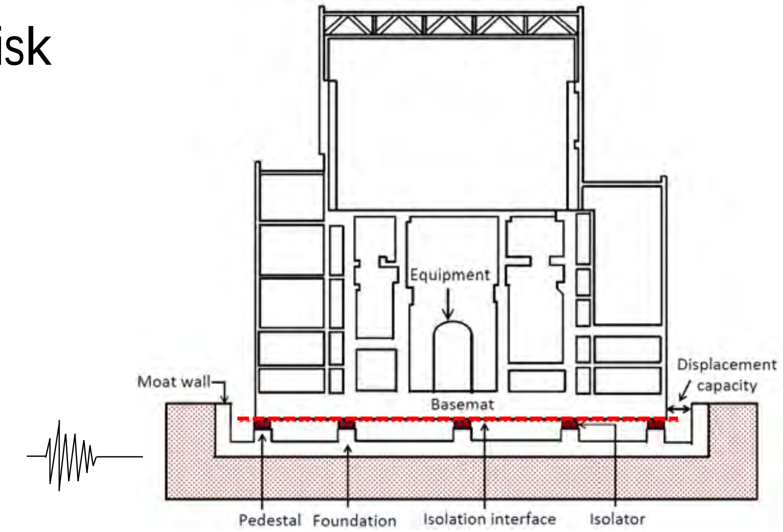



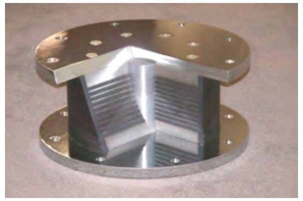

ISOLATION SYSTEM RISK-BASED DESIGN

- Target performance goal
  - Component level (SDC) or fraction of seismic plant risk
- Achieving a TPG for an isolation system
  - Displacement demand curve
  - Fragility function: *m* and β



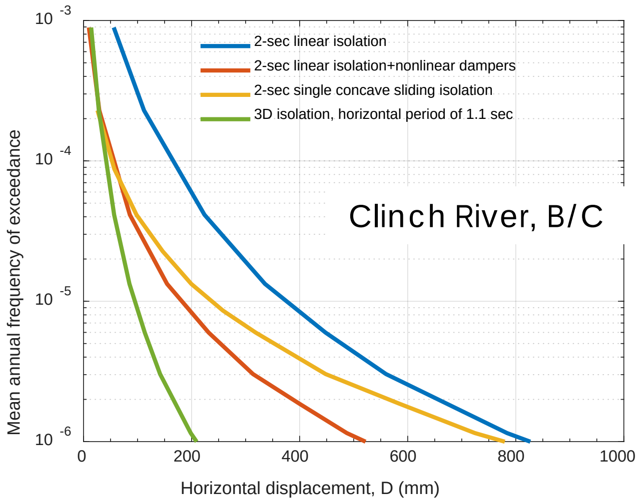


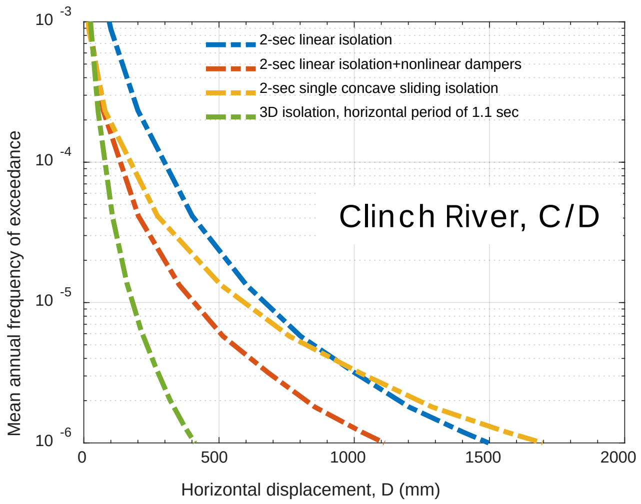


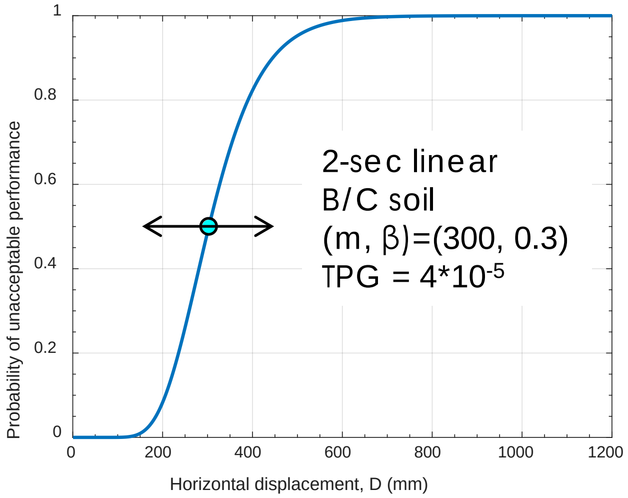


ISOLATION SYSTEM RISK-BASED DESIGN

- Achieve a target performance goal
  - Generate demand curve: nonlinear dynamic analysis of SDOF systems
    - Ground motions consistent with site-specific seismic hazard curves
  - Fragility function
    - β addresses ground motion, isolation system properties, and superstructure mass
    - Adjust *m* to achieve target performance goal







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FURTHER DISCUSSION

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NRC Standards Forum

September 28, 2022

Modernization of the ASME Section III, Div. 2 Code

John McLean
ASME Section III, Div. 2

ASME Sect. III, Division 2 Committee

Committee organization

- **Joint ACI/ASME Committee (ASME Section III Division 2/ ACI 359), 3 WGs:**
  - **Working Group (WG) on Design**
  - **WG on MF&E (Materials, Fabrication & Examination**
  - **Special Working Group (SWG) on Modernization**
- **Joint Committee and WGs meet twice a year, with several teleconferences in between**
- **Shen Wang is Chair of SWG Modernization, but resides in China currently**

ASME
SETTING THE STANDARD

SWG Modernization

SWG Modernization Charter

- **The Special Working Group on Modernization is responsible for making recommendations to the ACI/ASME Joint Committee on Concrete Components for Nuclear Service (BPV III-2) on the opportunities and initiatives identified by Code users, regulators or self-identified by the Code Committee members to ensure that the Code is up to date with the industry while preserving its design robustness features. The Special Working Group will investigate and develop plans for an identified opportunity, and share with the Joint Committee for approval to proceed.**

Tasks on the SWG Modernization Agenda

1. Work with ACI to issue ACI 349.4R and modify CC-3900 to improve guidance for impulsive and impactive loading
2. Harmonize design provisions of containments (ACI 359) with non-containment nuclear structures (ACI 349)
3. Perform a study for the next generation containment design, using high strength concrete, high strength post tensioning single strand tendons
4. Add provisions for fiber reinforced concrete to enhance concrete tensile capacity and resistance to impulsive/impactive loading
5. Work to potentially eliminate the need for a costly liner if the post-tensioning can keep the concrete in compression
6. Develop Code Case or new Code for Steel Plate-Concrete Composite construction
7. Review the Code to determine if there are outdated requirements that drive cost but in 2020 add little to ensure safety

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Improving guidance for impulsive and impactive loading

- ACI 349.4R was written to incorporate recent published blast analysis guidance, recent testing of prestressed concrete panels for blast loading, additional penetration equations, and design of blast walls for support rotation criteria in addition to ductility
- Changes due to TAC comments on ACI 349.4R are currently being balloted in ACI 349 and ACI 359
- ACI 349.4R gives suggestions for revisions to ACI 349 Chapter F and ACI 359 CC-3900
- ACI 349 and 359 will issue proposals and ballot those suggested changes within their respective committees

ASME SETTING THE STANDARD

Harmonize design provisions of containments (ACI 359) with non-containment nuclear structures (ACI 349)

- Designers of nuclear plants are expected to design the containment to ACI 359 and the other nuclear safety related structures (including those inside containment) to ACI 349
- Both are typically within the same 3D model, but have different required load factors and acceptance criteria
- This requires evaluating the 3D model to both sets of load combinations

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SETTING THE STANDARD

Harmonize design provisions of containments (ACI 359) with non-containment nuclear structures (ACI 349)

- Before changes to load factors and/or acceptance criteria can be changed, we need to understand how much design margin is included in both Codes
- A comparison of a typical BWR has been performed using typical loading from an example DCD and sections were evaluated to both ACI 349 and 359 and the margin provided by each code is compared
- A parametric study was performed adjusting the ratio of the containment height to diameter ratio, shell/mat thickness, and SSE and LOCA loading by +/- 25%. Results not significantly affected
- A study for a typical PWR is currently underway

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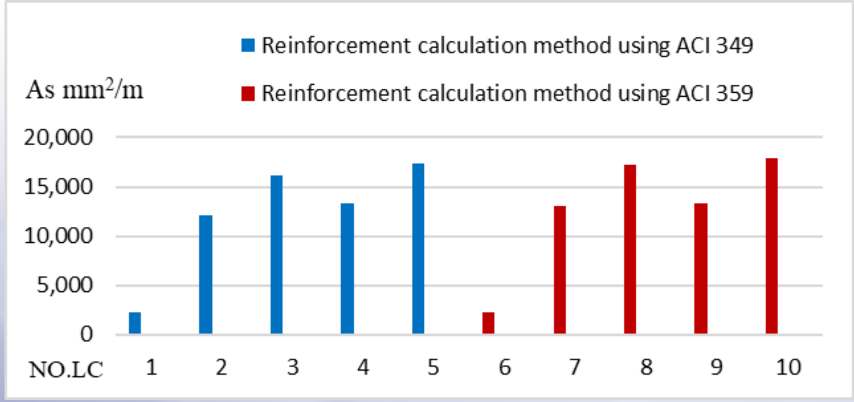
SETTING THE STANDARD

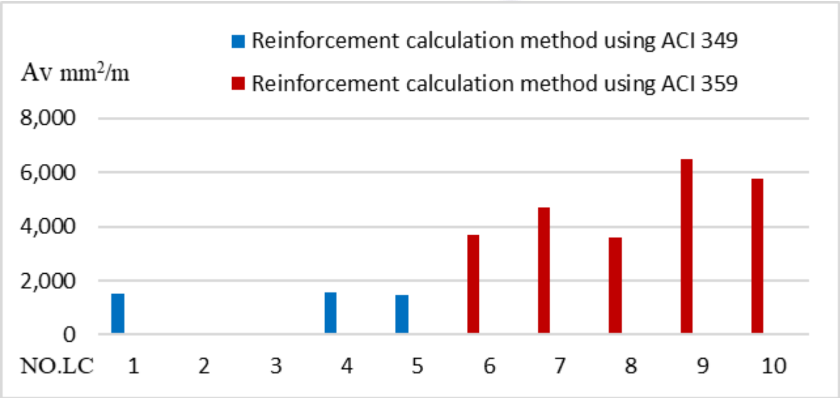
Harmonize design provisions of containments (ACI 359) with non-containment nuclear structures (ACI 349)

- The result showed as expected that ACI 359 was generally the more conservative Code, especially in the area of in-plane and tangential shear.
- For the ACI 349 demands, LC 1 is SSE alone, LC 2/3 is Large & Small LOCA, LC 4/5 is Large & Small LOCA with SSE. LC 6-10 are the same with ACI 359

As required for axial forces and bending moments



Av required for in-plane shear



Hoop direction

ASME SETTING THE STANDARD

Study on next generation containment design

- Problem: Current concrete containments are increasingly becoming less competitive from cost and schedule point of view.
- The concrete containment design can be significantly improved to achieve better cost efficiencies, schedule improvement and sustainability by utilizing the latest industry trends, technologies and innovations.
- The next generation containment is expected to include:
  - High-strength/high-performance materials to handle both accident pressure and SSE events
  - Elimination or minimization of conventional reinforcing through high post-tensioning
  - Elimination of liner plate or minimize to around penetrations
- Study underway and funding approved from ASME to pay for continued research to further the study

ASME
SETTING THE STANDARD

Study on next generation containment design

- Use of flowable concrete SCC with fiber reinforcement to accelerate placement time, eliminate labor for consolidation

Study on next generation containment design

- Add provisions for fiber reinforced concrete to enhance concrete tensile capacity and resistance to impulsive/impactive loading
- Work to potentially eliminate the need for a costly liner if the post-tensioning can keep the concrete in compression
- Research where 3D printing applications could be used

ASME
SETTING THE STANDARD

Develop Code Case or new Code for Steel Plate-Concrete Composite construction

- Problem: SMR designers want to use the Steel Plate-Concrete Composite construction for their new containment designs
- A Code Case was developed giving provisions to use a Steel Plate-Concrete Composite construction design for a nuclear containment
- The Code Case was balloted but not approved within the Joint Committee because some members believed the committee did not have enough experience in this area to develop and maintain the Code Case
- A special task group has been formed under the Special Work Group on Modernization to resolve comments and develop the provisions further and to be able to maintain the Code Case or new Code section

ASME SETTING THE STANDARD

Review the Code to determine if there are outdated requirements that drive cost but in 2020 add little to ensure safety

- A similar effort is underway within ASME Section III
- Work has begun in Division 2, but more construction experience on the committee is needed.
- Examples of cost drivers:
  - SSI and SSSI Analysis Process
  - Envelop of Loading & Element Based Elastic Design
  - "When in Doubt Make it Stout", "Too cheap to meter" Mentality
  - Excessive Rebar and Concrete
  - NQA-1 and 10CFR50 Appendix B requirements

ASME SETTING THE STANDARD

2022 NRC Standards Forum: Recent and Planned Developments and Updates in Codes and Standards, Part 2

ACI Technical Committee 349, Concrete Nuclear Structures

Madhumita Sircar, Chair

Madhumita.Sircar@nrc.gov

Carlos Cantarero-Leal, Secretary

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Sep/28/2022

ACI 349 Status Update (1/8)

Status of main publications by American Concrete Institute (ACI) Technical Committee 349, “Concrete Nuclear Structures”:

- ACI CODE-349-13, “Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary”; in the process of being revised, next edition planned for 2023
- ACI PRC-349.1-07, “Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures”; Last published 2007; in the process of being revised, next edition planned for 2023
- ACI PRC-349.2-07(20), “Guide to the Concrete Capacity Design (CCD) Method – Embedment Design Examples”; Last published 2007; Reapproved 2020
- ACI PRC-349.3-18, “Report on Evaluation and Repair of Existing Nuclear Safety-Related Concrete Structures”; Last published 2018
- ACI PRC-349.4, “Guidelines for Design of Nuclear Safety-Related Structures for Impactive and Impulsive Loads Using ACI 349 and ASME Section III, Div. 2 Provisions”; in preparation (new document)

ACI 349 Status Update (2/8)

Status of next edition of ACI CODE-349:

- Committee resolving ACI Technical Activities Committee (TAC) comments
- Major change: reorganization of the Code according to the new table of contents introduced in ACI CODE-318-14
- Technical improvements (see next slide)
- ACI CODE-349-xx depends on ACI CODE-318-14 and should be used in conjunction with that Code, with the following exceptions:
  - Chapter 17 (NEW), “Anchoring to Concrete”, is independent -- in ACI CODE-349-13 was Appendix D
  - Chapter 18, “Provisions for Earthquake-resistant Design”, is independent -- in ACI CODE-349-13 was Chapter 21
  - All appendices, which are unique to ACI CODE-349

ACI 349 Status Update (3/8)

Next edition of ACI CODE-349 (in process) main technical changes:

- Changes in chapter 5 – Loads and Load Combination
    - Section 5.3.1 includes instructions on when Operating Basis Earthquake (OBE) does not need to be considered (consistent with NRC regulation, 10CFR50 Appendix S)
    - Minor changes in 2 load combinations (wind load, normal operating thermal, 5.3.1d, 5.3.1e and R5.3.1)
- Provisions for 80,000 psi rebar
    - Yield strength limit for shear reinforcement for walls and slabs increased from 60,000 to 80,000 psi (Table 20.2.2.4a—Nonprestressed deformed reinforcement)
    - Chapter 25 includes detailing requirements for 80,000 psi rebar taken from ACI 318-19
    - Note that ACI 349-13 introduced the use of 80,000 psi as longitudinal rebar for flexure only
- New commentary refers to ASME Section III Division 2 for guidance on how to implement QC for welded splices (R25.5.7.1.1 and R25.5.7.1.2)
- Major changes in Impulsive and Impactive Loading (Appendix F)

ACI 349 Status Update (4/8)

Chapter 17, "Anchoring to Concrete":

- ACI CODE-318-14 moved Appendix D, "Anchoring to Concrete" into Chapter 17, and ACI CODE-349-xx follows the same structure
- ACI CODE-349-xx Chapter 17 is not dependent of ACI CODE-318-14 Chapter 17, but its contents are based on information from the following documents:
  - ACI CODE-349-13 App. D – Anchoring to Concrete
  - ACI CODE-318-14 and 318-19, Chapter 17
- Technical changes:
  - Shear lug provisions
  - Tension-shear interaction provisions
  - Use of groups of straight reinforcing bars as anchors

ACI 349 Status Update (5/8)

Technical Committee’s new business item list:

- Introduce changes to ACI CODE-349 in response to NEI 19-03, Rev 1, "Advanced Reactor Codes and Standards Needs Assessment", Nuclear Energy Institute, March 2020
  - Reassess temperature limits for structural concrete (some information related to advanced reactors environment is proprietary)
- Anchorage of embedment plates using groups of reinforcing bars
  - Ongoing testing will result in future new provisions

ACI 349 Status Update (6/8)

Technical Committee's vision-casting for next few years:

- Subcommittee B, "Design":
  1. Expand analysis and design recommendations for nuclear structures that are labyrinthine in plan comprised of several inter-connected, intersecting, connected walls
  2. Design for combined forces, moments, and shears. Interaction of in-plane and out-of-plane shear
  3. Recommendations for Averaging of Demands over finite lengths
  4. Innovations and Advances:
     - High strength materials
     - Ultra high-performance materials
     - 3D printed materials

ACI 349 Status Update (7/8)

Next edition of ACI PRC-349.1 (in process), Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures", main changes:

- New chapter on design of concrete walls for thermal loads (Chapter 5), including:
  - brief background describing thermal loads and structural response
  - procedure for calculating the required strengths under thermal loads
  - detailed design example using finite element method
  - closed form solution for thermal induced stresses in a cylindrical compartment
- Changes to Chapter 3, frame structures:
  - design example using finite element method
  - The example is based on a previously existing example using moment distribution method
- The report clarifies that thermal loads due to fire events are outside the scope of this document (Chapter 1)
- All references to fire events have been updated
- The report now refers to ASCE 43 for stiffness properties of members under thermal loads (previously a value of 0.5E was recommended in the report)

ACI 349 Status Update (8/8)

New ACI PRC-349.4 (in process), “Guidelines for Design of Nuclear Safety-Related Structures for Impactive and Impulsive Loads Using ACI 349 and ASME Section III, Div. 2 Provisions”:

- Prepared by the ACI 349/359/370 task group, which had the charter of aligning and updating Impulsive and Impactive Loading provisions for both ACI 349 and ACI 359 (ASME BPVC Section III Div. 2)
- Impulsive and Impactive Loading provisions are included in ACI CODE-349 Appendix F and ASME BPVC Section III Div. 2 CC-3900, 2011 edition
- The report gives the genesis of the provisions that are proposed to be incorporated into these code documents