Enclosure 3
Slides associated with technical topics to be discussed
(Redacted)

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B&W mPower™ Reactor
SC Construction, Seismic, and Hydrology Discussions

June 25, 2013

(Redacted Version)

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Objectives

The objectives of this presentation are:

- Provide an update on the plant physical layout
- Discuss the application of steel-plate concrete composite (SC) construction for mPower
- Present results of SASSI validation studies for the analysis of deeply embedded structures.
- Provide an overview of the Topical Report on Random Vibration Theory for SSI Analysis
- Discuss stability and hydrology parameters for generic design

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Agenda

- Plant Layout
- Steel-Plate Composite Construction

------------------------- Break -------------------------

- Validation of SASSI

------------------------- Lunch -------------------------

- RVT Topical Report

------------------------- Break -------------------------

- Stability / Hydrology
- Recap

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Plant Layout

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Plot Plan

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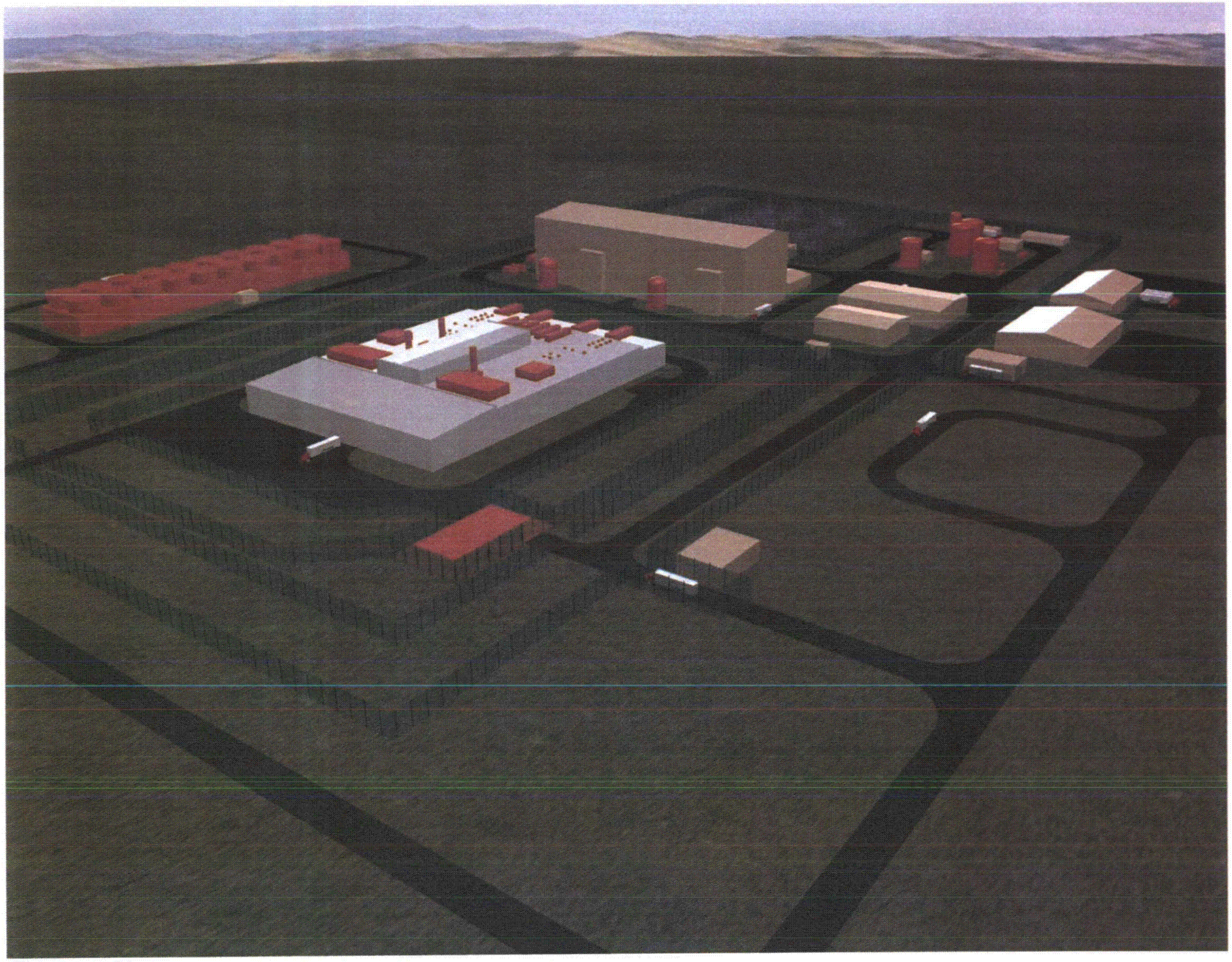
Site Overview Looking North



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Discussion

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Steel-plate Concrete Composite for the B&W mPower™ Reactor

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Objective

- The objective of this presentation is to discuss the application of steel-plate concrete composite (SC) construction in mPower in lieu of reinforced concrete (RC)

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Topics

- Containment Layout
- Scope of SC Construction
- SC Design Methodology
- SC Construction Considerations
- Conceptual Sizing for SC Walls
- Path Forward

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Containment Layout

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Elevation View Looking East

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Elevation View Looking North

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Scope of SC Construction

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Scope of SC Construction

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Scope of SC for CIS

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Scope of SC for CIS

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SC Construction for SFP

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Scope of SC

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Scope of SC

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SC Design Methodology

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SC Design Methodology

Outline

- Behavior of SC walls
- Issues with use of current codes and regulations
- Brief summary of SC research/codification activities
- Scope and status of SC Supplement to AISC N690-12
- General requirements for SC design
- SC connection design philosophies
- Typical SC testing needs
- Need for early NRC feedback on the SC Supplement

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SC Design Methodology

SC Wall Behavior:[

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Design of SC Connections:

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SC Design Methodology

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SC Design Methodology

Issues with use of current codes and regulations

- Lack of SC-specific US consensus standard
- Lack of SC-specific SRP acceptance criteria
- AISC N690 only deals with linear composite elements
- ACI 349 deals with RC slabs and walls (with slabs primarily in flexure, and walls primarily in in-plane shear and moment)
- ACI 349 does not address interaction of in-plane shear and out-of-plane flexure and that of various membrane forces
- Unique SC issues such as local buckling, composite action, and bi-directional interaction effects not addressed in the current consensus standards and SRP review criteria
- Use of RC criteria for SC design is difficult and inefficient

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Brief summary of Japan SC research/codification activities

- SC research Japan since the early eighties
- A number of in-plane shear and compression tests; SC wall anchorage tests; and scaled tests entire CIS and reactor cavity walls to failure
- Some plants designed and built using SC walls for CIS
- JEAG-4618 was published as a guide in 2005, followed by JEAC-4618 as the SC design standard in 2009
- JEAC-4618 is based on working stress design method; non-compact faceplates are permitted; no detailing requirements for tie-bars
- Min/max reinforcement ratio: 1% to 6.67%

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Brief summary of Korean SC research/codification activities

- South Koreans performed SC research and codification activities since 2005
- The KEPIC-SNG standard for SC slabs and walls was issued in December 2009
- Non-compact faceplates permitted; no minimum tie-bar requirement; faceplate ribs are explicitly permitted
- Min/max reinforcement ratio of 1% to 6.67%
- Interaction equation is based on Von Mises yield criterion on the entire SC section
- Local interaction effect due to attachment load is directly added to the global interaction effect

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Brief summary of SC research/codification activities in USA

- SC research started in 2004 with Bechtel-proprietary SC wall concepts
- Analysis and testing for thermal plus out-of-plane load was conducted at Purdue University in 2005-2007
- Subsequently, AISC committee activities, and AP1000 and APWR review activities served as a catalyst for research
- US research topics: interaction effects, general SC detailing requirements, faceplate local buckling, thermal loading, etc
- Additionally, Japanese and Korean research results have been studied and synthesized to aid codification efforts
- AISC codification efforts started in Fall 2006; current status presented in a later slide

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Brief summary of SC research activities in USA

1. Interaction Equation (Purdue/Bechtel)
2. Composite Action Efficiency/Local Buckling (Purdue/Bechtel)
3. Effective Stiffness/Analysis Requirements (Purdue/Bechtel)
4. In-Plane (IP) Shear Behavior (Purdue/WEC/Bechtel/URS)
5. Thermal plus IP Shear Loading (Purdue/URS)
6. Thermal plus OOP Loading (Bechtel/Purdue/WEC/URS)
7. OOP Shear (Purdue/Bechtel/WEC/URS)
8. Push-out tests for shear connectors (Purdue/WEC/URS)
9. Wall Anchorage and Joint Shear tests (Purdue/WEC/URS)

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AISC SC Subcommittee Milestones

- Inception in early 2006; first meeting in November 2006
- Several topical presentations and preliminary ballots done during the first three years
- First draft Ballot 1 conducted in Spring 2011
- Final Ballot 1 completed in June 2012 (covers 70-80% of the final document)
- First round of Ballot 2 conducted in Fall 2012
- Final Ballot 2 to be completed in June 2013
- Commentary to be completed by August 2013
- AISC to issue white paper for SC specification in Fall 2013
- AISC Main Committee Ballots to occur from during 2014
- Standard to be issued as N690-12 supplement by May 2015

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SC Design Methodology

Additional Information about AISC's SC Subcommittee

- SC subcommittee is under AISC N690 (TC12) committee
- SC subcommittee membership from AISC TC12 and ACI 349
- Voting members in SC subcommittee come from industry, academia, and fabrication community
- Bechtel has been in leading position since inception of subcommittee
- NRC staff and several additional industry professionals are observers/corresponding members
- Two advisory members from Korean Society of Steel Construction
- In August 2011, detailed info was provided at NRC meeting (http://pbadupws.nrc.gov/docs/ML1125/ML112500005.pdf)
- More industry/AISC/NRC interaction is anticipated

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SC Design Methodology

Examples of General requirements for SC design:

- Minimum and Maximum Section Thickness
- Minimum and Maximum Plate Thickness
- Minimum and Maximum Reinforcement Ratio
- Minimum and Maximum Plate Yield Strength
- Minimum Concrete Compressive Strength
- Faceplate Compactness Requirement
- Relative Parity of Faceplate Yield Strengths
- Composite Action Requirement
- Tie-System Requirement

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SC Design Methodology

General requirements for SC design – Composite Action

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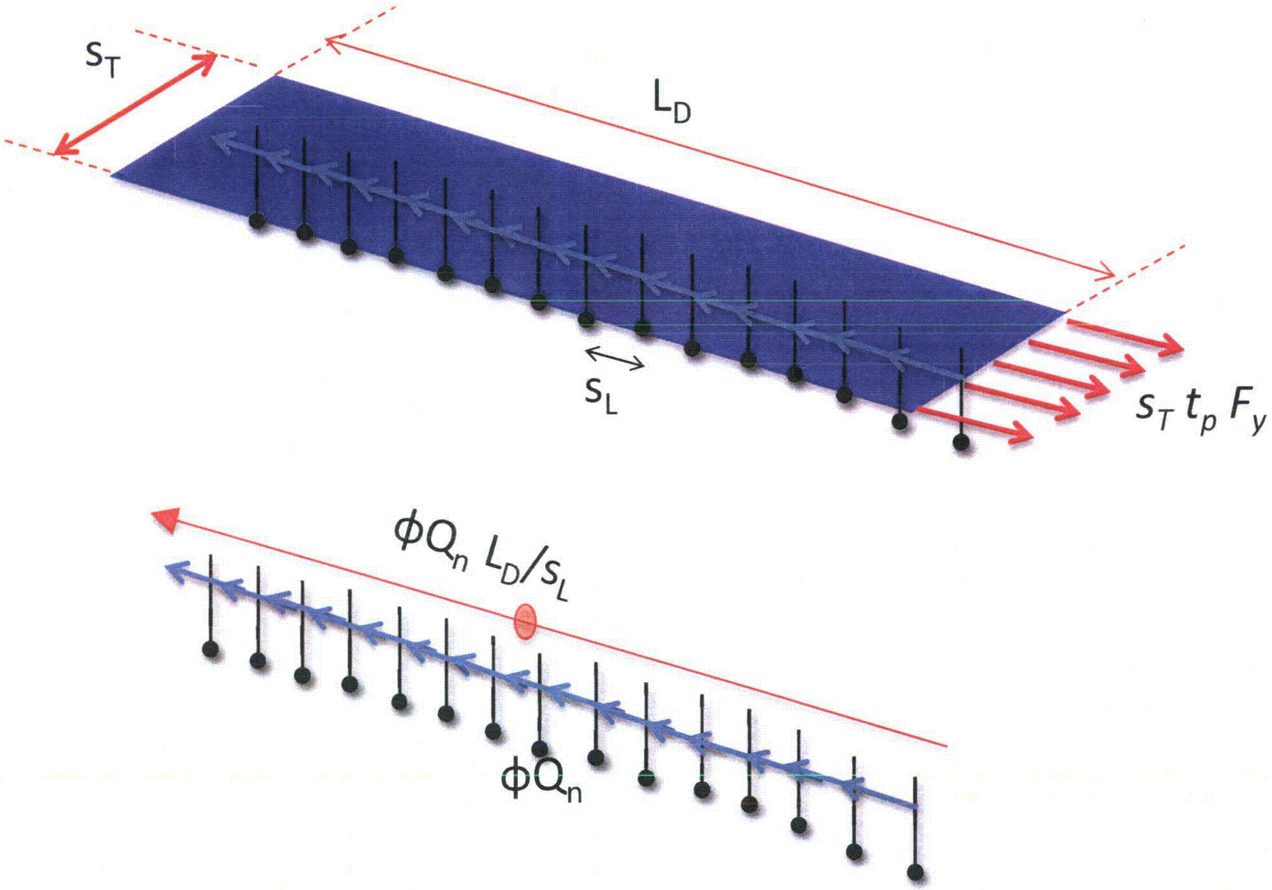
SC Design Methodology



$$\phi Q_n \frac{L_D}{s_L} \geq s_T t_p F_y$$

$$\therefore \frac{\phi Q_n L_D}{t_p F_y} \geq s_T s_L$$

$$s \leq \sqrt{\frac{\phi Q_n L_D}{t_p F_y}}$$

Composite Action Requirement – Faceplate Development Length Requirement

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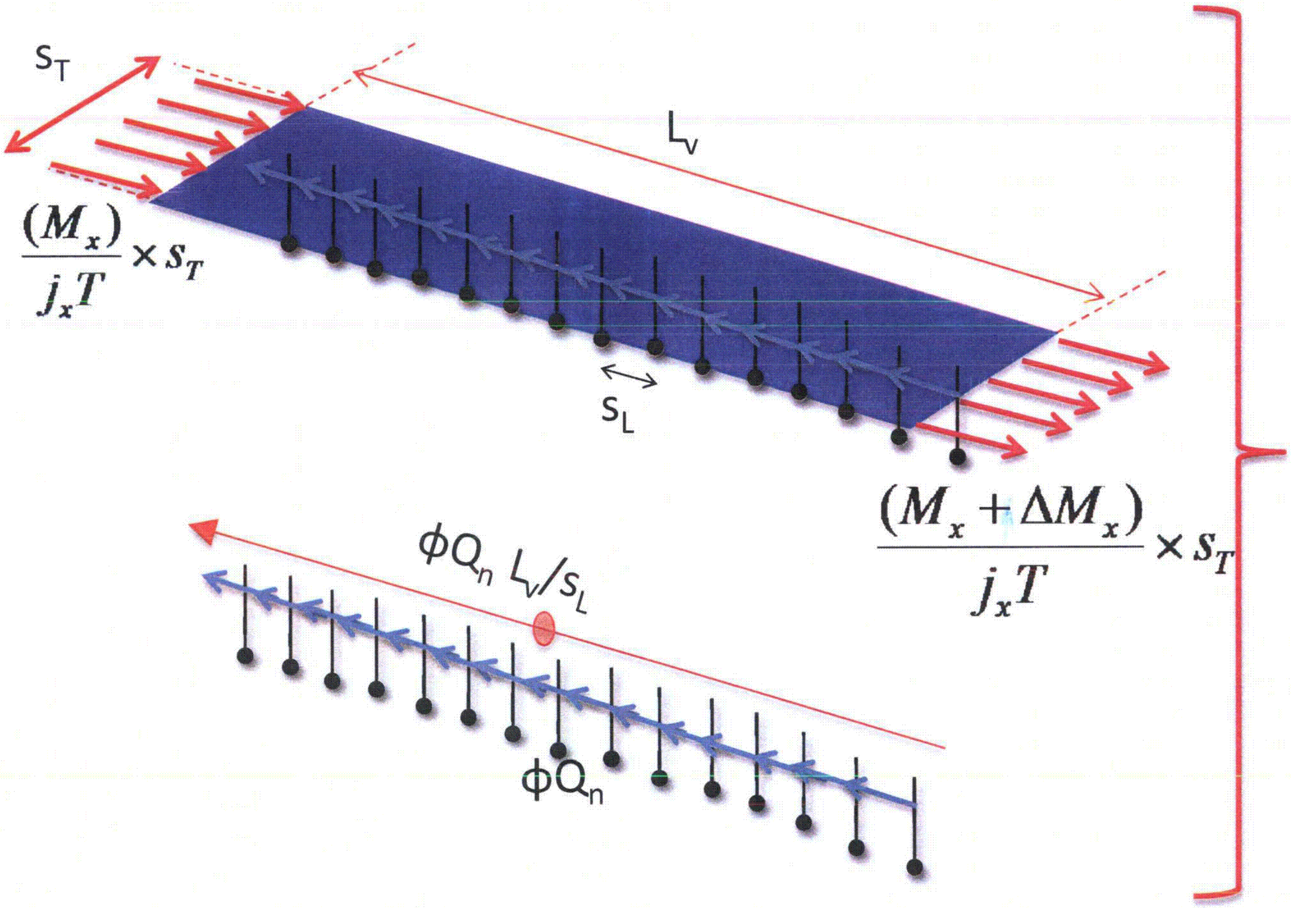

$$\varphi Q_n \frac{L_v}{s_L} \geq \frac{\Delta M_x}{j_x T} s_T$$

$$s_T s_L \leq \varphi Q_n \left(\frac{L_v}{\Delta M_x} \right) j_x T$$

$$s \leq \sqrt{\frac{\varphi Q_n (j_x T)}{V_{no}}}$$

$$Where: \frac{\Delta M_x}{L_v} = V \leq V_{no}$$

Composite Action Requirement – Interfacial Shear Strength Requirement

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SC Design Methodology

General requirements for SC design - Tie-System

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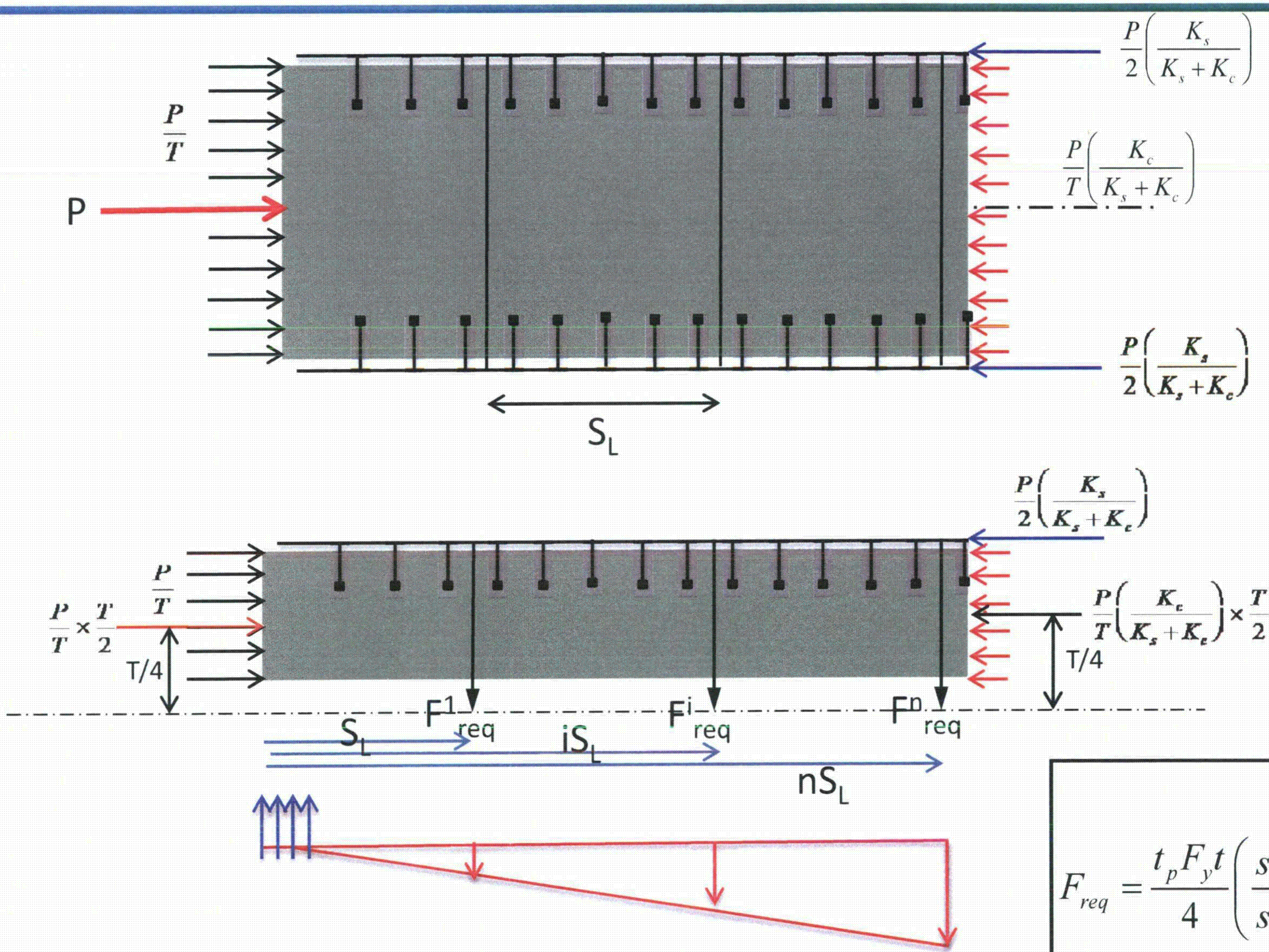

$$F_{req} = \frac{t_p F_y t}{4}\left(\frac{s_T}{s_L}\right)\left(\frac{6}{2\left(\frac{L_{TR}}{s_L}\right)^2 + 1}\right)$$

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SC Design Methodology

SC Damping, Modeling, and Member Evaluation Basis

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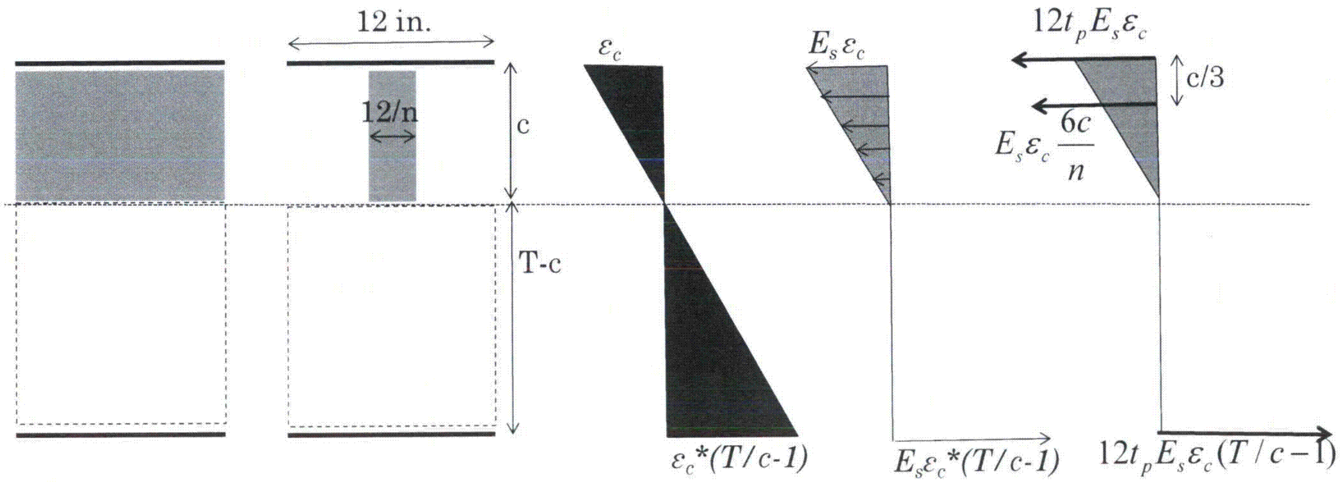
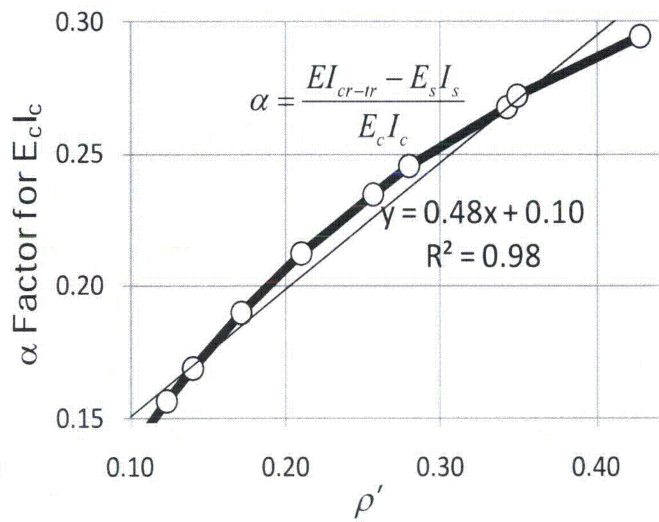
SC Design Methodology

SC Effective Member (Element) Stiffness

- Flexural Stiffness:





$$EI_{eff} = E_sI_s + (\alpha E_cI_c)\left(1 - \frac{\Delta T_s}{150F}\right) \geq E_sI_s$$

Where, $\alpha = 0.48\rho' + 0.10$; $\rho' = \frac{2t_p}{T}\frac{E_s}{E_c}$ *; and* ΔT *is the thermal gradient*

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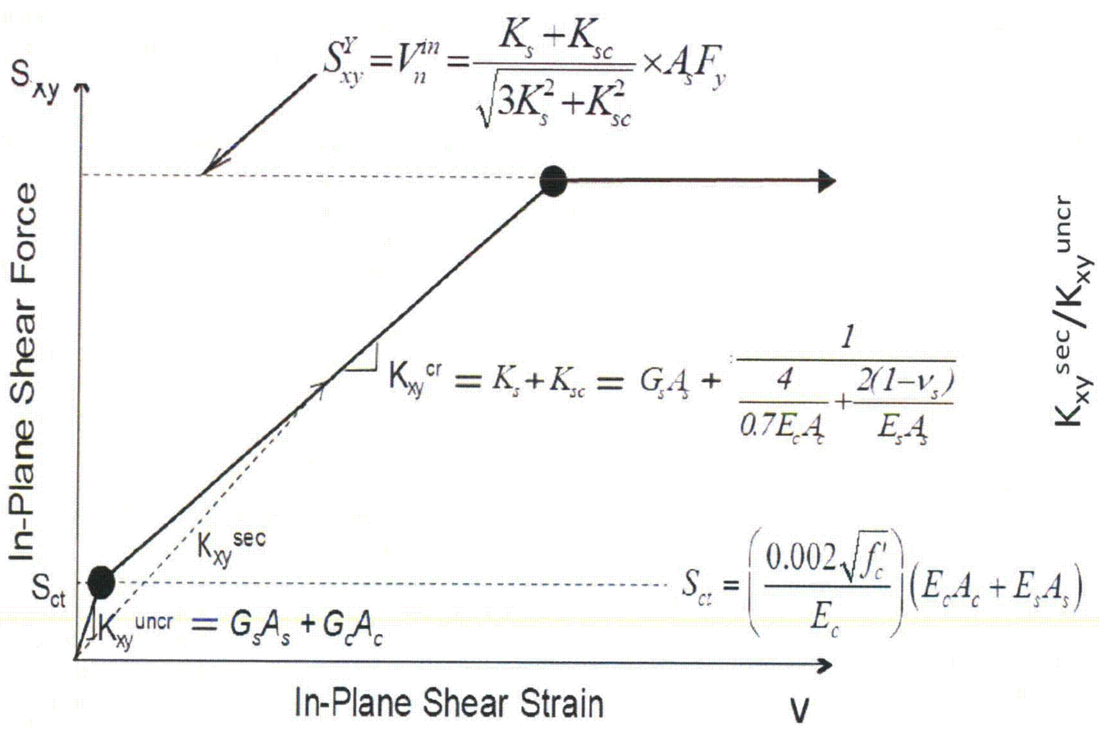
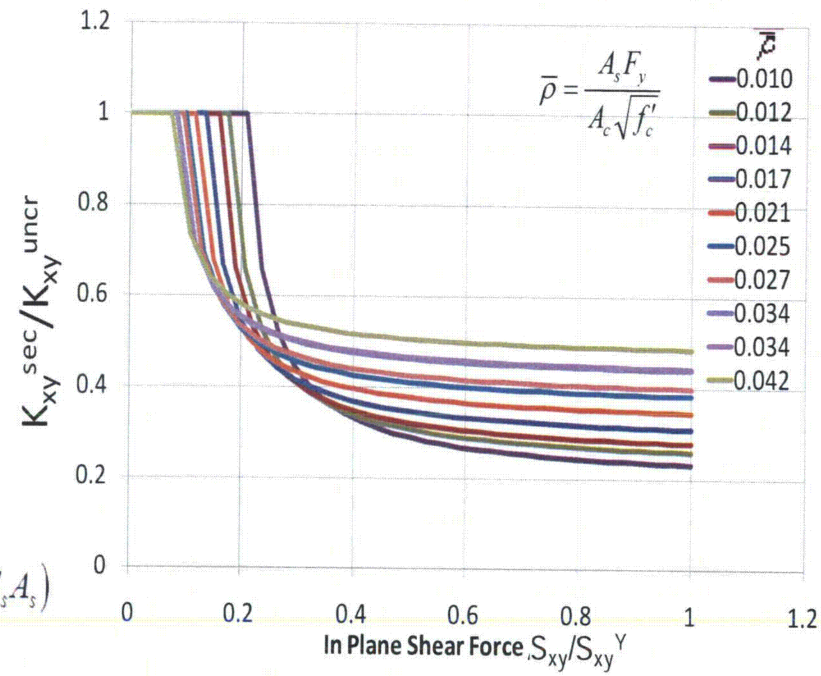
SC Effective Member (Element) Stiffness

- <u>In-Plane Shear Stiffness</u>:



Monotonic Stiffness



Secant Stiffness for Cyclic Loading

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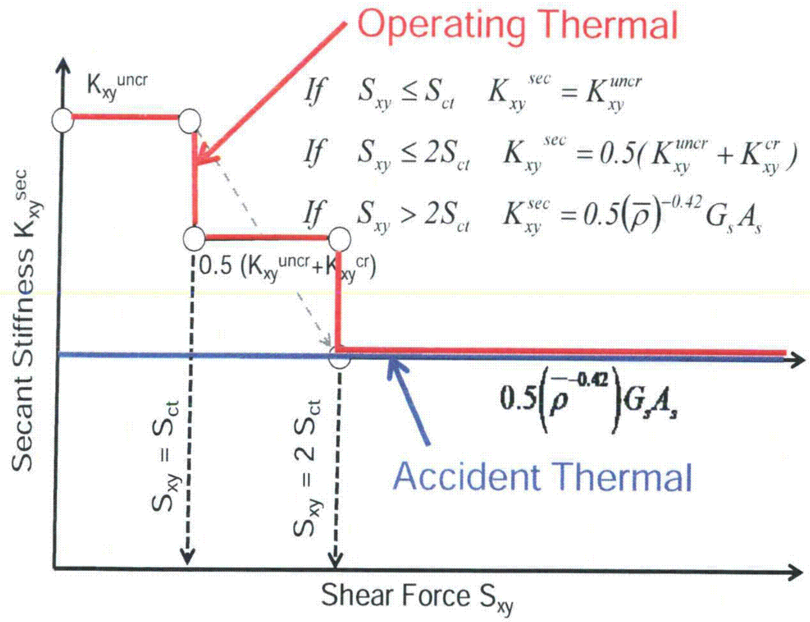
SC Effective Member (Element) Stiffness

- In-Plane Shear Stiffness:
- $\bar{\rho}$ is strength normalized reinforcement ratio $\bar{\rho} = \frac{A_s F_y}{A_c \sqrt{f'_c}}$
- Three-Step Secant Stiffness Model is used for effective stiffness
- Good prediction for reinforcement ratios between 1.5% - 5%, f'_c from 4000 psi to 6000 psi, and F_y from 50 ksi to 65 ksi



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SC Design Methodology

SC Connection design philosophies

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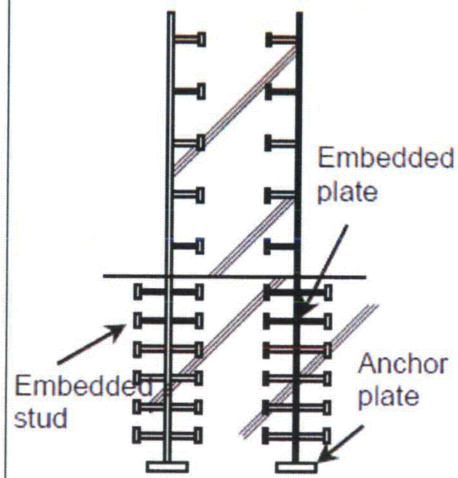
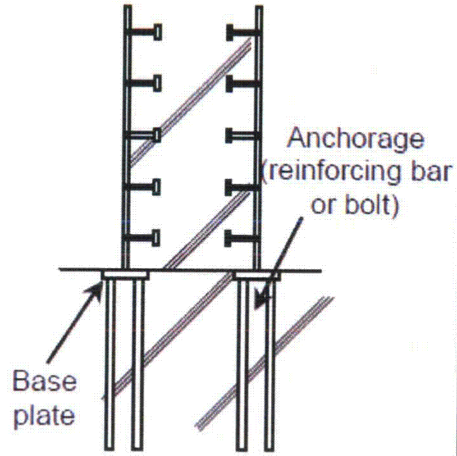
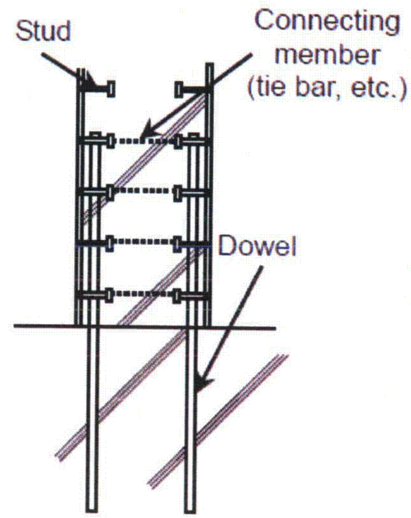
SC Design Methodology

	Embedding method	Anchor method	Dowel method
Concept			
Applicable guidelines	"S standard" or "SRC standard" are applied.	Basic structure of this guideline	
Design policy by the guidelines	Anchoring strength exceeding the ultimate strength of the wall shall be secured.		Anchoring strength appropriate for design stress shall be secured.
Constructability	Possible	Good	Good
Application	Anchoring method for special sections	Anchoring method for general shear walls, etc.	Anchoring method for members with enough strength margin

SC Wall Anchorage Options (from JEAG-4618)

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SC Design Methodology

Typical SC testing needs

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SC Design Methodology

SC Design Methodology

- Preliminary SC design based on Ballot 1 version of SC specification
- The mPower team is familiar with changes/additions due to Ballot 2
- The mPower team is also familiar with the SC topics that came up during recent standard plant reviews

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SC Design Methodology

Need for early NRC feedback on AISC SC Supplement

- Review process for previous SC applications was complicated due to lack of US standard and SRP criteria for SC design
- Generic/application-specific NRC-industry meetings have occurred in recent years (e.g., August 2011 NRC meeting, http://pbadupws.nrc.gov/docs/ML1125/ML112500005.pdf)

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SC Construction Considerations

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SC Construction Considerations

Topics

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Path Forward

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Path Forward

- mPower Containment Internal Structure will include SC construction

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- mPower SC design will be based on impending SC design standard supplement to AISC N690

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Validation of SASSI Solution for Deeply Embedded Structures

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Background

NRC Seismic Update May 2012 presentation of a comparison of SASSI and SAP results

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Background

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Methodology

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SASSI Subtraction Method

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[ ] Harmonic Analysis

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Structural Model

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Soil Properties

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Input Motions

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SSI Analyses

The following SSI analysis cases are performed:

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SASSI Model Boundary Conditions

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[ ] Model Conditions

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[ ] Soil Island Properties

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Generation of Responses

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Comparison of Free-Field Response

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Location of Comparison Nodes

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Global HR TF Comparisons

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Local HR TF Comparisons

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Global C2 TF Comparisons

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Global C2 TF Comparisons

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Global C2 TF Comparisons

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Global C5 TF Comparisons

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Global C5 TF Comparisons

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Global C5 TF Comparisons

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Global C7 TF Comparisons

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Global C7 TF Comparisons

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Local C2 TF Comparisons

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Local C5 TF Comparisons

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Local C7 TF Comparisons

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Global C2 CEUS ARS Comparisons

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Global C2 WUS ARS Comparisons

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Global C5 CEUS ARS Comparisons

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Global C7 CEUS ARS Comparisons

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Global C7 WUS ARS Comparisons

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Validation of the SASSI Solution

Conclusions

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Considerations for Hydrology and Stability

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Considerations for Hydrology

- Groundwater loading on exposed subsurface portions of structure included in design
- No regulations regarding the selection of a design groundwater depth value for the Standard Plant
- Established design groundwater depth of [ ]

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Considerations for Hydrology

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Stability of NI for Generic Design

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Stability of NI for Generic Design

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- COL Applicant may perform site specific stability evaluation if site parameters exceed generic design parameters

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Seismic Bearing Demand

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RVT vs. TH Bearing Demand

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RVT vs. TH Bearing Demand

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Conclusions

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Discussion

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