Constellation Demonstration
Augmented Containment Inspection

Workshop on Nuclear Plant Life Extension Research and Development

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Objective

- Prepare a Containment Inspection Guide to support operation beyond 60 years.
- Obtain information on containment integrity from the Ginna and Nine Mile Point plants.
Program Activities

- Program activities are selected to:
  - Demonstrate a linkage between a degradation mechanism that may occur and inspections or tests that are to be performed.
  - Provide inspections and tests that are quantifiably reproducible over a 40 year period.
Scope

- The scope includes concrete and other materials associated with a containment function.
  - Concrete containment structures including reinforced, pre-stressed, and post-stressed systems.
  - Tendons including wires, anchorages, shims, etc.
  - Drywell/torus/suppression pool.
  - Basements and foundations of the containment.
  - Concrete structures inside the containment.
  - Structural members housed within the concrete (RCS supports, embeddings, etc.).
  - Containment liner, penetrations, and attachments.
# Concrete Degradation Mechanisms

<table>
<thead>
<tr>
<th>Degradation Mechanisms</th>
<th>Stressor</th>
<th>Effect</th>
<th>Augmented Tests Or Inspections At Ginna</th>
</tr>
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<tbody>
<tr>
<td>Local Loss Of Moisture</td>
<td>Chronic Intermediate Temperature Exposure (&gt;200°F)</td>
<td>Reduced Elastic Modulus and Rupture Strength</td>
<td>Measure strain near penetration. Measure concrete temperature at time of DIC.</td>
</tr>
<tr>
<td></td>
<td>Neutron Radiation (&gt;10^{19} N/Cm²)</td>
<td>Swelling of Aggregates. Reduction In Strength.</td>
<td>None proposed.</td>
</tr>
<tr>
<td>Leaching Of Calcium Hydroxide (Seen As Efflorescence)</td>
<td>Exposure To Water Through Cracks (Depends On Temperature And Chemistry)</td>
<td>Diminished Strength Of Cement Paste And Reduced Concrete Strength. Lowered pH And Subsequent Breakdown Of Protective Film On Rebar.</td>
<td>No augmented testing proposed. Latest inspection did not show any active areas of leaching or efflorescence. If detected in the future, samples could be collected and tested.</td>
</tr>
<tr>
<td>Chemical Attack</td>
<td>Magnesium And Sulfates Of Potassium, Sodium, And Magnesium.</td>
<td>Swelling Causing Cracking And Spalling, Leading To Reduced Strength.</td>
<td>None Proposed.</td>
</tr>
<tr>
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<td>Acids</td>
<td>Increased Porosity And permeability, Reduced Alkalinity</td>
<td>None Proposed.</td>
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<td>Alkali-Aggregate Reaction</td>
<td>Some Constituents Of Aggregate Are Reactable In The Presence Of Moisture, With Chemical Compounds Present In Cement, Mostly Alkalis But Also Includes Potassium, Sodium, And Calcium Oxides.</td>
<td>Expansive Stresses And Severe Cracking</td>
<td>No augmented testing proposed. This is effectively covered by visual examination of outside surface in the existing IWL/IWE exams.</td>
</tr>
<tr>
<td>Carbonation</td>
<td>Carbon Dioxide From Air Reacts With Calcium Hydroxide In Cement In The Presence Of Moisture Producing Calcium Carbonate</td>
<td>Reduced pH, Rebar Corrosion</td>
<td>Carbonation test on containment exterior wall.</td>
</tr>
<tr>
<td>Abrasion</td>
<td>Heavy Load Traffic Exposure To Strong Wind Exposure To Turbulent flow And Cavitation</td>
<td>Pitting, Loss Of Cement And Aggregate Exposure</td>
<td>No augmented testing proposed. This is effectively covered by visual examination of the outside surface of the Containment in existing IWL.</td>
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<td>Creep (Mostly In Prestressed Concrete)</td>
<td>High Loading Such As Under Tendon Anchors, High Temperature Such As Near Penetrations, Changes Of Moisture In Concrete</td>
<td>Cracking Along Cement/Aggregate Boundary And Continued Strain Under Constant Load Causing Loss Of Prestress.</td>
<td>Monitor tendon loads by strain gages. Measure strain at penetration.</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Cyclic Loading, Including Loads From ILRT</td>
<td>Concrete Cracking And Creep Tendon Relaxation Loss of Bond With Rebar Surface Spalling And Internal Cracking</td>
<td>Measure strain of concrete during SIT. Monitor strain gage on rebar and concrete.</td>
</tr>
<tr>
<td>MIC</td>
<td>Moisture Environment Such As Below Grade Exterior Walls</td>
<td>Cracking And Loss Of Cement.</td>
<td>None Proposed.</td>
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</table>
Summary of Augmented Inspection

- Tendon load monitoring with fiber optic strain gages.
- Rebar strain gage monitoring.
- Concrete surface strain monitoring with Digital Image Correlation.
- Rebar corrosion protection monitoring with carbonation test.
Fiber optic strain gages will be applied to the shims of 20 tendons.
Post–Tensioning Tendon
Can Covering the Tendons

- TEE CONDUIT BODY WITH ACCESS PORT
- 1" TO 3" BUSHING
- FIBER OPTIC CABLE CONNECTOR
- WATERTIGHT JUNCTION BOX
- 8" SCH 40 STEEL PIPE
- FIBER OPTIC CABLE COILED AROUND PIPE
- TENDON BUSHING
- 12" SCH 20 STEEL CAN WALL
- STEEL SHIMS
- CAN BASE PLATE
- STRAIN GAUGE
- NEOPRENE GASKET
- 3/4" FLEXIBLE CONDUIT
- 3/4" THREADED CONDUIT COUPLING
- 1" THREADED CONDUIT COUPLING
- CASKET
Tendon Monitoring
Structural Behavior during Structural Integrity Test (SIT)
Rebar Strain Monitoring

- Select one currently exposed rebar and install fiber optic strain gage.
- Install concrete strain measuring fiber optic gage in close proximity to the rebar strain gage.
- Monitor both with the tendon monitoring system.
Digital Image Correlation (DIC)

- DIC is a non-destructive non-contact technique to measure changes in shape and strain on structure surface.
- DIC requires that a pattern be painted onto the surface.
- High-strain locations selected for DIC.
- Can be used to demonstrate that concrete shape is not changing due to swelling or other degradation and that strain is appropriate during SITs.
Digital Image Correlation (DIC) Lab Qualification

1. Concrete compressive strength, f_c, is 4,000 psi
2. Steel yield strength is 40,000 psi
3. Main rebar are #4 (0.5" diameter)
4. Stirrups are #1
5. Main rebar center is 1.5" from near concrete surfaces

Beam Second Loading Fri Oct 29

DIC Camera and Lights
Concrete Beam
Concrete Carbonation Test

- Carbonation is a chemical reaction of Portland cement with the atmosphere that causes reduction in concrete pH.
- Reduction in concrete pH makes rebar more susceptible to corrosion attack.
- Tests are performed on external surface concrete with holes drilled into the concrete.
- If depth of carbonation penetration is less than rebar cover, corrosion protection is adequate.
An improved understanding of behavior and the results from the Ginna and NMP inspections will lead into the preparation of the Containment Inspection Guide.

The guide will provide a methodology for baseline inspections and examinations and follow-up inspections for long term operation.