Bluestone Dam
AAR – A Case Study
Presentation Overview

- Site Overview
- Ongoing DSA Projects
- AAR Project Issues
- Sample Retrieval
- Laboratory Testing
- Conclusions
Bluestone Dam – Existing Project

- **Concrete Gravity Dam - 1940’s**
- **Length - 2,060 ft, Height 165’**
- **Top of Dam Elevation 1,535’**
- **Spillway Crest Elevation 1,490’**
Bluestone DSA Phase I

- Project Features
  - 2 Lane Bridge
  - Thrust Blocks
  - Extending Penstocks
  - Sacrificial Bulkheads
Pre-cast Concrete Wall

Raise Walls

Route 20 Closure

New Training Wall

**Bluestone DSA Phase II**

- Project Features
  - Rock Anchors
  - Parapet Wall
  - Rt 20 Gate Closure
  - New and Modified Training Walls
What is AAR?

- Alkali Reaction with Silica (ASR)
- Alkali Reaction with Carbonates (ACR)
- Severity Influenced by:
  - Aggregate
  - Cement – Alkali
  - Humidity
  - Temperature
  - Stress Level
  - Time
- Decreased Serviceability and Design Life
Issues for Bluestone Dam

- Growth Mechanism – ASR or ACR?
- Growth Rate
- Impacted Areas of the Dam
- Compressive Strengths
- Influence on Planned Construction
- Same Quarry OK?
Snowflake Quarry - Potentially ASR Reactive
Sample Retrieval from Dam

- Roughly 30 Sample Locations
- 4” and 6” Thin Wall
- NQ, PQ and 3”
- Positioned Primarily in Spillway Bridge
- Selected other Locations
  - Galleries
  - Abutments
Damage Rating Indicies

- Stereobinocular MS
- Mag = 16x
- Natural and UV Light
- Uranyl Acetate
- Gel Fluoresces
- DRI ~ 30

<table>
<thead>
<tr>
<th>Weighting Factors for Determination of DRI</th>
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<tbody>
<tr>
<td><strong>Feature measured</strong></td>
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<tr>
<td>Cracks in coarse aggregate</td>
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<tr>
<td>Cracks in coarse aggregate + gel</td>
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<tr>
<td>Open cracks in coarse aggregate</td>
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<tr>
<td>Coarse aggregate debonded</td>
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<tr>
<td>Reaction rims</td>
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<tr>
<td>Paste with cracks</td>
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<tr>
<td>Paste with cracks + gel</td>
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<td>Gel in air voids</td>
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DRI Results

BLUESTONE DAM CORES

Damage Rating Indices (arbitrary scale)
Petrography

- Alkali Silica Gel Observed
- Chert
- Chalcedony
- Greywacke
- Alkali Contents < 2 kg/m$^3$
Expansion Tests

- On Cores, CSA A864-00
- 100% Relative Humidity, 38 C
- Over Water and w/NaOH Added – Insufficient Alkalis

![Graph showing expansion over storage time](image)

\[ y = 0.0014x - 0.0087 \]

\[ R^2 = 0.9426 \]
Compressive Strengths – 1940s

![Graph showing compressive strengths over time for different numbers of bags per cubic yard of cement. The graph illustrates how compressive strength increases with time and the number of bags used.](image)

- **Compressive Strength (psi)**
- **Days Since Casing**
- **Number of Bags Per Cubic Yard of Cement**
  - 3.5 Bags
  - 4.5 Bags
  - 5.5 Bags
  - 4.0 Bags
  - 5.0 Bags
  - 6.0 Bags

**Key Points**
- Compressive strength increases as the number of bags increases.
- Strength generally increases over time, reaching a peak after some days.
- Air entrained mixes are shown with distinct markers for each bag count.
Compressive Strengths – 2000

Compressive Strength (psi)

Days Since Casing

Number of Bags Per Cubic Yard of Cement

Range in Current Compressive Strengths

One Year

[Graph showing different lines representing different numbers of bags per cubic yard of cement, with X-axis representing days since casing and Y-axis representing compressive strength (psi).]

50 Years

3.5 Bags
4.5 Bags
5.5 Bags
3.0 Bags
3.5 Bags
4.5 Bags
6.0 Bags
Conclusions

- Growth Mechanism – ASR
- Growth Rate ~ Very Small
- Insufficient Alkalis to Support any Further Significant Expansion
- Compressive Strengths Decreased – Consider in Future Designs
- Spillway Bridge Capacity
Questions ??
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