License Amendment Request:

Methodology for the Analysis of Concrete Seismic Category I Structures with Concrete Affected by Alkali Silica Reaction

Seabrook Station

June 15, 2016

NextEra Energy (NYSE: NEE) is comprised of two strong businesses supported by a common platform

- $17B Consolidated Revenues (1)
- 44,900 MW in operation (1, 2)
- 13,800 employees

FPL

- One of the largest U.S. electric utilities
- 4.8 MM customer accounts
- 25,100 MW in operation

NextEra Energy Resources

- U.S. leader in renewable generation
- Assets primarily in 25 states and Canada
- 19,800 MW in operation (1, 2)

World's largest generator of renewable energy from the wind and sun

Among *Fortune's* 2015 list of 'World's Most Admired Companies' and among top 10 companies in the world in both the categories of innovativeness and community responsibility

Named to 2015 World's Most Ethical Company list (Ethisphere Institute)

(1) As of Dec. 31, 2014 from 10-k
(2) Includes NEE's ownership share of NextEra Energy Partners' portfolio

NextEra Energy Nuclear Fleet

The foundation for everything we do are the Values and Core Principles of our Nuclear Excellence Model

Nuclear Excellence Model

Vision	We are a team that delivers consistent excellent performance					
Mission	We will produce energy in a safe, reliable, cost effective way, while caring for our employees, communities and the environment					
Values	Conduct all activities to demonstrate a deep respect for Nuclear Safety	Live the Safety Guiding Principles	Be a Self-Improving Culture & Learning Organization	Maximize the time spent on Prevention and Detection to minimize / eliminate Correction activities	Foster a work environment where we are the employer of choice	
Core Principles	Operationally Focused	Passion for Excellence	Engaged Leaders	Standardized Processes	Responsive to Stakeholders	Effective Workforce Planning
	Engaged Employees	Effective Long-Range Planning	Strong Teamwork	Strong Ownership & Accountability	Effective Supervisors	Worklife Balance

Strategic Focus Areas

Operational Excellence

Organizational Effectiveness

Generation Reliability

Effective Business & Financial Performance

Seabrook Attendees

• Ken Browne	NEE Seabrook ASR Project Manager
• Mike Ossing	NEE Seabrook Licensing Manager
• Brian Brown	NEE Seabrook Principal Engineer
• Larry Nicholson	NEE Fleet Licensing Director
• John Simons	MPR Gen Manager Power Projects
• Dr. Said Bolourchi	SG&H Senior Principal Engineer
• Jim Moroney	MPR ASR Test Program PM
• Phil Rush	MPR Engineering Associate

MPR

SIMPSON GUMPERTZ & HEGER
Engineering of Structures
and Building Enclosures

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Presentation Outline

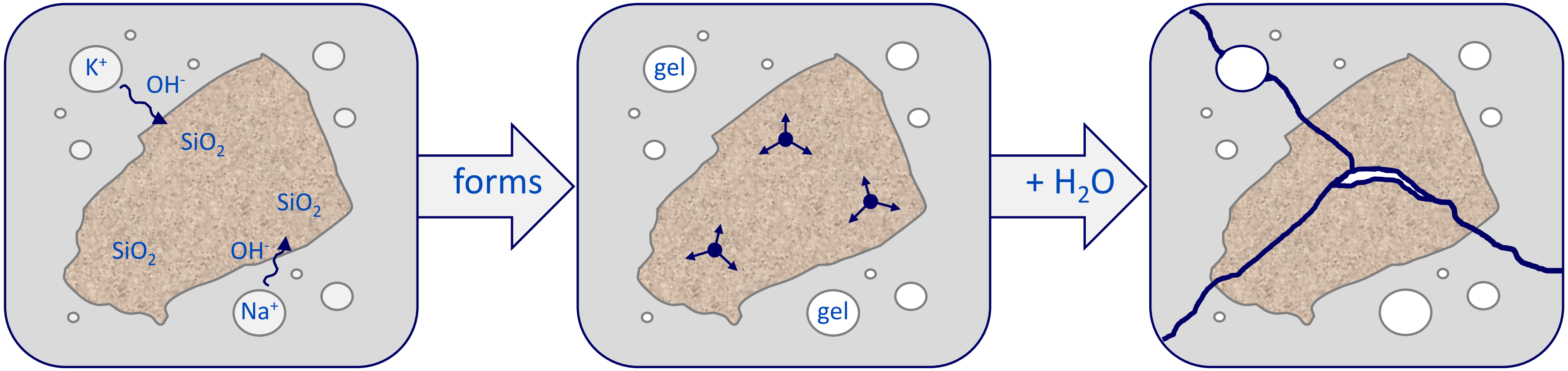
- Alkali-Silica Reaction
- Overview of License Amendment Request (LAR)
- Structural Capacity Testing of ASR-Affected Specimens
- Evaluation of Structural Deformation
- Monitoring of ASR Expansion and Structure Deformation
- Summary of LAR changes
- Closing Remarks

-Presentation describes Next Era current intent regarding License Amendment Application

Alkali-Silica Reaction

Alkali-Silica Reaction

- ASR (alkali-silica reaction) is a chemical reaction between silica from the aggregate (gravel and/or sand) and alkali constituents in the cement
- Reaction produces a gel that expands as it absorbs moisture and exerts a tensile stress from within the concrete



alkali cement + reactive aggregate

expansive gel

cracking of the aggregate and paste

Overview of License Amendment Request

Overview of License Amendment Request

- Next Era proposes a change in the UFSAR methodology to address ASR concrete degradation at Seabrook Station
- ACI 318-71 and the ASME Code do not include provisions for addressing ASR and its effects
  - Incorporate loads imposed by ASR into the design basis
- Evaluate structures affected by ASR to demonstrate that they satisfy the acceptance criteria of the original construction code
  - ACI 318-71 for all seismic Category I structures other than containment
  - ASME Boiler & Pressure Vessel Code, Section III for containment

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Overview of License Amendment Request

- Applies to Seismic Cat 1 Structures and Containment Structure
- Establish ASR expansion limits from testing:
  - Shear capacity
  - Flexural capacity and reinforcement development length
  - Anchor bolts embedded in concrete with ASR
- 3 Stage Analysis process for Building Deformation Assessment:
  - Specify how ASR loads are combined with other design basis loads for analyzing structures including defining load factors
  - Include the effects of concrete creep, shrinkage and swelling in structure deformation analyses
  - Identify ANSYS as the computer code used for ASR building deformation analyses
  - Permit use of the 100-40-40 procedure from Regulatory Guide 1.92, Revision 3 for detailed evaluations (“Stage Three”) analyses of ASR-affected structures.
  - Use of cracked section properties and redistribution of self-limiting loads for ASR-affected structures
- Attachments:
  - UFSAR Markup and ‘Clean’ Pages
  - MPR 4288, Rev 0 Seabrook Station: Impact of ASR on Structural Design Structural Design Evaluations
  - MPR 4273, Rev 0 Seabrook Station: Implications of Large Scale Test Program Results on Reinforced Concrete Affected by ASR
  - SGH (#*TBD*) Computation of Load Factors for ASR Demands

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Structural Capacity Testing of ASR-Affected Specimens

Structural Capacity Testing of ASR-Affected Specimens

- MPR conducted large-scale test programs to investigate structural impact of ASR on reinforced concrete
  - Improve current understanding of ASR and its effects on reinforced concrete structures
  - Evaluate instruments for monitoring (measuring) the through-thickness (out-of-plane) expansion of concrete from ASR

Structural Capacity Testing of ASR-Affected Specimens

Anchor Test Program

Shear Test Program

Reinforcement Anchorage Test Program

Instrument Evaluation Program

Beam Test Programs

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Structural Capacity Testing of ASR-Affected Specimens

Test Program	Results	Key Conclusion

Anchor Test Program	• Anchor performance
	  • insensitive to through-thickness expansion
	  • reduces at high levels of in-plane cracking
	
	• No difference between performance of anchors installed before and after ASR expansion
		No impact on anchors at Seabrook based on expansion levels expected

Beam Test Programs	• Control specimens showed consistency with ACI 318 equations for shear capacity, flexural capacity and lap splice length
	
	• ASR-affected specimens showed:
	  • No adverse impact of ASR on shear capacity, flexural capacity, reinforcement anchorage and lap splice performance
	  • Behavior indicative of pre-stressing due to ASR expansion
		Original design strength and code equations can be used for ASR-affected reinforced concrete structures
		  • Shear capacity
		  • Flexural capacity
		  • Reinforcement development length

Instrumentation Evaluation Program	Snap ring borehole extensometers were accurate and reliable throughout duration of program	Snap ring borehole extensometers selected for use at Seabrook Station

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Structural Capacity Testing of ASR-Affected Specimens

- Licensing Implications
  - Impact on UFSAR
    - -- Large-scale testing or reinforced-concrete beams showed
      - – No adverse impact of ASR on shear capacity, flexural capacity or reinforcement development length
      - – Use of Code equations and design compressive strength to determine capacity is conservative
    - -- No change to the UFSAR-described methodology is necessary for determining capacity provided ASR expansion is within limits from testing
  - ASR expansion limits
    - -- Expansion limits established based on range of expansion covered in testing
    - -- Limits to be controlled within Structural Monitoring Program

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Evaluation of Structural Deformation

Evaluation of Structural Deformation

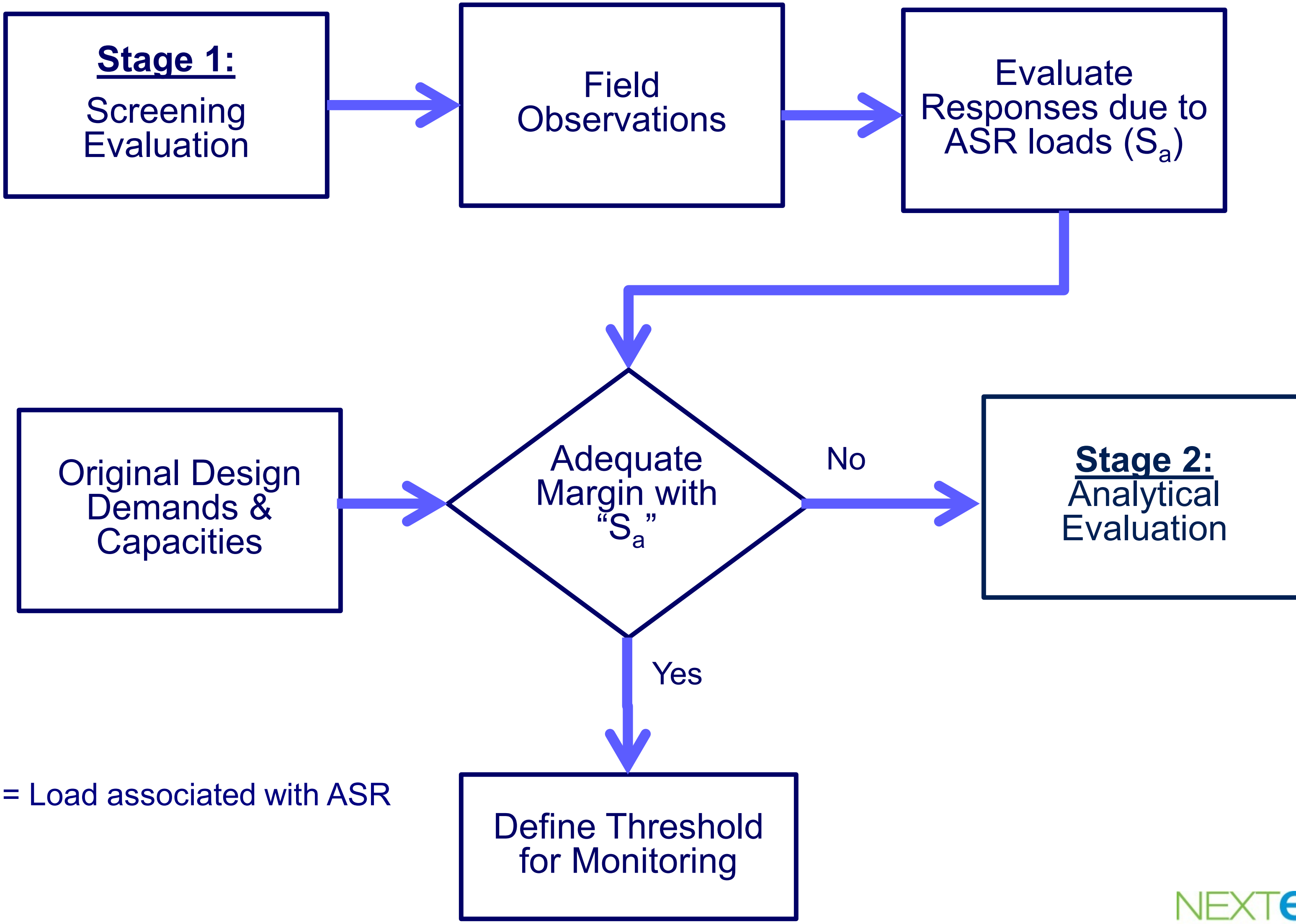
- **Inspections of Seabrook structures have identified deformation due to ASR expansion effects**
  - ASR-related expansion may impose an additional, internal load on reinforced concrete adjacent to ASR-affected areas
  - ASR-related expansion of concrete backfill can impose an external load on adjacent structures
  - Seismic gap widths and close clearances between structures and plant components may be reduced

Methodology for Analysis of Structural Deformation

- **LAR describes progressive approach for evaluating structures with deformation**
  - Stage One – Screening Evaluation
  - Stage Two – Analytical Evaluation
  - Stage Three – Detailed Evaluation

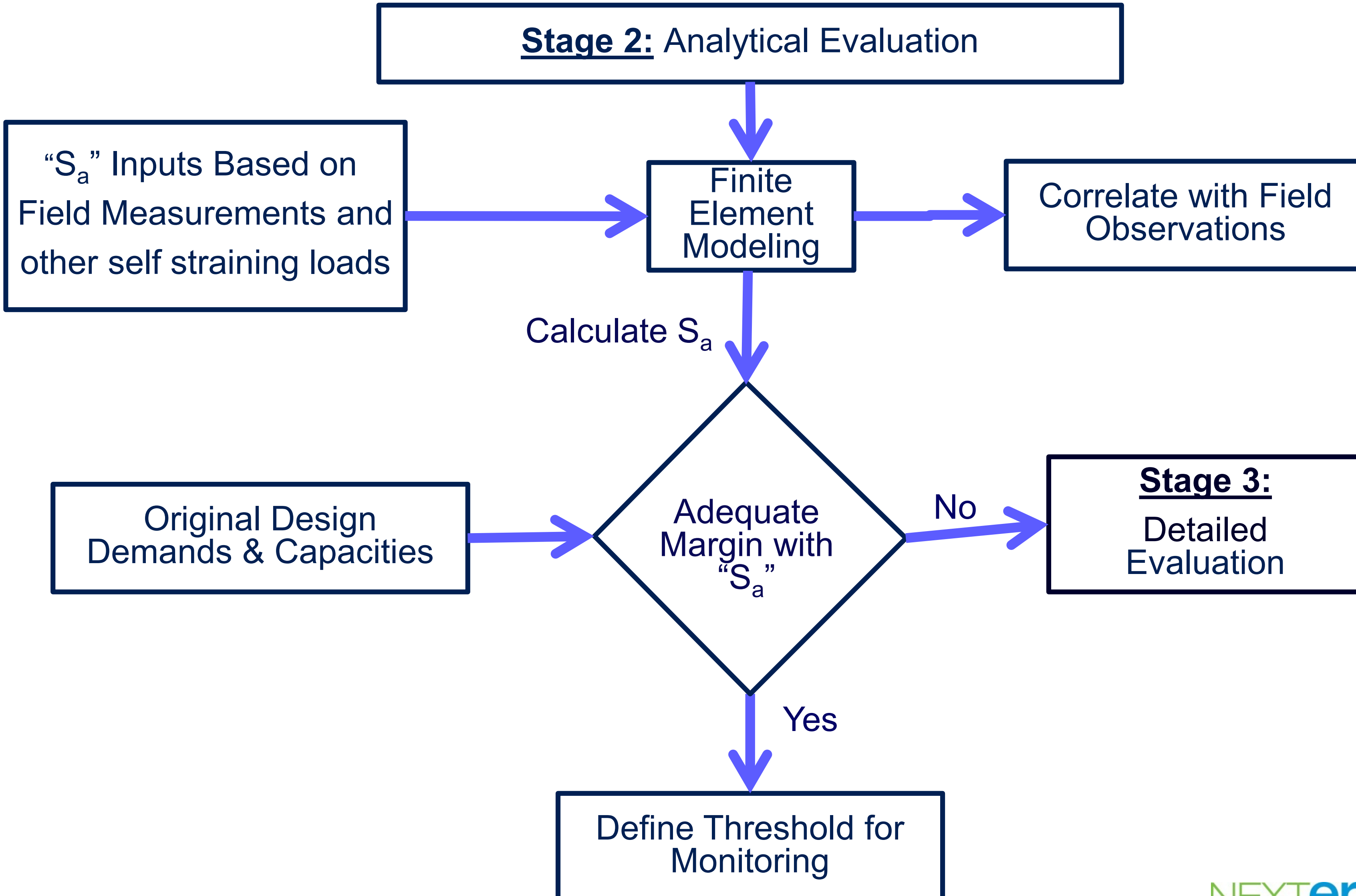
- **Structures require an analysis of all load combinations with ASR loads included**

Evaluation of Structural Deformation



"Sa" = Load associated with ASR

Evaluation of Structural Deformation



Evaluation of Stage 3 Structural Deformation

Stage 3: Detailed Evaluation

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Original Design Loads Inputs → Finite Element Modeling ← Refined "S_a" Inputs Based on Additional Field Measurements

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Evaluate Using Total Factored Design Demands Including "S_a"

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- Cracked section
- Redistribution of Self-limiting load
- 100-40-40 Combination of seismic components

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Define Threshold for Monitoring

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Evaluation of Structural Deformation

- **Including ASR loads with other design basis loads requires definition of load factors for each loading combination**
  - ACI 318-71 and 1975 Edition of ASME B&PV Section III Division 2 does not include load factors for ASR
  - SGH developed load factors consistent with ACI 318-71 and ASME 1975 Edition load factor development
  - Load factors for ASR will be used in the analysis of Seabrook structures and included in Tables 3.8-1 and 3.8-16 of the UFSAR
- **Structures evaluated to demonstrate that additional ASR expansion is permissible**
  - Margin is included in the acceptance criteria for each stage to ensure that additional deformation does not challenge design limits
  - A higher level of deformation is analyzed relative to current measurements to set the threshold for monitoring

Evaluation of Structural Deformation

- **Stage 2 or Stage 3 evaluation will use an ANSYS finite element model**
  - Alternate computer codes were used in the original analyses of Seabrook structures
  - ANSYS has been used for analyzing safety-related structures in other plant designs (e.g., AP1000, ESBWR)
  - NRC has previously accepted the use of ANSYS for structural analysis at other facilities

- **Effects of creep, shrinkage, and swelling of concrete must be accounted for in the structure deformation analyses**
  - Creep, shrinkage and swelling loads are discussed in the Seabrook UFSAR but they were considered negligible in the original design analyses
  - ACI 318-71 includes load factors for loads caused by creep, shrinkage and swelling

Review of ASR Expansion and Structure Deformation Monitoring

Review of ASR Expansion and Structure Deformation Monitoring

- **Continued monitoring of ASR and its effects is necessary**
  - Expansion caused by ASR must be measured and remain bounded by limits established from the large-scale test program
  - Periodic measurements of structure deformation are necessary to ensure limits from deformation analyses are satisfied
- **Separate monitoring requirements will be included in the Structural Monitoring Program (SMP) for ASR expansion and structure deformation**
- **SMP uses a three-tiered approach to classify the results of inspections**
  - ASR expansion levels and structure deformation measurements will be evaluated using classification levels
  - Increased monitoring and analysis are necessary for progressively higher levels of ASR expansion and structure deformation

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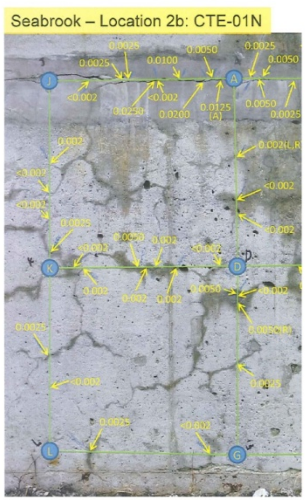
Review of ASR Expansion and Structure Deformation Monitoring

Typical methods used to measure ASR expansion at Seabrook



Combined Cracking Index

Measurement of crack widths over a defined area on structure surface. Used at Seabrook since 2011.

Expansion Measurements

In-plane measurement to determine changes in length between embedded pins.

Snap Ring Borehole Extensometers

Measure changes in through-thickness expansion using gauge rod affixed to anchor

Review of ASR Expansion and Structures Monitoring

Tiers for classifying ASR cracking

Tier	Structural Monitoring Program Category	Recommendation for Individual Concrete Components	CRITERIA Combined Cracking Index (CCI)
3	Unacceptable (requires further evaluation)	Structural Evaluation	1.0 mm/m or greater
2	Acceptable with Deficiencies	Quantitative Monitoring and Trending	0.5 mm/m or greater
		Qualitative Monitoring	Any area with visual presence of ASR (as defined in FHWA-HIF-12-022) accompanied an estimated summation of crack widths not supporting a 0.5 mm/m CI in the vertical or horizontal direction.
1	Acceptable	Routine inspection as prescribed by the Structural Monitoring Program	Area has no indications of pattern cracking or water ingress- No visual presence of ASR

- Limits established in the large-scale test program will be included in the Structural Monitoring Program

Review of ASR Expansion and Deformation Monitoring

- Inspection requirements for structures with ASR-induced deformation

Stage	Deformation Evaluation Stage	Monitoring Interval
1D	Screening	3 years
2D	Analytical	18 months
3D	Detailed	6 months

- Parameters that are measured are specific to each structure
  - Parameters will be defined in the structure deformation evaluation
  - Limits established from deformation evaluation

Summary of LAR Changes

- **NextEra will submit the following changes to the Seabrook UFSAR:**
  - ASR expansion loads are taken into account for seismic Category I structures
  - Load factors for ASR loads are included in the design load combinations
  - Creep, shrinkage and swelling effects are evaluated in the process of analyzing structures with ASR-related deformation
  - ANSYS is used for deformation evaluations
  - Stage Three deformation evaluations may use 100-40-40 method from NRC Regulatory Guide 1.92, Revision 3, for combining seismic loads instead of the SRSS method in Revision 1 of this regulatory guide.

Closing Remarks

- License Amendment Request Represents multiple years of research and learning about ASR
- Third Party Reviews in progress
- Submit to NRC by July 31st

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