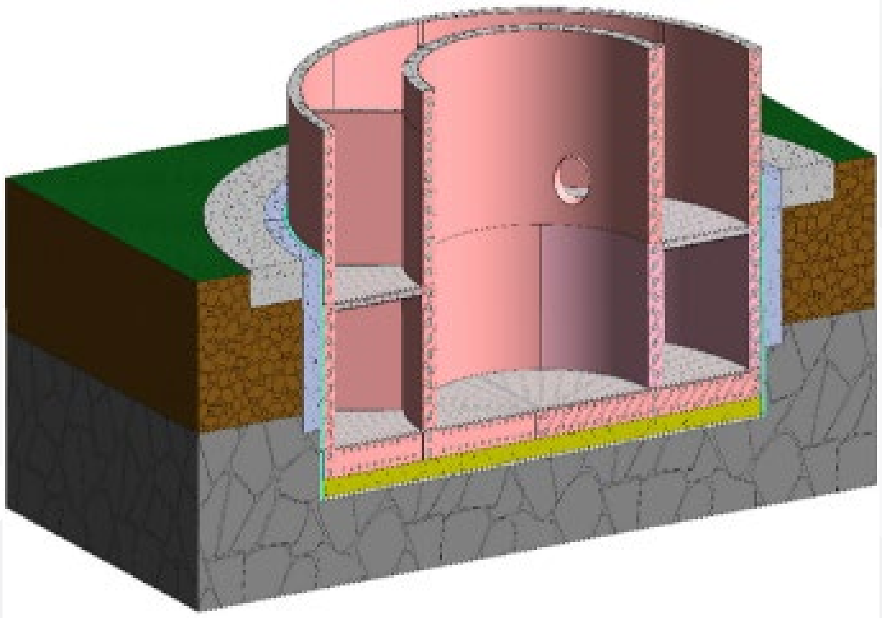
NRIC National Reactor Innovation Center

Advanced Construction Technology Initiative (ACTI) Program Update

Brad Tomer, Director NRIC

04/03/2025



MIS-25-83644

Advanced Construction Technologies

Prototype & Demonstrate Technologies

- Significantly reduce cost of new SMR builds
- Compress construction schedule by as much as 25%
- Reduce required site work & improve overall quality of structure
- Support long-term structure monitoring

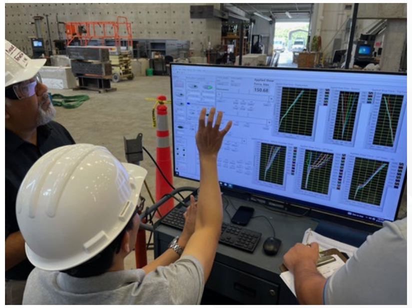
Cost Shared Project

Phase One – Prototype & Test

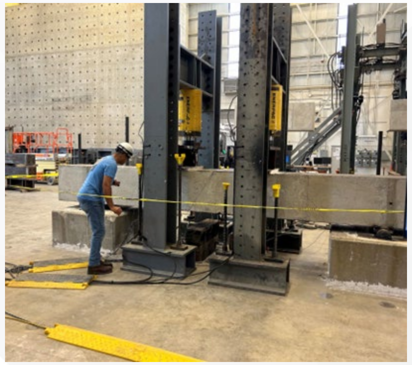
- Prototyped modular steel/concrete composite walling system
- Developed non-destructive examination and welding techniques
- Demonstrated strength of wall systems
- Developed digital twin and monitoring approach
- Designed optional phase two test unit
- Submitted phase two proposal

Optional Phase Two - Field Demonstration

- Demonstrate 60-degree pie shape containment walling system
- Inner and outer walls, base mat integration, multi-story
- Deploy digital twin plus sensor technology for monitoring
- NDE Execution and Deployment
- NRC Engagement & Decommissioning



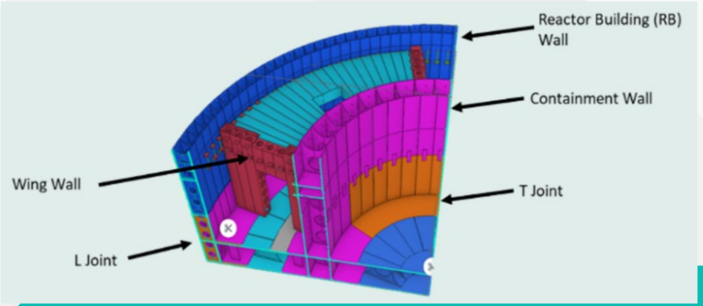
Testing DPSC samples at Purdue

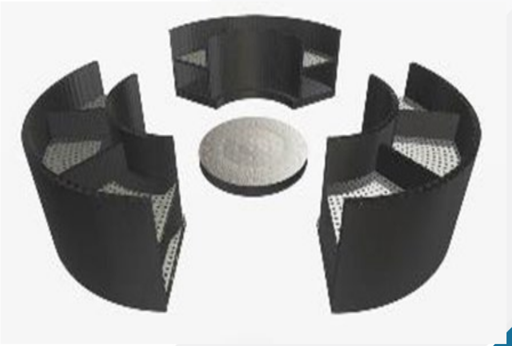


Team – General Electric Hitachi

EPRI, Black & Veatch, Purdue Applied Research Institute, UNCC, Aecon, and Tennessee Valley Authority

Proposed Phase II containment system





Modular Wall Concept

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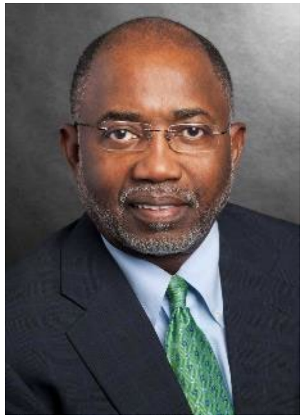
NRC Collaboration

- 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

Benefits of Demonstration & Testing

- Bridge the gap between development and commercialization:
    - Mature technology readiness and reduce risks to participants for first of a kind build.
    - Facilitate partnership between technology developers, end users, national labs, universities, regulators, industrial participants.
- Hands on learning reduces risks associated with first commercial build.
- Build confidence with regulators.
- Develop supply chain.

Agenda

- GEH – Kyle Sena
  - GEH Project Phase 1 accomplishments and updates
- Purdue – Jungil Seo: Sr. Principal Research Scientist
  - DPSC Testing Results.
- EPRI – Bruce Greer: Principal Technical Leader for the Advanced Nuclear Technology Program
  - Digital Twin & NDE Techniques

GE VERNOVA

PHASE 1 COMPLETION PROJECT
NRIC PROGRAM REVIEW

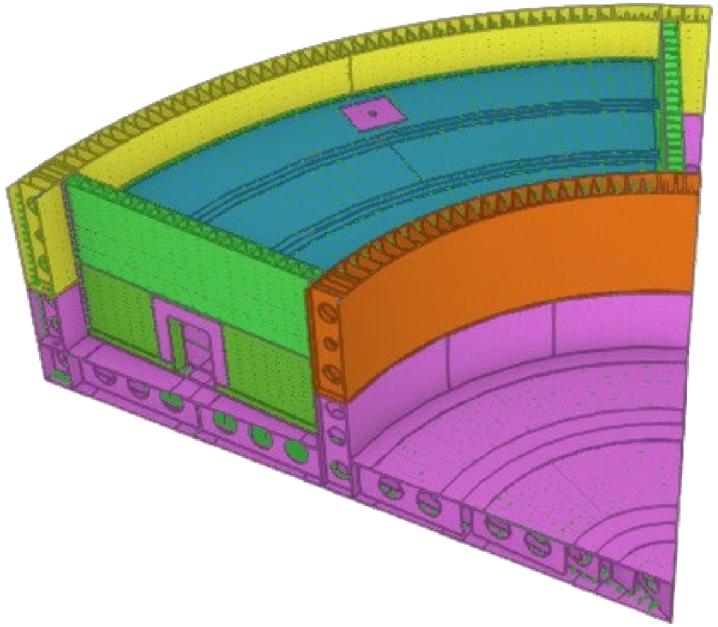
National Reactor Innovation Center (NRIC) Advanced Construction Technology (ACT)
04/03/2025

Project Phase 1 Completion

GE VERNOVA

- **Original Phase 1 Project (2023)**
  - Completed through 90% Design Review with SteelBricks™ (SB) Technology

- **Phase 1 Completion Project (2024)**
  1. DPSC Engineering to support demonstration facility construction
  2. DPSC Sample Fabrication and Testing
     - 9 specimens and tests
     - All exceeded acceptance criteria
  3. Phase 2 Proposal
     - Issued to BEA December 2024
     - Progressing through review and feedback cycle with NRIC

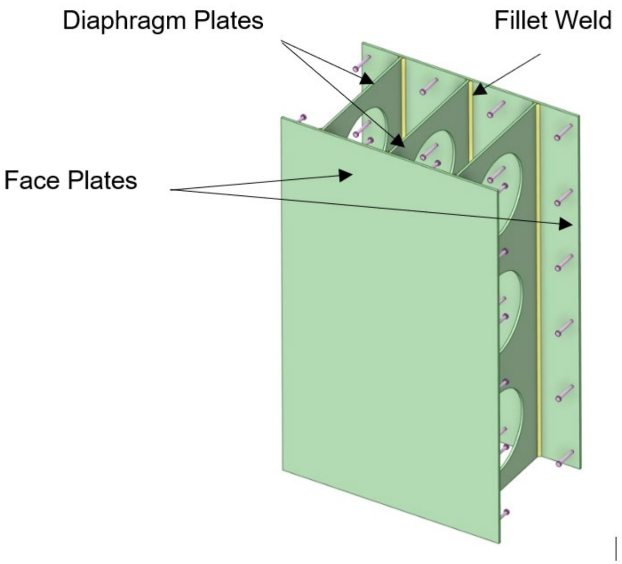


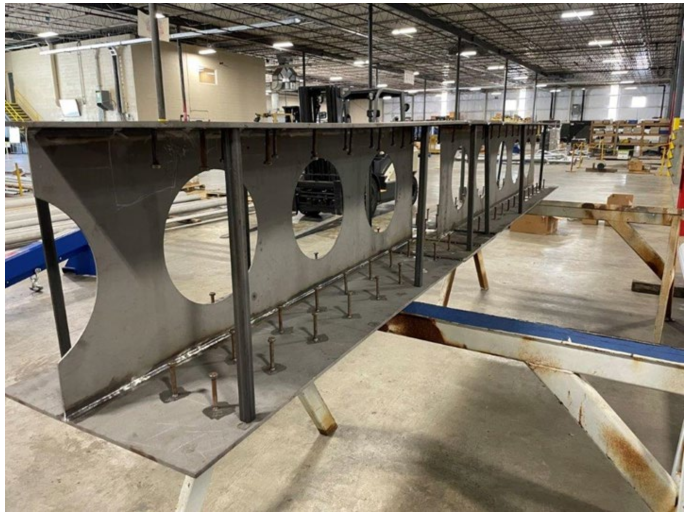
Potential Project Phase 2

GE VERNOVA

- **Phase 2 Scope:**
  - Implementation of Phase 1 Deliverables
    - Design drawings, construction plan, test plan, decommissioning plan
  - Site Prep work at TVA's Clinch River
  - Offsite Fabrication of DPSC Panels
  - Onsite Assembly & Construction of Demonstration Facility
  - NDE Testing and Digital Twin (EPRI)
  - Decommissioning

- **Phase 2 Support:**
  - Estimated ~5 months of fabrication, ~7 months of construction
  - Provide ongoing lessons learned to industry as Phase 2 progresses
    - Phase 2 expected to occur in parallel to BWRX-300 construction in Canada



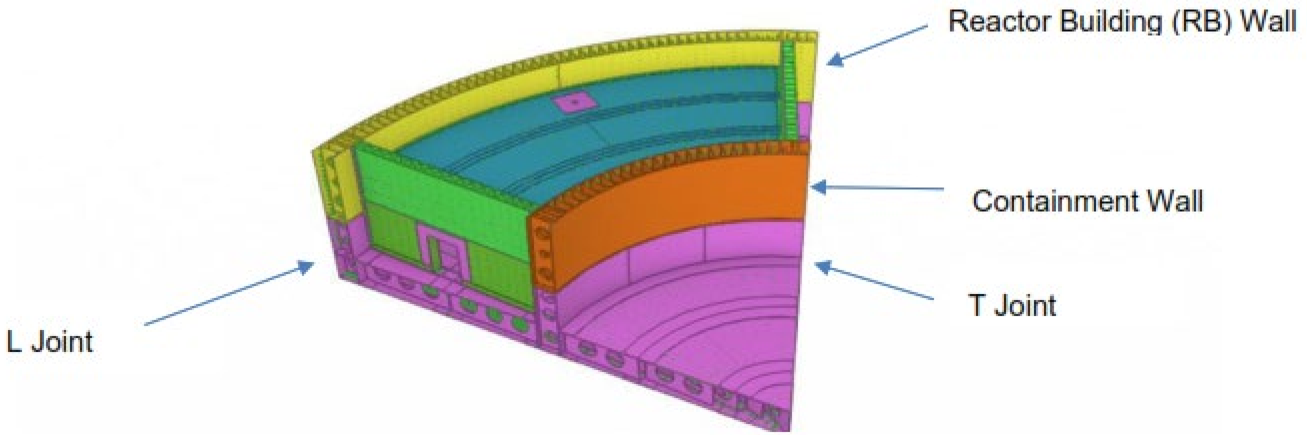


Project Objectives & Benefits

The NRIC ACT Project will benefit the nuclear industry through the following:

- Demonstrate **advanced fabrication & construction techniques** for DPSC technology
- The **workforce will be educated** in building techniques using advance welding and assembly processes
- Module fit up techniques will be advanced with **digital twin technology** to better align sections
- **Automated welding techniques** will be employed to prove a reduction in construction time and improved quality
- Capture **Lessons Learned** in a robust program to share with future projects
- Develop construction and **fabrication workforce capability** for DPSC modules
- Reduce **regulator risks** for using SC for containment and basemat structures
- Demonstrate **improvement of costs and schedule** of new nuclear build projects as well as mitigation of construction risk during construction preventing cost overruns and schedule delays experienced by many new nuclear builds.
- Establish and improve **supply chain capabilities** for mass deployment to nuclear industry

Phase 1 Mockups & Phase 2 Model



Q&A

GE VERNOVA

Questions?

GE VERNOVA

Diaphragm Plate Steel-plate Composite (DP-SC) Prototype Testing

Dr. Amit Varma, Dr. Jungil Seo

04/03/2025

Objectives

- To experimentally confirm the structural performance of Diaphragm Plate Steel-plate Composite (DP-SC) system and its connections used in SMR.
- A total of 9 DP-SC scaled prototype specimens were constructed and tested for various loading conditions applicable for containment (i.e., pressure-retaining) applications.

Objectives

The scaled prototype specimens were designed to be representative of the following components:

(i) Mat foundation (basemat),

(ii) Inner cylindrical shaft (i.e. SCCV wall),

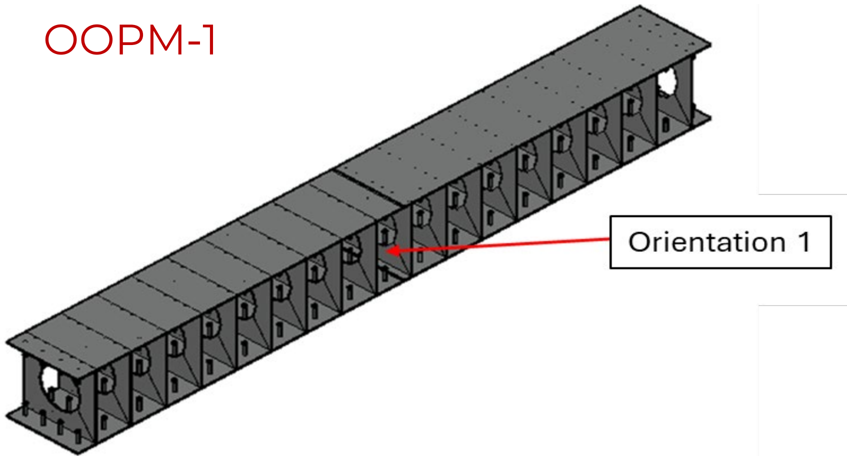
(iii) Inside cylindrical shaft (i.e. SCCV wall)-to-mat foundation connection.

Summary of Testing

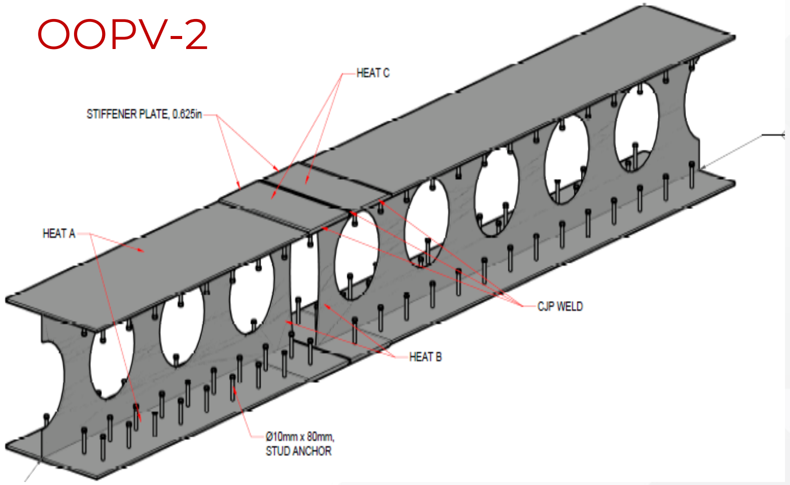
Test	Prototype	Test Objective	Number of Tests	Scale
Out-Of-Plane Moment (OOPM)	Mat foundation	Out-of-plane flexure strength	2	1:2
Out-Of-Plane Shear (OOPV)	Mat foundation	Out-of-plane shear strength	2	1:2
Bi-Axial Tension	SCCV	Strength of containment vessel walls under biaxial loading and thermal	2	1:3
In-Plane Shear (IPV)	SCCV-to-Mat Connection	Strength of SCCV-to-mat foundation connection under seismic loading and accident thermal	3	1:3

Summary of Testing

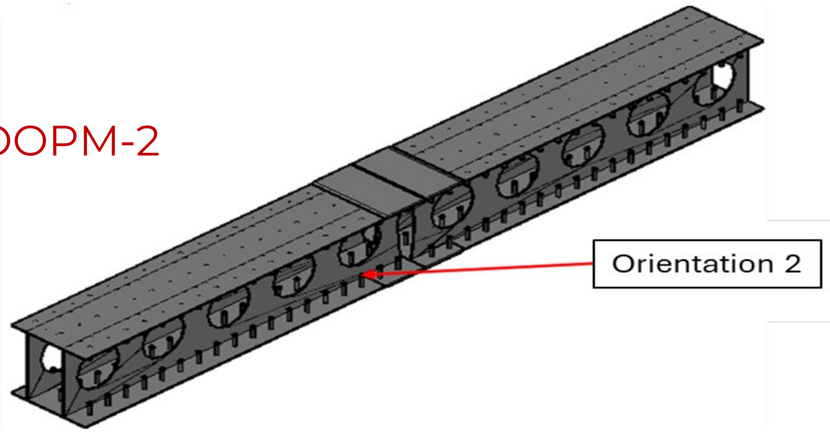
OOPM-1



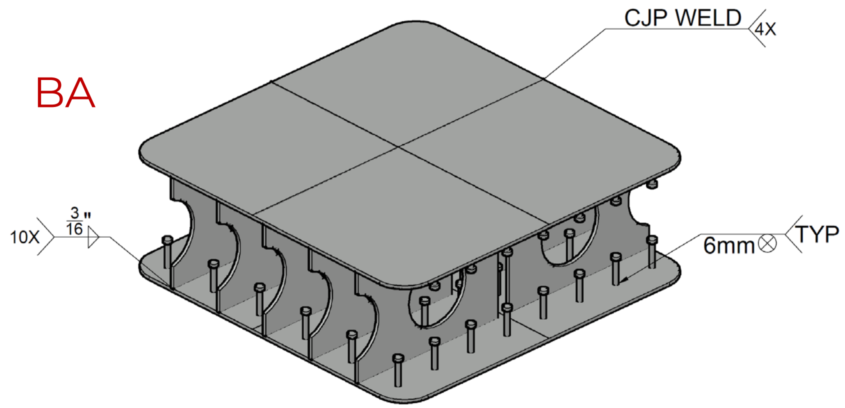
OOPV-2



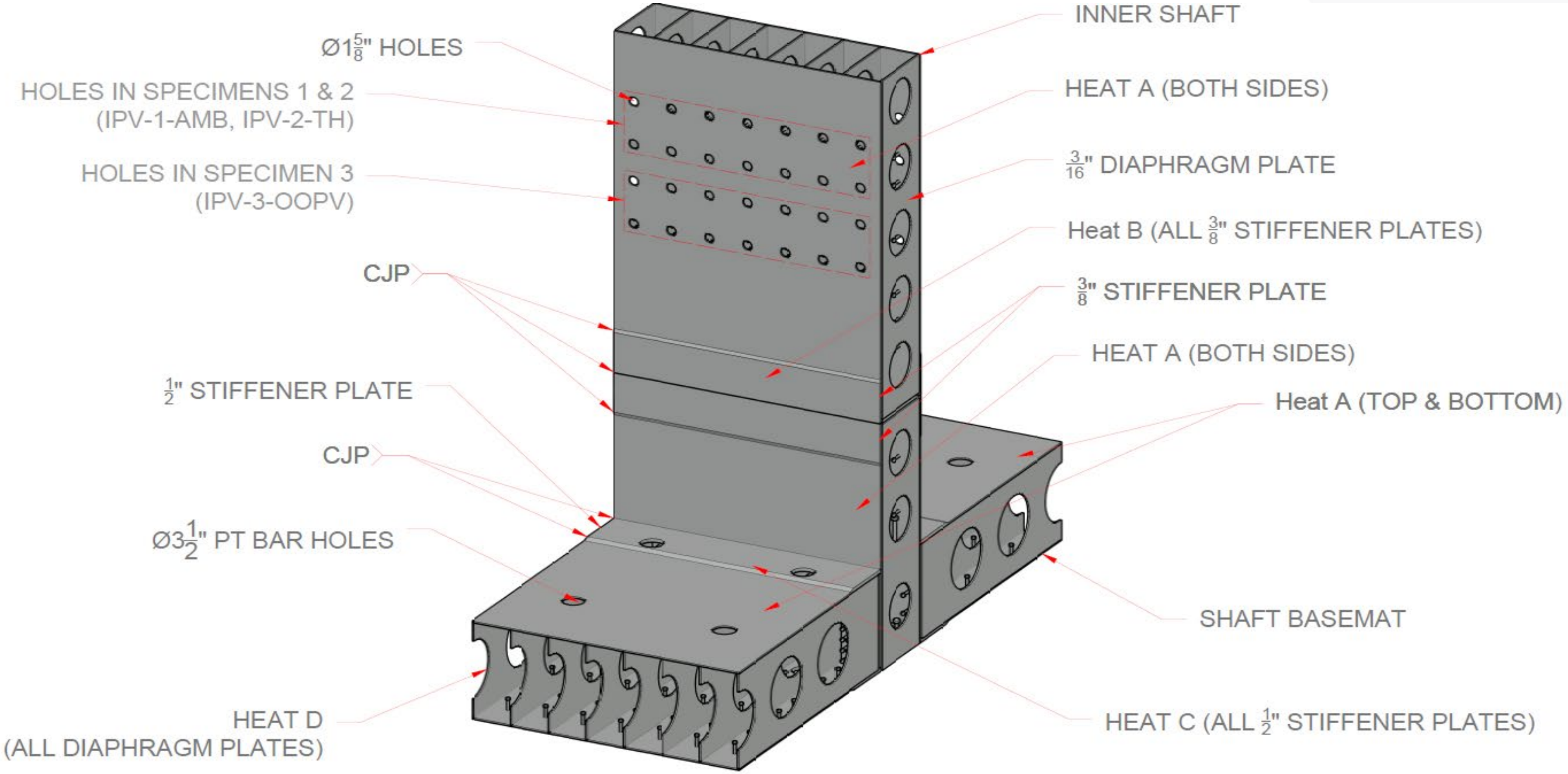
OOPM-2



BA



Summary of Testing



Summary of Test Results - OOPM

Test Series	Acceptance Criteria	Brief Summary of Testing Results
Out-Of-Plane Moment (OOPM)	Specimens develop flexural yielding before shear failure. Load carrying capacity is equal to or greater than the nominal flexural capacity calculated using ANSI/AISC N690 or ACI 349 code-based equations Specimens exhibit a minimum ductility ratio of 3.0.	The OOPM specimens developed and exceeded their nominal flexural capacities. The OOPM specimens exhibited ductility ratios of 3.83 and 8.16. No sign of out-of-plane shear failure prior to developing flexural capacities.

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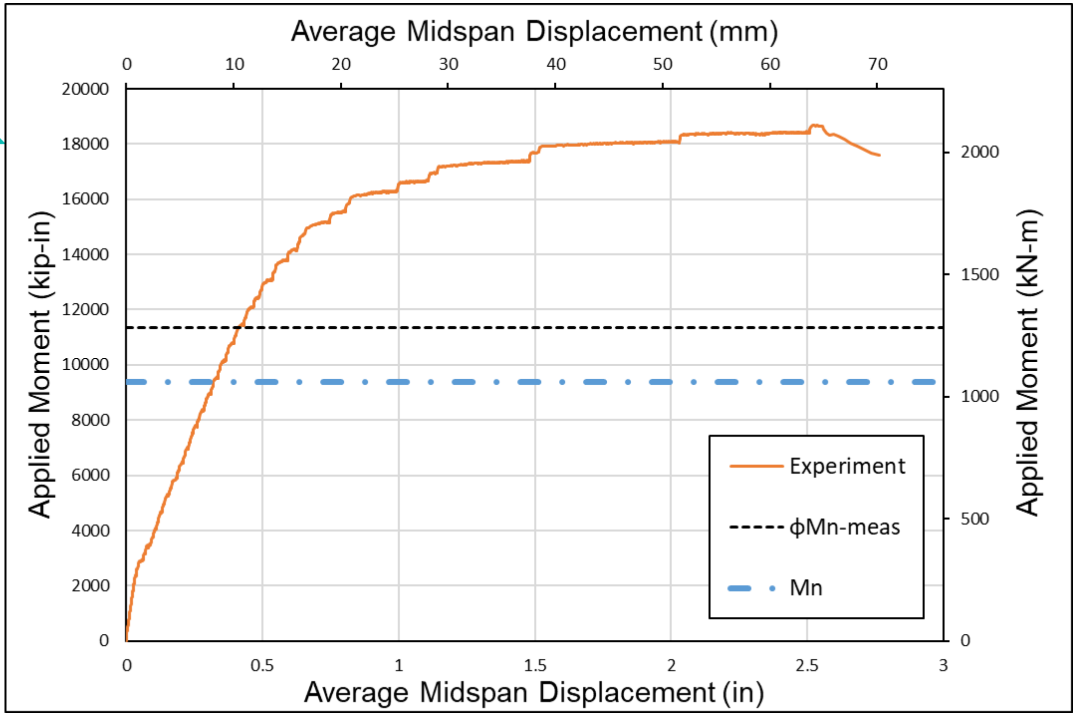
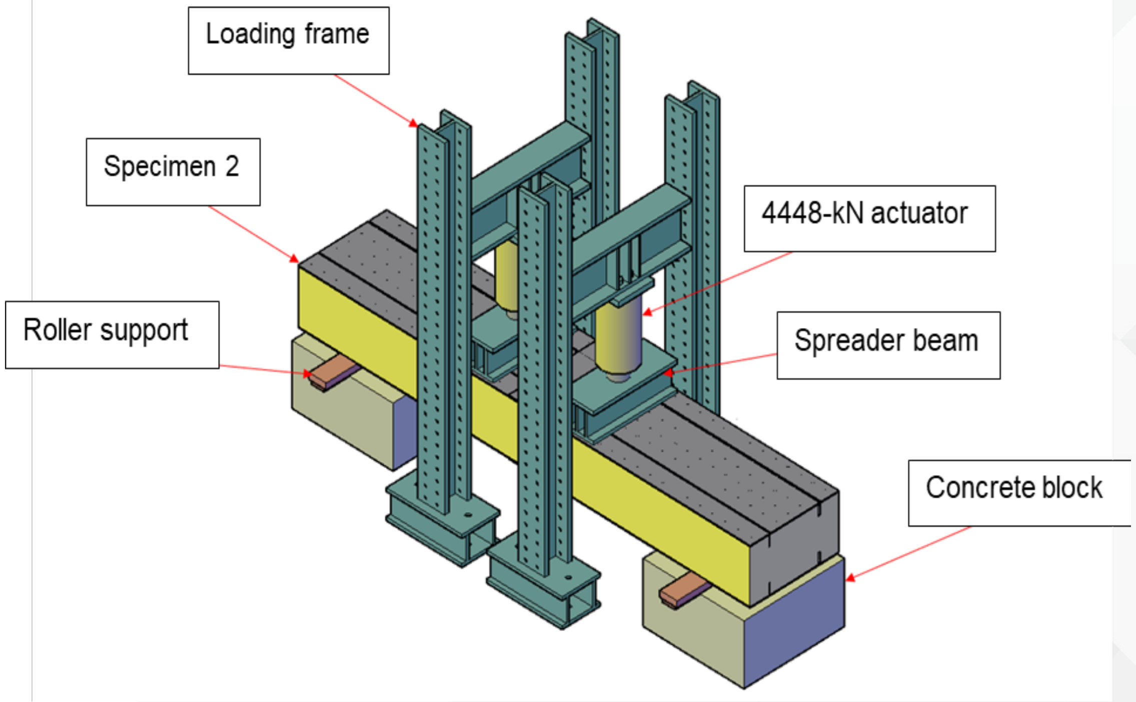
Summary of Test Results - OOPM

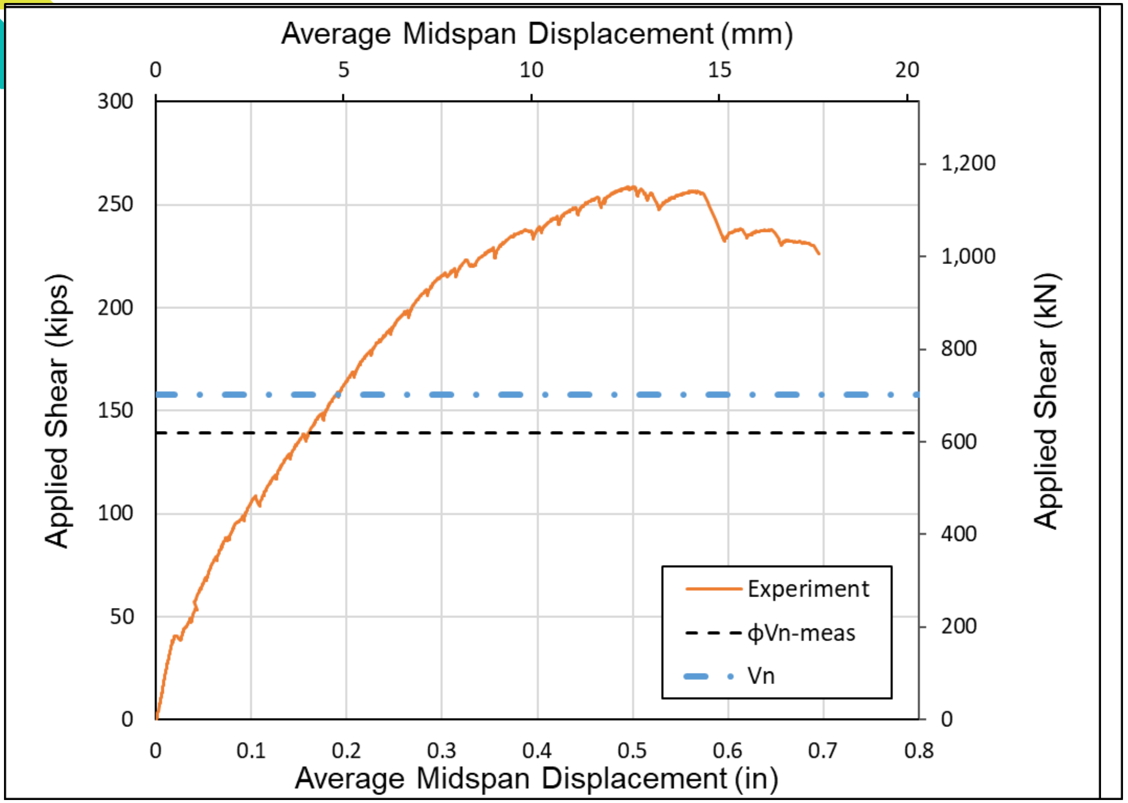


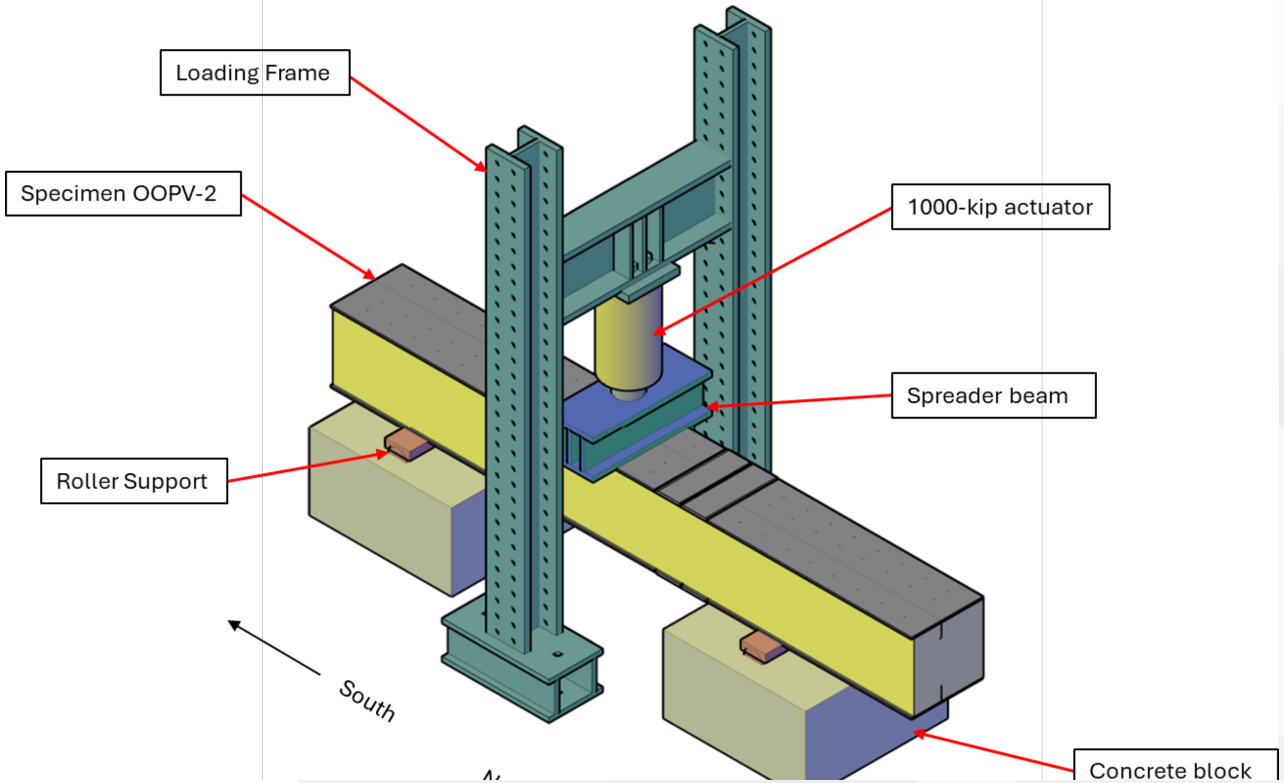


Summary of Test Results - OOPV

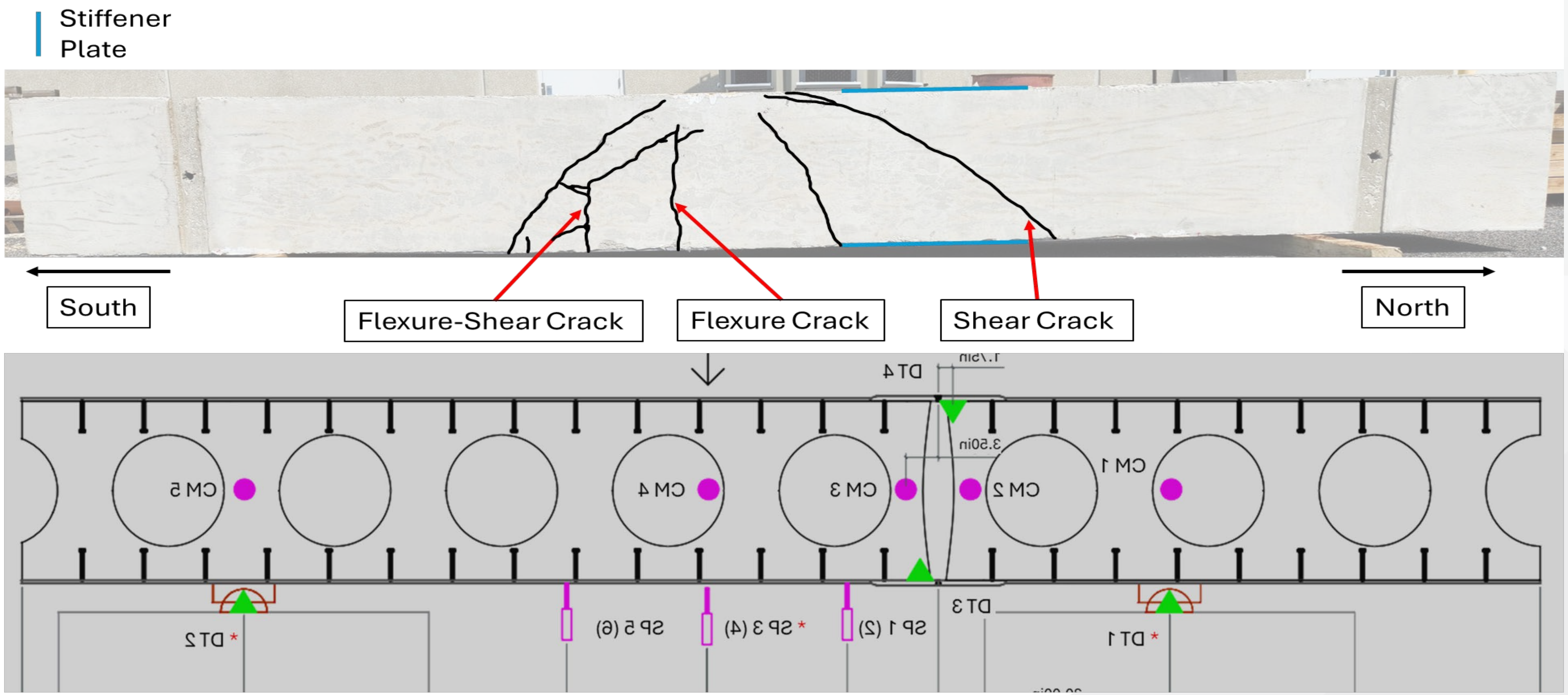
Test Series	Acceptance Criteria	Brief Summary of Testing Results
Out-Of-Plane Shear (OOPV)	Load carrying capacity is equal to or greater than the nominal shear capacity calculated using ANSI/AISC N690 or ACI 349 code-based equations	The OOPV specimens developed and exceeded their nominal shear capacities. No sign of out-of-plane flexure failure prior to developing shear capacities.

Summary of Test Results - OOPV





Summary of Test Results - OOPV



Summary of Test Results - BA

Test Series	Acceptance Criteria	Brief Summary of Testing Results
Bi-Axial Tension	The Bi-Axial specimens develop the yield strength (calculated with the measured steel properties) of the steel faceplates for biaxial stress state.	Maximum applied tension exceeded the yield strength accounting for biaxial stress state and thermal loading. There was no failure of the specimen or the splice detail included in it.

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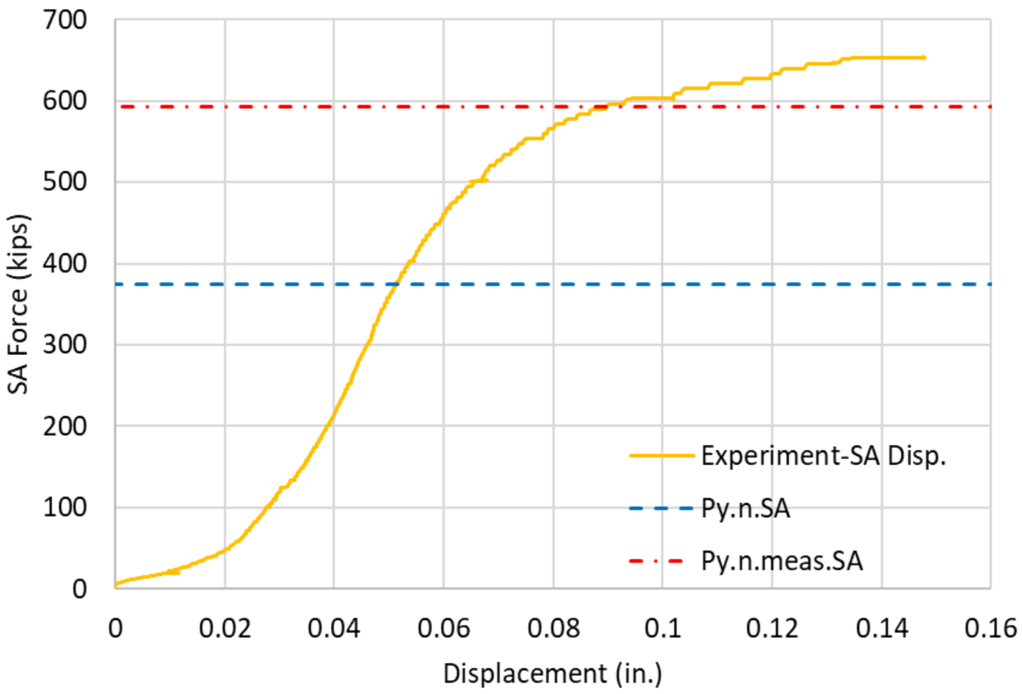
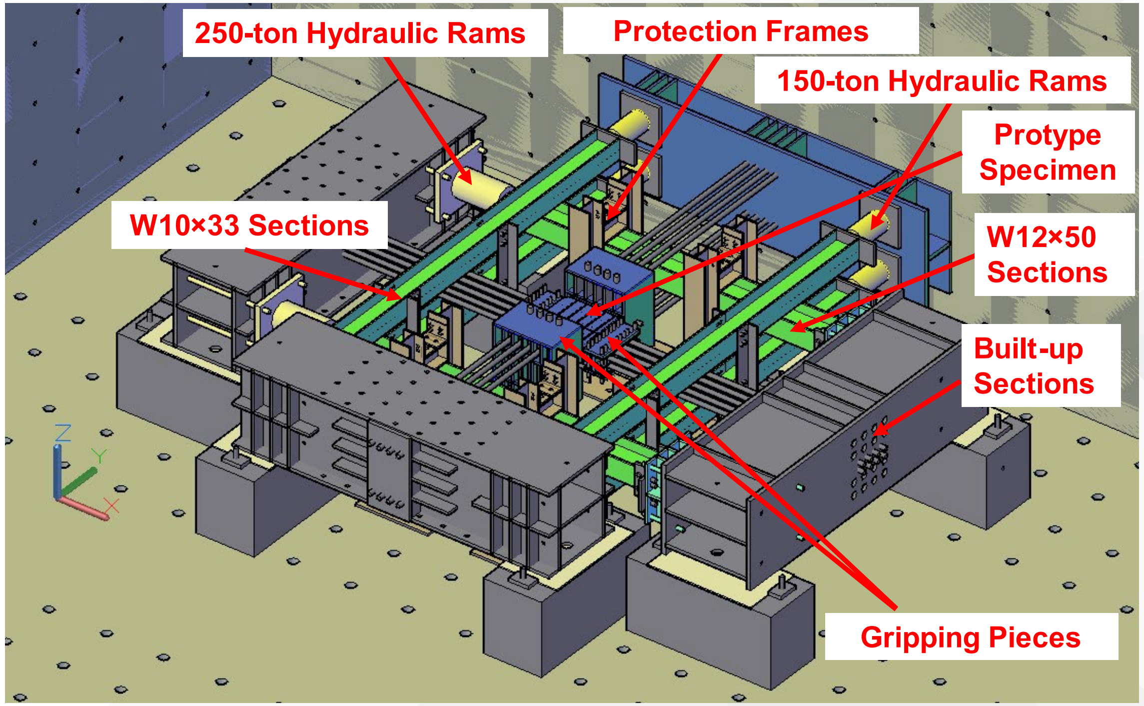
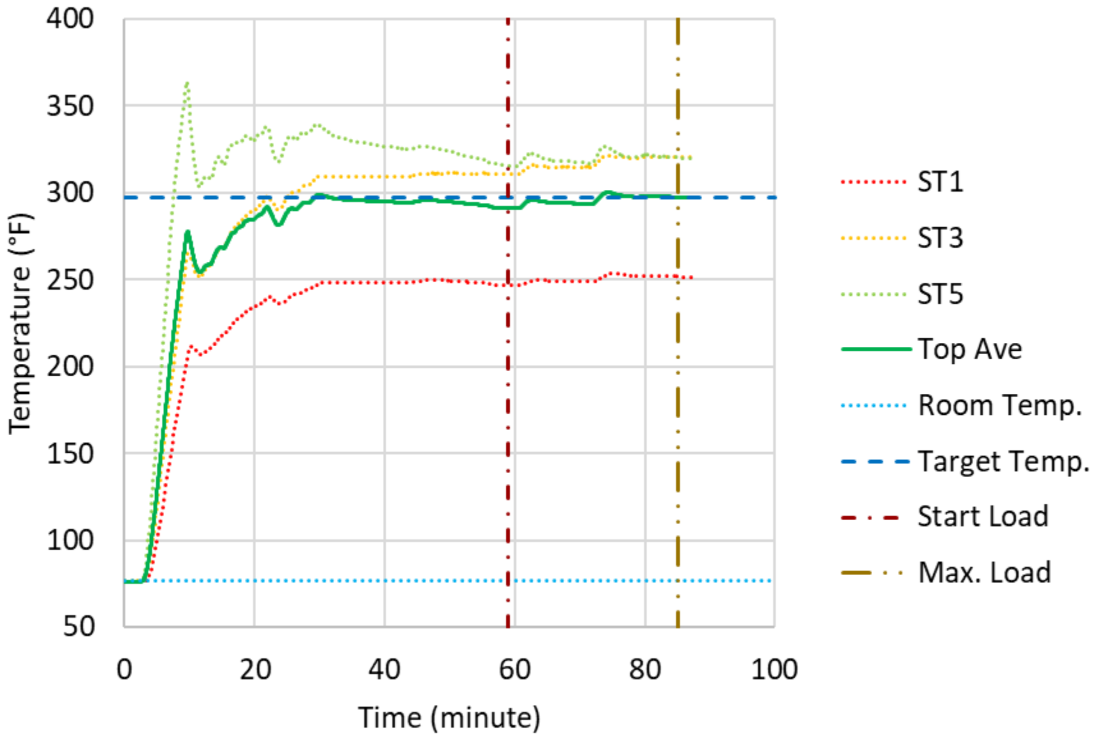
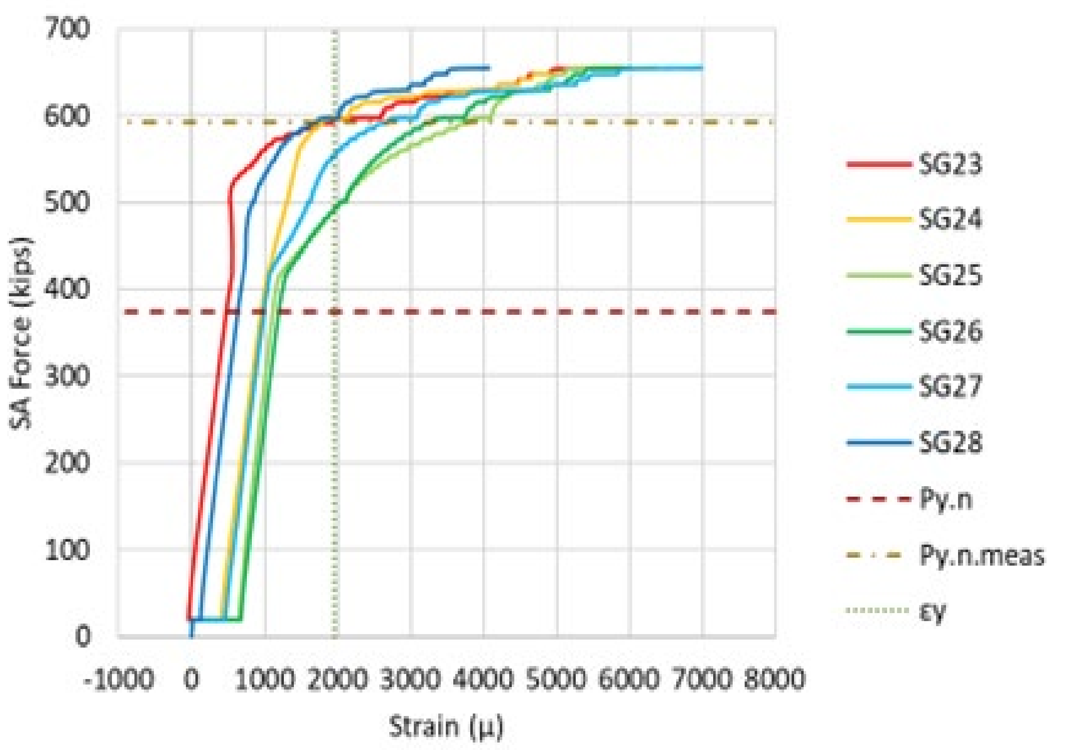
Summary of Test Results - BA





Summary of Test Results - BA





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Summary of Test Results - IPV

Test Series	Acceptance Criteria	Brief Summary of Testing Results
In-Plane Shear (IPV)	Develop the nominal in-plane flexural capacity, defined by the plastic moment capacity of a DP-SC wall segment simplified as a concrete-filled composite member. Develop the nominal out-of-plane flexural capacity (Mn.OOP) estimated using the ACI code-based equation.	The IPV specimens developed their nominal in-plane and out-of-plane flexural capacities. No sign of in-plane or out-of-plane shear failure prior to developing flexural capacities. There was no failure of the specimen or the splice detail included in it.

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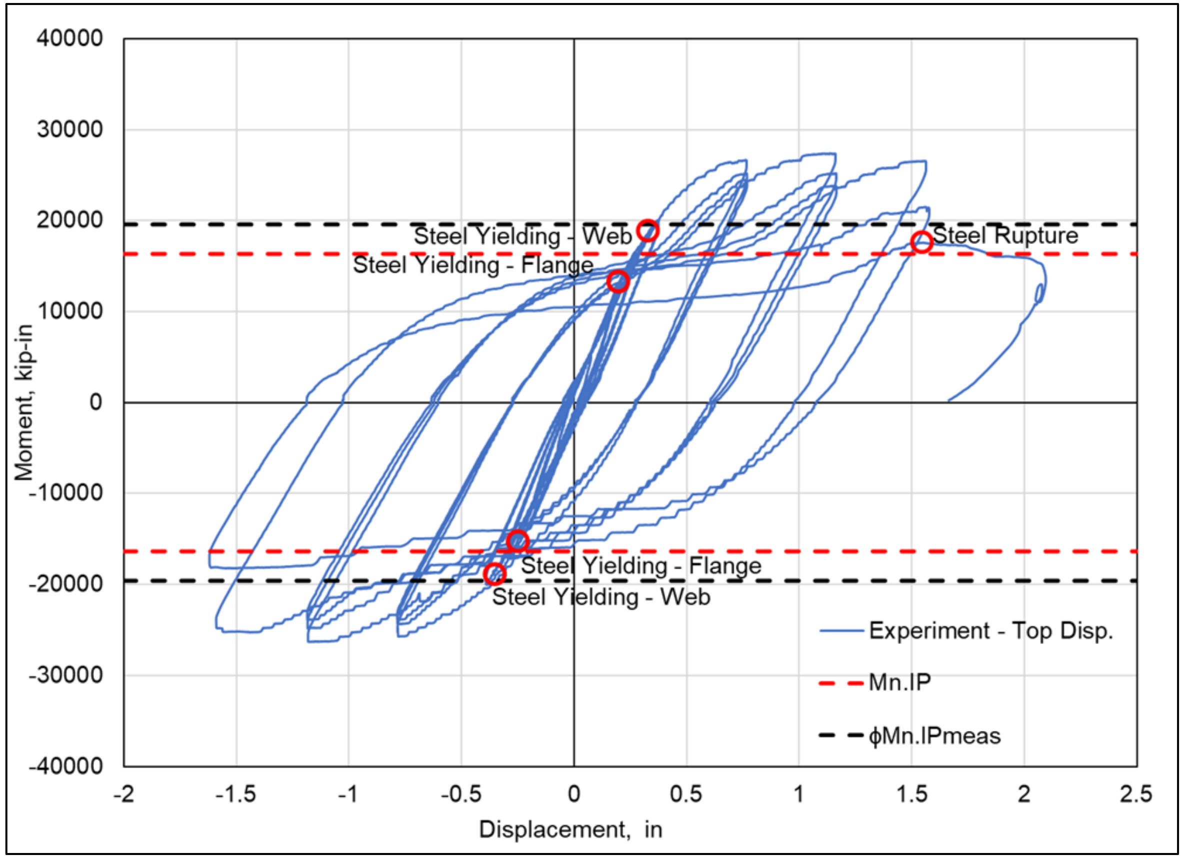
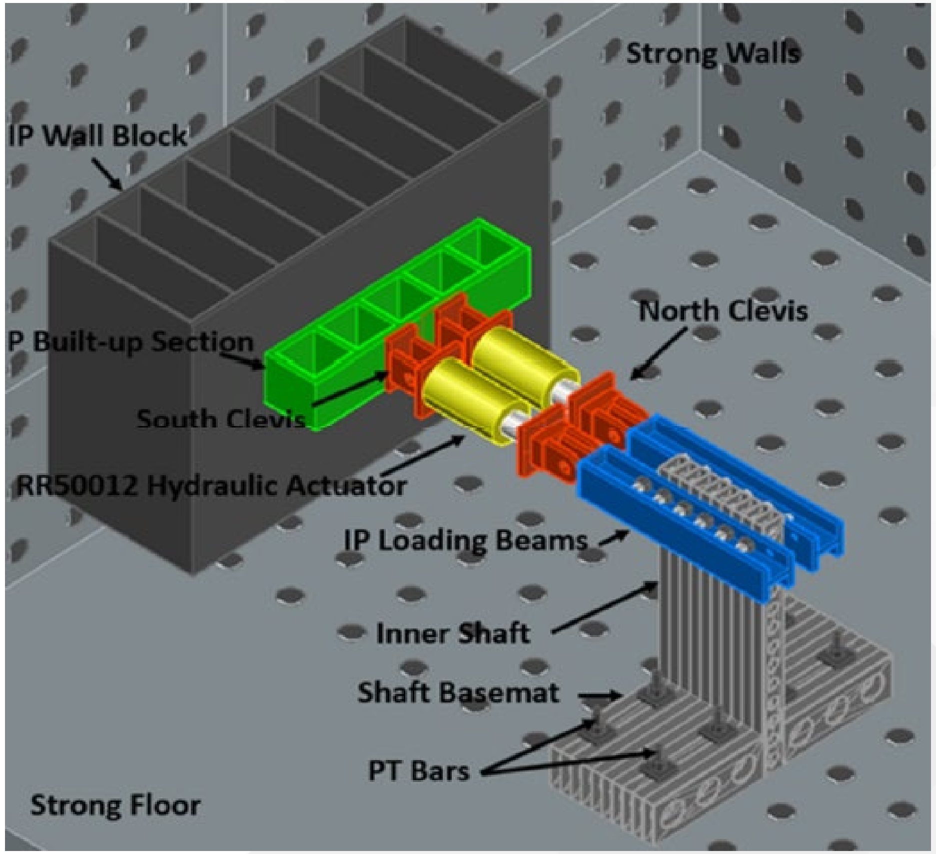
Summary of Test Results - IPV





Overall Summary and Conclusions

- All the prototype tests completed successfully.
- All the tests confirmed behavior and met acceptance criteria.
- Test results confirm the conservatism and applicability of the design equations being used for various parts of the structure.

Questions?

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NRIC Advanced Construction Activities

- Demonstration of Nondestructive Examination of Concrete in Mockup and Prototypes
- Demonstration of Digital Twins for Advanced Construction

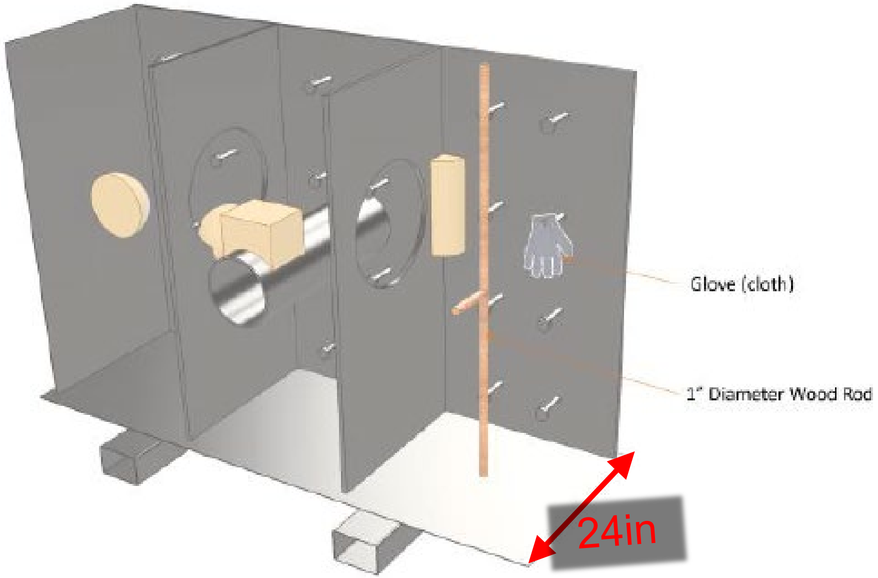
Bruce Greer
Principal Technical Leader
EPRI Advanced Nuclear Technology Program

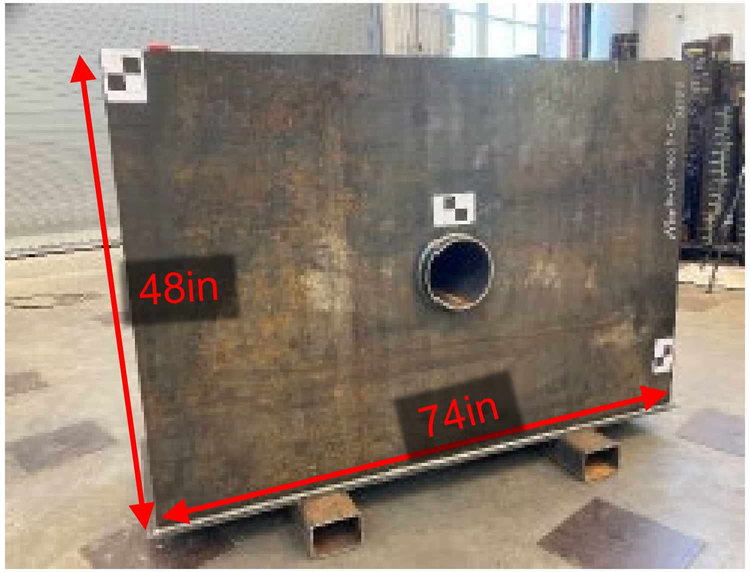
04/03/2025

Nondestructive (NDE) Examination

NDE Goals and Approach

- Goals
  - Identify and test methods that can be deployed on a steel-plate composite (SC) structure during construction
  - Ensure the quality of the concrete through nondestructive examination
- Approach
  - Build a mockup of SC construction and test NDE methods
- NDE Methods
  - Maturity Method
    - Provides an estimation of compressive strength based on temperature history
  - Guided Wave Phased-Array
    - Long range ultrasonic examination technique for screening for defects in the steel plates
  - High Energy X-Ray
    - Detection of voids and foreign material contained within the concrete
  - Low-Frequency Ultrasound
    - Evaluation on of steel plate contact with concrete
    - Detection of defects with concrete





Results

Maturity Method

- The method can be deployed in the field following the guidance of ASTM C1074-17 “Standard Practice for Estimating Concrete Strength By the Maturity Method” as demonstrated in this study.
  - Perform a temperature history and compressive strength correlation in the laboratory for the concrete mix to be used for the project

Guided wave phased array

- The effects of attenuation, due to concrete placement on the interior walls of the mockup were negligible. The technique can be deployed via an access port for screening the condition of an outer steel plate.
  - The transducer needs to be in contact with the plate being inspected. Therefore, for screening the wall in contact with the soil an access port to the plate is necessary

High Energy X-rays

- The technique can be used for detecting defects in concrete lined by steel plates.
  - The technique requires access to both sides of the structure being inspected.

Low frequency ultrasound

- When tested on a concrete surface, the technique was demonstrated to be able to detect reflections up to a depth of 48-in. (1.22-m). When testing on a surface of a 5/8-in. (16-mm) thick plate, the waves did not penetrate into the concrete and testing was not successful.
- The technique was capable of providing data from the full thickness of the steel-lined structures when the steel liner was at or below 0.31 in. (8mm).

Discussion

- **General Comments**
  - Access ports to allow for NDE of the back plate should be considered. The access ports are important because there are no NDE techniques that can bypass a steel plate and concrete to measure the thickness of a back plate.
    - This comment is relevant for a deeply embedded structure that has potential for corrosion when in contact with earth.
  - Mockups of highly congested areas should be fabricated to demonstrate the ability of the concrete to fill all the cavities within the area of interest.
  - Results from NDE report are still valid with change from Steel Bricks to DPSC
    - EPRI mockup was DPSC not Steel Brick

Digital Twins for Advanced Construction

Digital Twin Team

Amit Varma

Jungil Seo

Robert Cox

Malind Khire

Matt Whelan

Younjin Park

Tim Kernicky

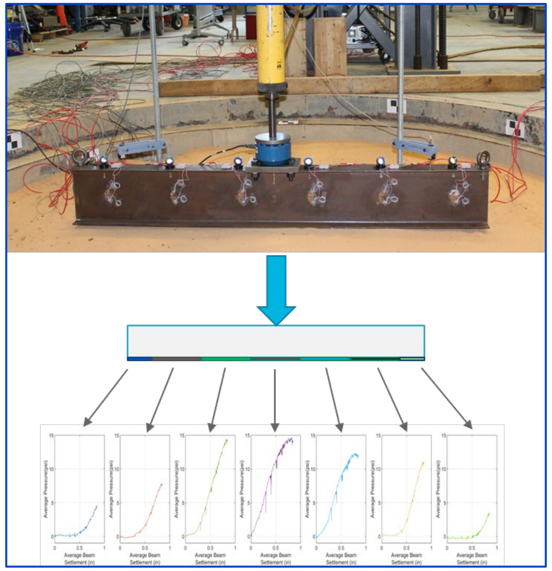
Jeff Hawkins

David Malley

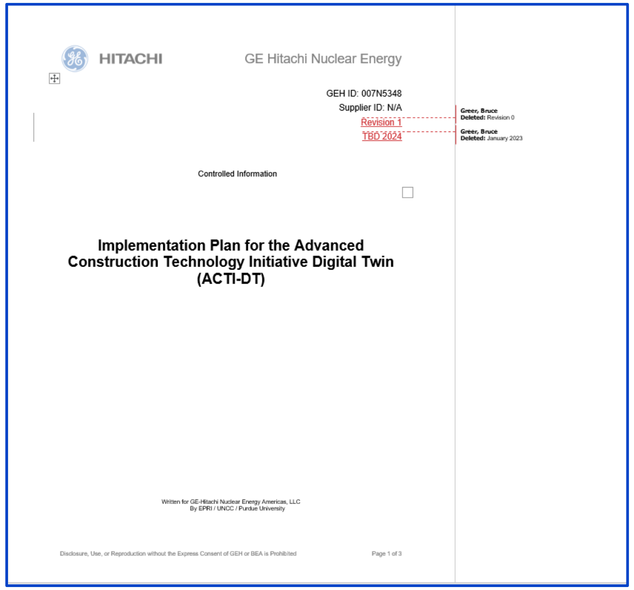
David Anson

Two Key Digital Twin Deliverables for Phase 1

- NRIC Mini Digital Twin Report
  - GEH ID: 007N5347
  - Describes work completed in Phase 1
  - Does not need revised



- Implementation Plan for the Advanced Construction Technology Initiative Digital Twin (ACTI-DT)
  - GEH ID: 007N5348
  - Describes planned implementation for potential Phase 2
  - Needs revised to address proposed design changes



HITACHI GE Hitachi Nuclear Energy

GEH ID: 007N5348
Supplier ID: N/A
Revision 1
TBD 2024

Greer, Bruce
Deleted: Revision 0
Greer, Bruce
Deleted: January 2023

Controlled Information

Implementation Plan for the Advanced Construction Technology Initiative Digital Twin (ACTI-DT)

Written for GE-Hitachi Nuclear Energy Americas, LLC
By EPRI / UNCC / Purdue University

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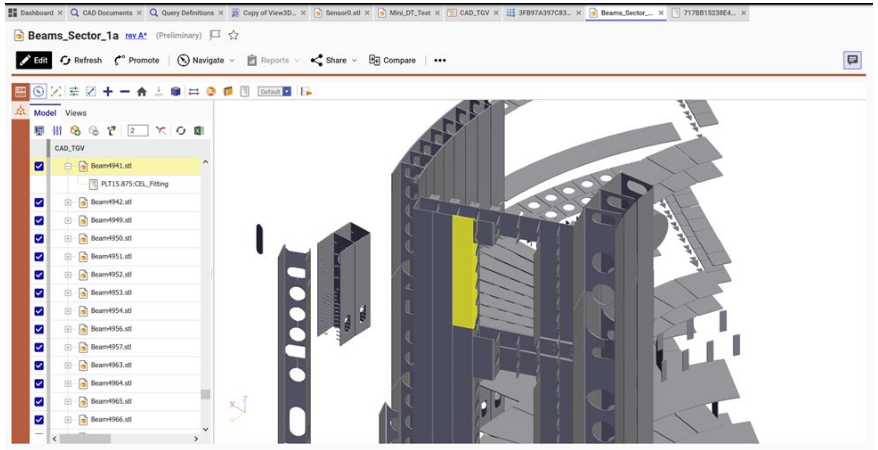
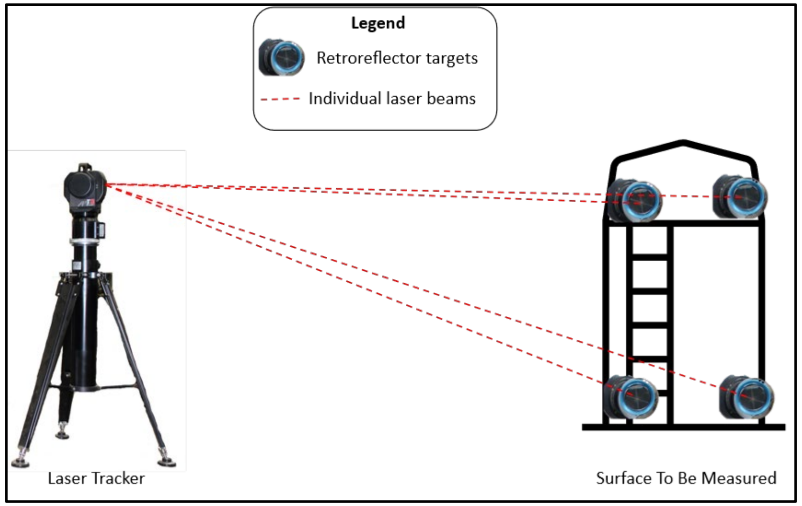
Key Items Proposed for Included in Phase 2 Plan (1 of 2)

- Creation of data-sharing platform known as Digital-Twin Environment (Section 3 & Section 5.3.1 of 007N5348)

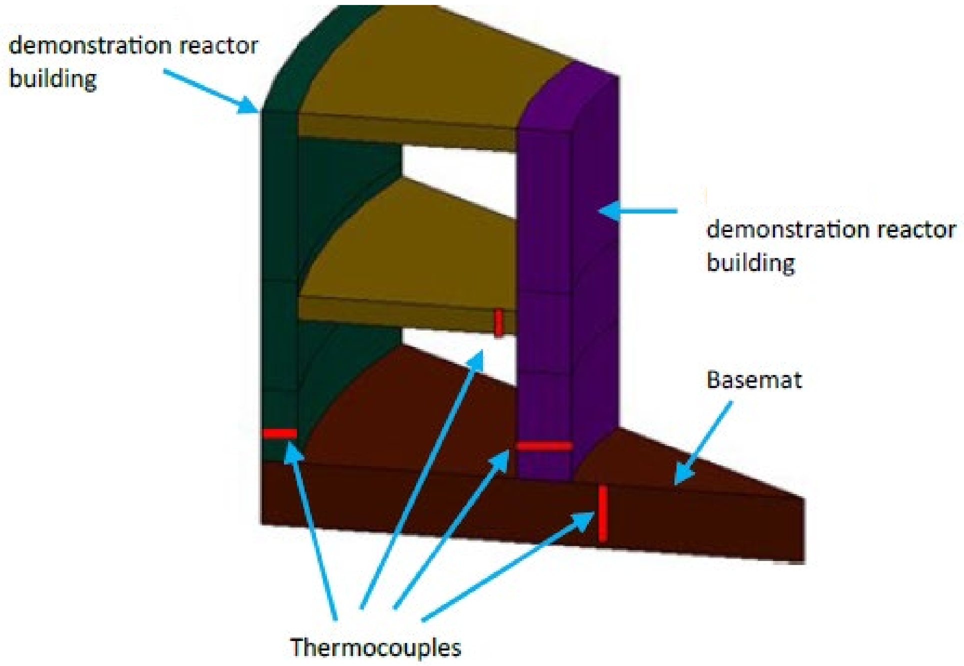


- “Scans” of modules and global structure throughout Phase 2 (Section 5.3.3 007N5348)
  - Semi-automated updates of BIM & FEA models

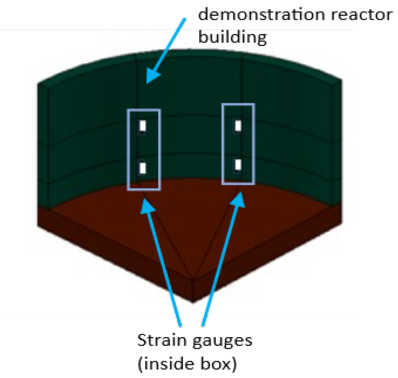


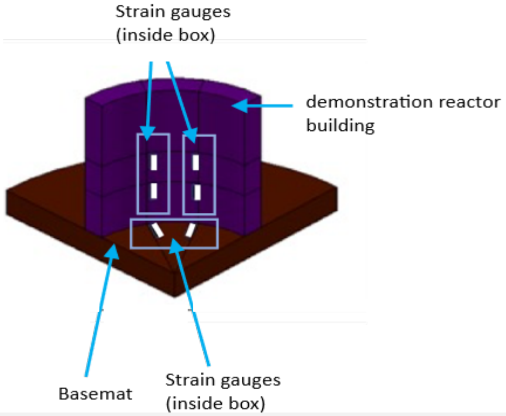
Key Items Proposed Included in Phase 2 Plan (2 of 2)

- Logging of critical structural sensors
  - Monitoring of strain on steel surfaces
    - This will feed into the structural model to complete the loop of data
  - Monitoring of temperature on steel surfaces
    - This information will be used to feed the analysis of the concrete strength



- Developing and testing DT use cases





Note: Strain gauge locations shown for illustration purposes only. Actual locations will be determined using modeling analysis.

Digital Twin Use Case Development

- Use Case Example 1: Module Fit-up
  - Laser tracker measurement performed in the field
  - Data uploaded to DT Environment
  - BIM model updates
- Use Case Example 2: Field Inspection Reporting and Records Repository
  - Inspector provided with tablet
  - PDF or similar files can be completed in the field
  - Data uploaded to DT environment
  - In addition to field inspections, should also be tested as repository for a percentage of quality records
- Use Case Example 3: Geotechnical Risk Reduction
  - Action based on differences between numeric models and sensor readings

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