IAEA Technical Meeting on Codes and Standards

EPRI's Engineering and Construction Innovations Updates

Hasan Charkas, PhD., P.E.
Principal Technical Leader

May 10th, 2022

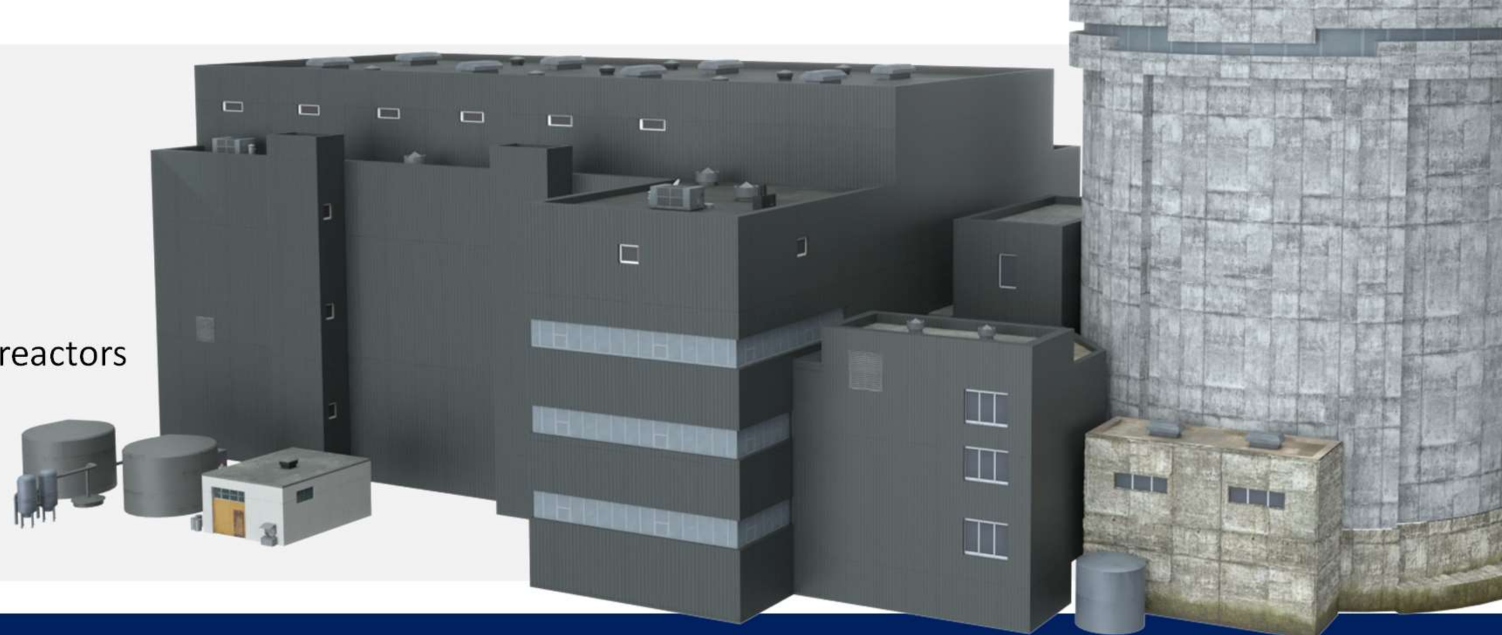
Date: Add submission date and/or revision date & #

Advanced Reactors are Here

In this decade…

- Microreactors
- Non-light water reactors
- Light-water small modular reactors

… will be deployed



THE TIME TO PREPARE FOR AN ADVANCED REACTOR FUTURE IS NOW

A sample of EPRI Products to Reduce Deployment Cost

Total Potential Savings from Top 5 Cost Drivers: ~$3000/kWe *(From: 3002015935)*

Potential Savings ($/kWe)

Construction Task Duration
- EPRIU Training Courses*
- New Plants Technical Assistance Program*
- Digital Twins*
- Artificial Intelligence and 3DM Research*
- Supplier Quality Management for Construction - 3002000521
- Best Practices for Construction Acceptance Tests- 3002021018
- Welding and Fabrication Critical Factors for New NPPs-1019209

Civil/Structural Design
- Siting Guide - 3002003126
- Owner-Operator Requirements Guide - 3002015751
- Cost Basis for Utilizing Seismic Isolation for NPP Design- 3002000561
- Mass Concrete Modeling - 3002007577
- Steel-Plate Composite Research*
- Concrete Under Elevated Temperatures*

Constructability
- Constructability Guide - 3002015932
- Demonstration of Self Consolidating Concrete- 3002007567
- Moisture Tolerant Coatings- 3002010563
- Optimizing Concrete Placement - 3002013041
- Modular Construction Roadmap - 3002016067

Materials
- SMR Advanced Manufacturing - 3002011037
- Modular In-Chamber EBW - 3002018146
- AR Material Development Roadmap*
- High Strength Reinforcement- 3002010486

Inspection
- NDE Needs for New Nuclear Plant Designs - 3002013494
- Inspection Guidance for Reinforced Concrete Construction- 3002015943
- Automated QA Inspection for Embedded Items in Concrete*

Cost Drivers

*Ongoing

EPRI

Engineering and Construction Innovation

GOAL & VALUE

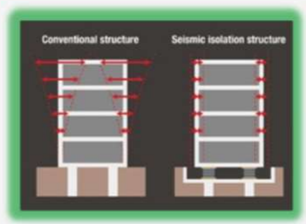
Identify, develop, qualify engineering and construction technologies that enable:

Reduced Cost | Increased Quality | Improved Efficiency

- Modular Construction Technologies
- Structural Health Monitoring
- Digital Twin Applications

Construction Technologies

- Risk-Informed Performance-based Design Solutions
- Steel-plate Composite (SC) Structures Analysis Guide
- Analysis of Systems and Components



Engineering Solutions

- Assessing Concrete Behavior under Elevated Temperatures
- Testing high-strength Large Steel Rebars for applications
- Self-consolidating Concrete for Mass Construction Applications

Concrete and High Strength Rebars

EPRI

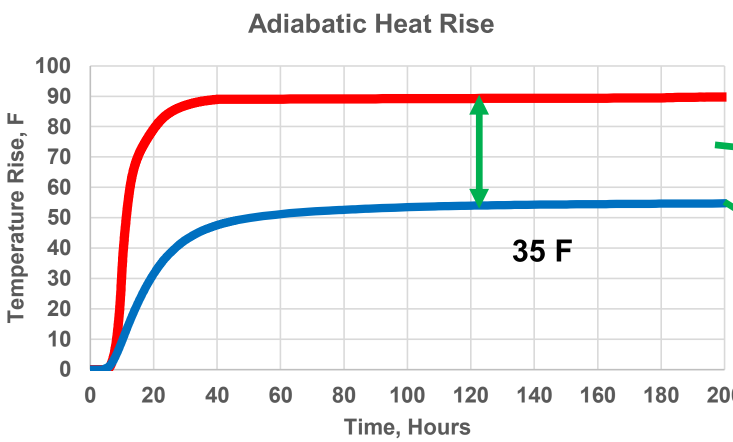
Self Consolidating Concrete (SCC) Used in Mass Concrete Structures

SCC has better flowing ability than conventional concrete and is better suited for areas of heavy congestion

- Traditional self consolidating concrete mixture has a higher heat of hydration than conventional concrete
- The use of alternative materials as a replacement of cement can help lower the temperature rise
- Sixteen SCC mixtures using different cementitious material replacements were evaluated
- Comparison of conventional concrete mixture and SCC
- Modeling was performed to evaluate the temperature heat rise

EPRI

Self Consolidating Concrete Used in Massive Concrete Structures

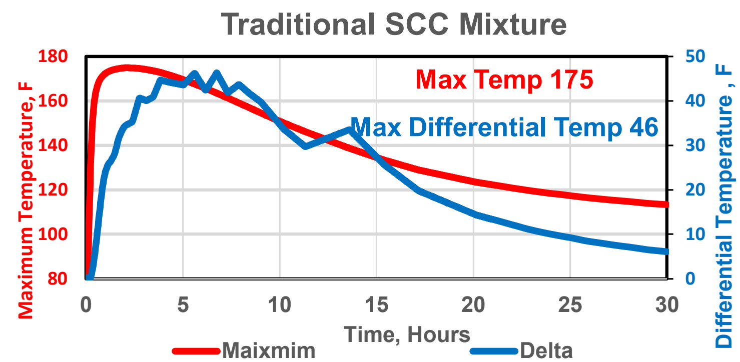


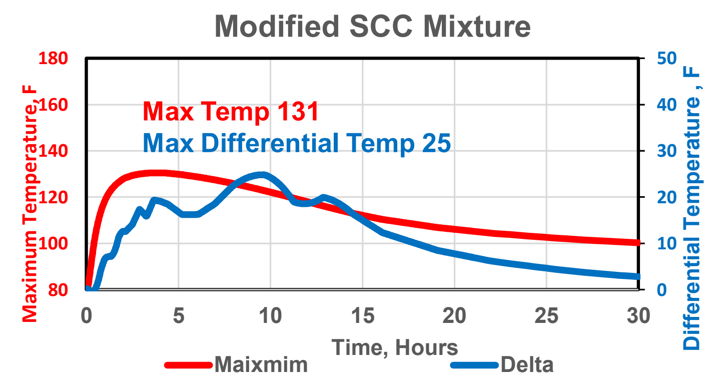
Traditional SCC mixture—adiabatic heat rise 90 F (33 C)

Modified SCC mixture– adiabatic heat rise 55 F (13 C)

<u>**Major Benefits:**</u>

- **Less cracking potential**
- **Less Risk of Delayed Ettringite Formation**
- **Shorter protection cycles—reduces construction time**
- **Allows for concrete placement of thicker elements**





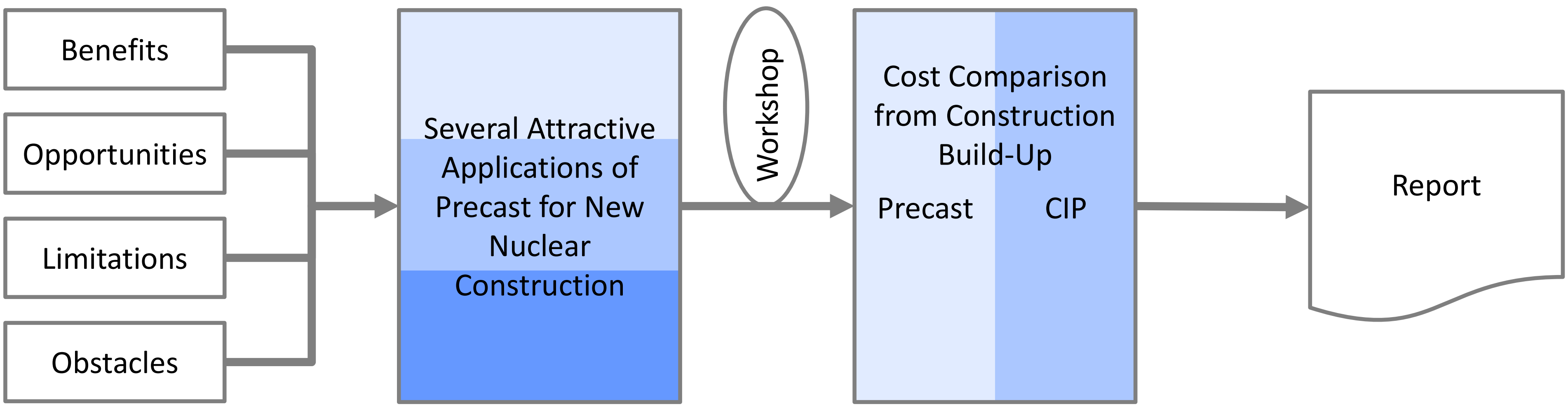
Temperature profile chart for an 8-foot thick (2.4 m) wall cast with concrete at temperature of 80 degrees (27 C)

6

EPRI

Evaluation of Precast Concrete Construction for New Reactors

Precast concrete may have potential to **reduce construction cost** of nuclear plants



Apply industry perspectives for meaningful study.

Evaluate Different Concrete Mixtures at Different Temperatures

Nine different concrete mixtures are currently being tested

The Process Begins

Making Test Specimens

Water Cured for 28 Days

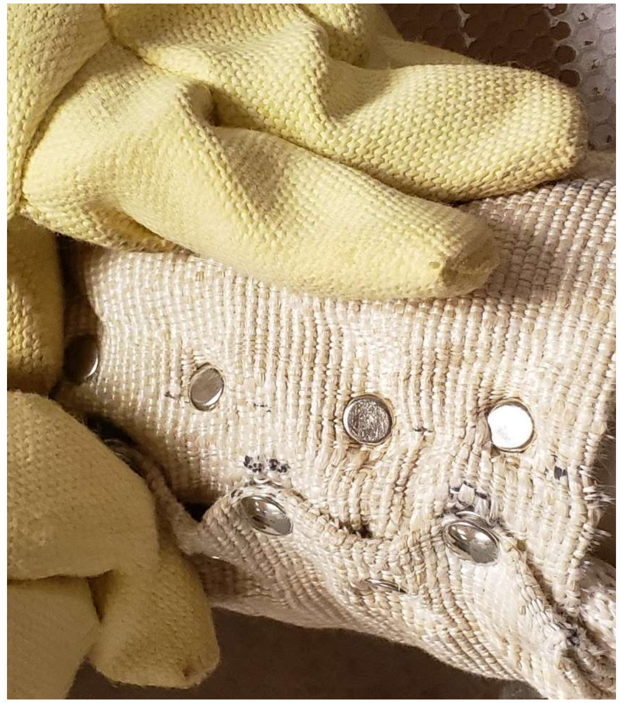
Record Temperatures

Concrete Heated to 350 to 800 F (177 C – 427 C)

Air Dried for an Additional 28 Days

Testing Protocol

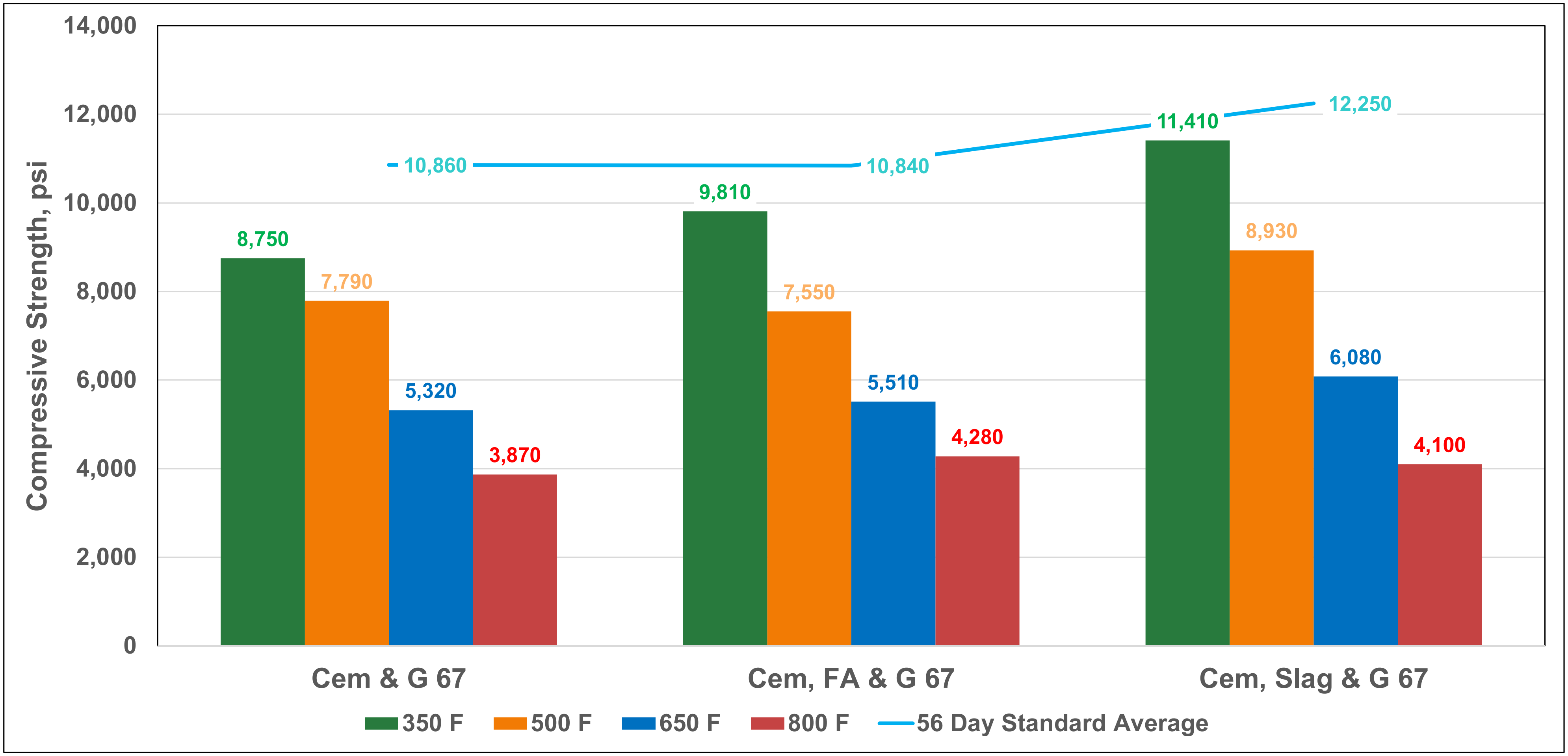
- Remove from oven



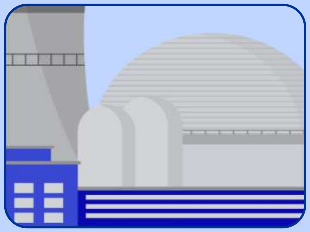
Wrap in heated blanket

Test at elevated temperature

Results for Cementitious Materials (10,000 psi = 69MPa)

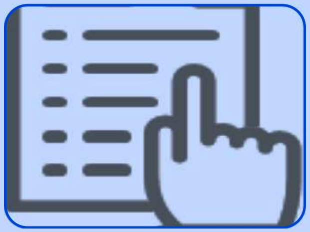


Assessment Guidance of SC Walls for New Reactors



Objective

- Identify items in the current design practices for the SCs that need clarifications
- Provide guidance for the identified items
- Experimentally verify the behavior of SC walls with critical flaws and develop approaches for repair and retrofitting of these flaws when identified.



Status

- Engaged diverse industry stakeholders with pertinent experience
- Developed a list of items based on input from designers and analysts
- Working on creating guidance and preparing the experimental studies for critical flaws

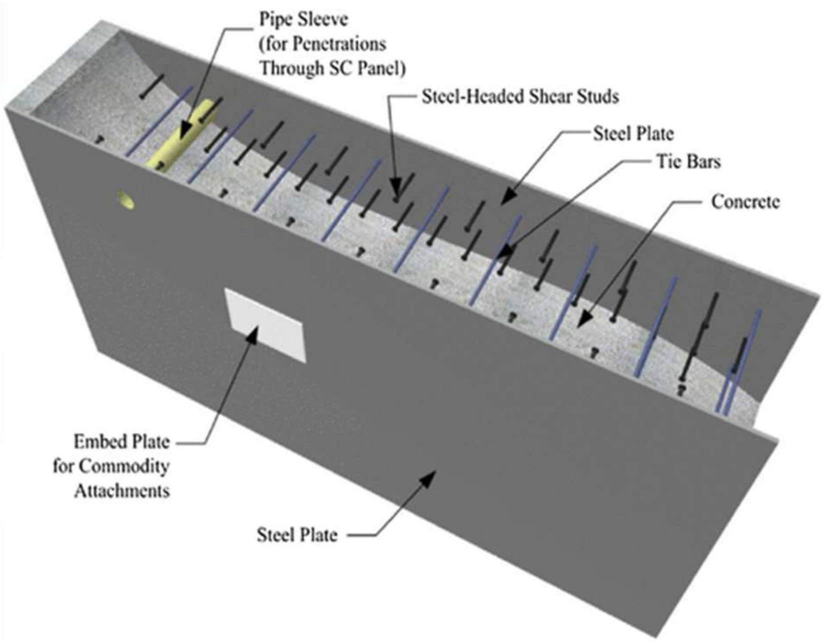
Next Steps

- Continue developing the guidance and engagement with industry stakeholders

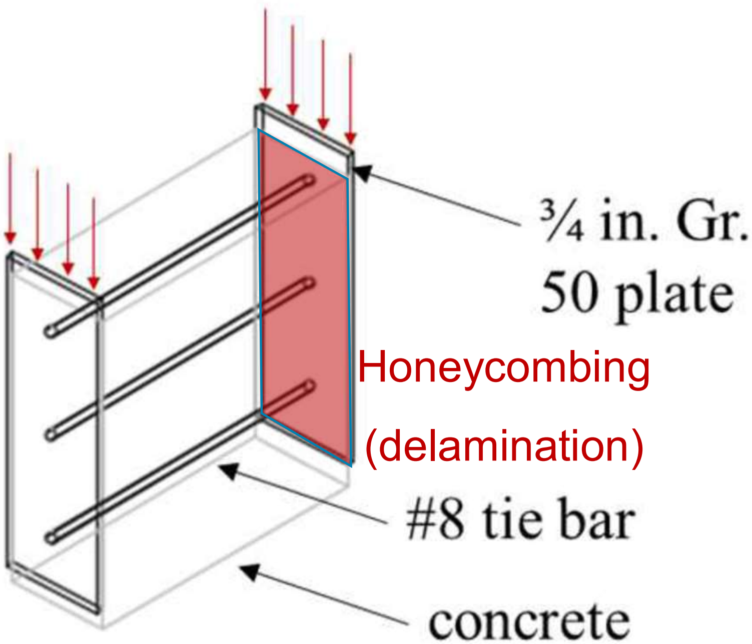
EPRI

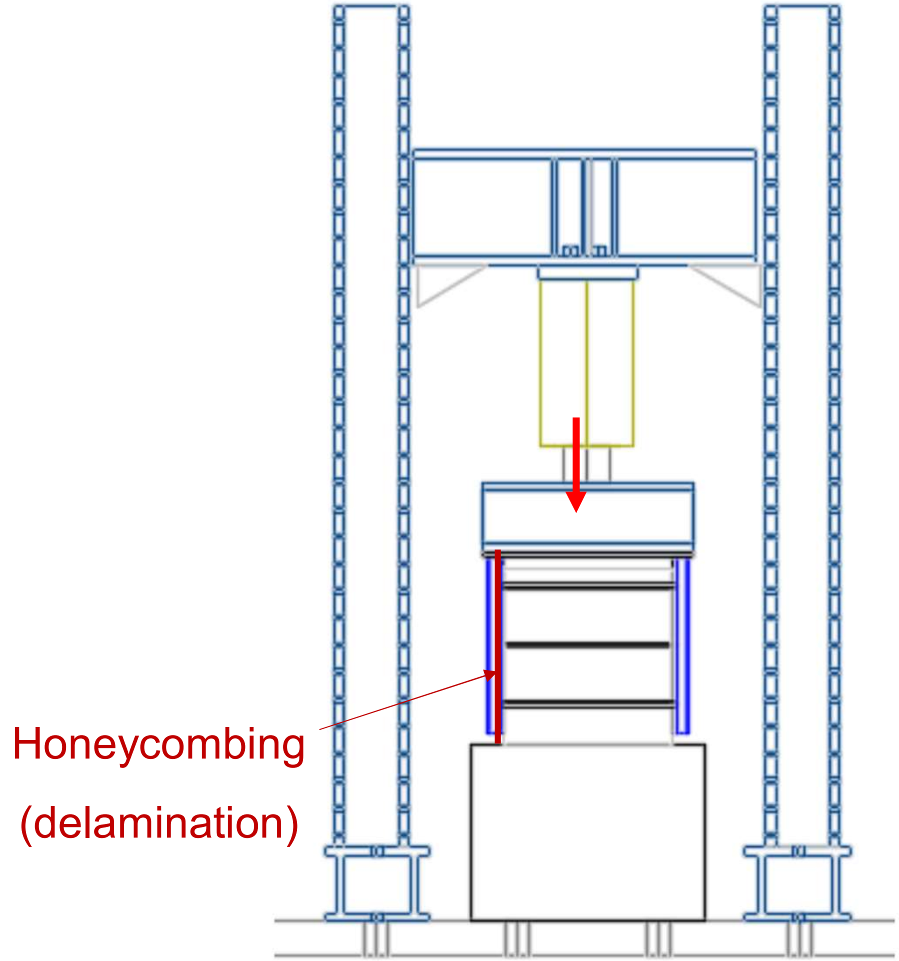
Assessment Guidance of SC Walls for New Reactors

Material	Components	Description	Construction Stage	Probability	Location
Steel	Steel Plate	Plate-plate welding	Fabrication Erection	Low	SC module to module SC wall connections
	Stud Anchor	**Stud welding**	fabrication	High	SC module
	Tie Bar	**Tie welding** (circumferential)	fabrication	High	SC module
	Tie Plate	**Fillet welding**	fabrication	High	SC module
Concrete	Concrete infill	**Void in concrete (center) Void in concrete (around stud anchor heads) Honeycombing (delamination)**	Erection	High	SC module

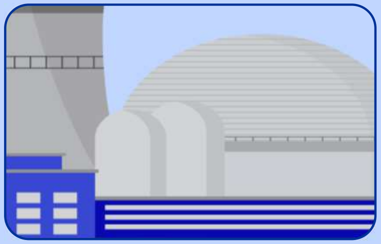


Example of experimental investigations on SC wall specimens



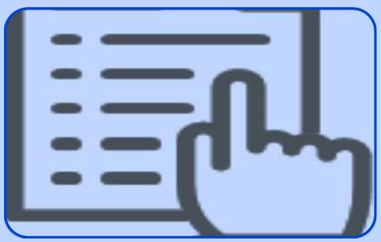


2022 Project – Geotechnical and Structural Monitoring Considerations for Deeply Embedded Facilities



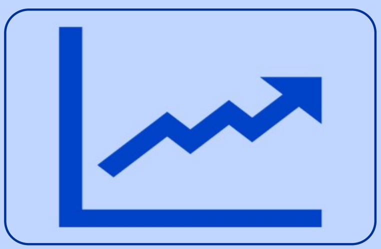
Issue

- Advanced Reactors (ARs) developers are exploring designs involving deeply embedded structures
- Guidance on geotechnical approaches that are not previously used in nuclear applications is needed
- Below grade monitoring and inspection programs will have an increased importance for long term applications.



Scope

- Characterize potential geotechnical and structural monitoring challenges for deeply embedded structures
- Summarize available techniques and technologies to mitigate and/or accommodate challenges
- List of excavation and engineering best practices for deeply embedded structures construction.



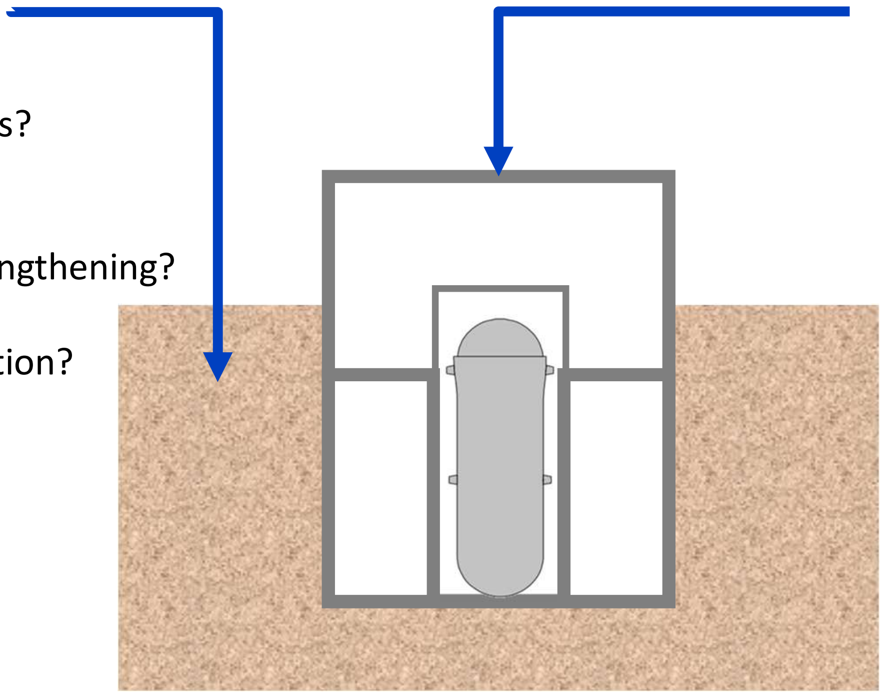
Value

- Inform engineers (structural, geotechnical and construction) of various geotechnical topics
- Proper designs and planning for more efficient and safe construction
- Inform utilities of various pertinent monitoring and inspection programs.

How to address engineering challenges to enable leveraging safety advantages of deeply embedded structures?

Geotechnical

- Site categorization?
- Subsurface conditions?
- Geo-hazards?
- Site suitability?
- Soil stabilization/strengthening?
- Deep excavations?
- Foundation construction?

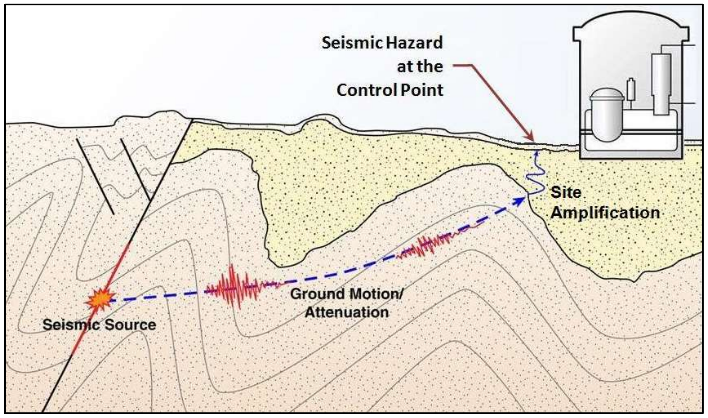


Structure Monitoring

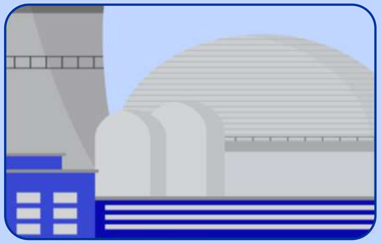
- Degradation mechanisms?
- Precursor indications?
- Instrumentation and hardware?
- Uncertainties and variability?
- As-built vs. design configuration?
- Construction loads?
- Accessibility for maintenance?

How to assess the challenges associated with AR design against External Hazards?

- Risk informed performance-based methods for External hazards (i.e., seismic, external flooding, high winds,….) continue to have an important role in the design
- Risk informed due to incorporating seismic PRAs in the design process and inclusion of defense-in-depth adequacy
- Performance based due to using Frequency Consequence (F-C) and performance target of SSCs.

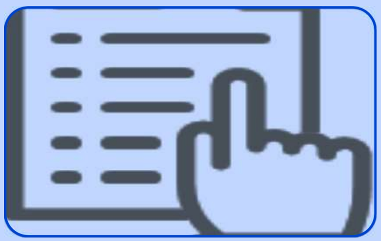


2022 Project – Risk-Informed Performance Based Design Methods for External Hazards



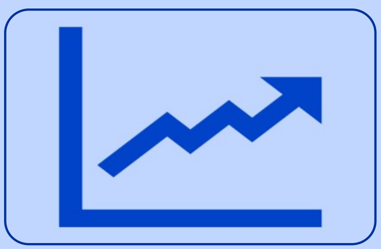
Issue

- Increasing efforts in the industry is focused on the Licensing Modernization Project (LMP) to enhance the risk informed and performance-based (RIPB) methodologies for ARs (alternative to Standard Review Plan methodology)
- How will this affect the designs and how will it be implemented?



Scope

- Identify challenges and best practices for implementing RIPB methodologies in design for external hazards
- Research design strategies to leverage RIPB methodologies to optimize construction costs
- Work with the AR community to identify common tools and methodologies to enable proper design implementations
- Demonstrate the guidance through engineering design examples



Value

- Common reference for RIPB methodologies in design and a chance to identify challenges to plan resolutions for a smoother implementation
- Identify design strategies for construction cost optimizations


Together…Shaping the Future of Energy™