Bluestone Dam DSA
Anchor Challenges

Tri-Service Infrastructure Systems Conference

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Topics

- Brief Overview of Bluestone Dam
- DSA efforts completed to date / ongoing and future efforts
- Lessons learned from the field anchor study
Location

Huntington District Coverage:
- Ohio
- West Virginia
- Kentucky
- Virginia
- North Carolina

- Bluestone Lake

Kanawha River Basin Bluestone Drainage Area:
- Bluestone drainage area highlighted in yellow

Note: Bluestone drainage area highlighted in yellow

US Army Corps of Engineers
Huntington District

One Corps, One Regiment, One Team
Concrete gravity dam
- 165’ high
- 2060’ long

4600 mi² drainage area

Outlet works
- 16 sluices
- Gated spillway (21)

6 penstocks
Construction

- Started in 1942
- Suspended in 1944 (WWII)
- Resumed in 1946
- Completed in 1948
- Hydropower not implemented
  - Storage re-allocated for flood control
  - Pool elevation reduced from 1490 feet to 1410 feet
Bluestone Dam Overview

Spillway 790’ long
Bluestone Dam Overview

◆ Project foundation:
  ● Valley floor:
    ■ Founded on orthoquartzite or interbedded orthoquartzite and carbonaceous shale
  ● Abutments:
    ■ Shales
    ■ Siltstone
    ■ Sandstone
DSA Project History

Fault was not removed from monoliths 10 through 12
Bluestone DSA Phase 1

- **Phase I Contract**
  - Awarded Sept. 2000
  - Completed 2004

- **Project Features**
  - 2 Lane Bridge
  - Thrust Blocks
  - Extending Penstocks
  - Sacrificial Bulkheads
Bluestone DSA – Phase 2A

- Crest gate guide extensions
- Route 20 gate closure
- Upgrade access road to stilling basin
- Monolith (not shown)
Bluestone DSA – Phase 2B

- Awarded 31 May 2005
- Brayman Construction Corporation
- $30,000,000
Bluestone DSA – Phase 2B

Anchor nonoverflow

Complete thrust block
Bluestone DSA – Phase 2C

- 8’ Precast concrete wall
- Raise Walls 5’
- New Training Wall 200’ Long
- Anchors
- Scour Protection
Lessons Learned from the Field Anchor Study

- Corrosion Protection
- Drill Hole Alignment
2002 Field Anchor Study

- Install Four 61 Strand Production Anchors
  - Two from top of dam and instrumented (8°)
  - Two from face of dam (45°)
  - Corrosion protection is 10" corrugated polyethylene pipe 70-mil.
  - Bond zones forty feet.
  - Stressed lengths 130 to 200 feet.
Field Anchor Study (cont.)

- Install Eight Bond Stress Test Anchors
  - 18 strand anchors in 5" holes
  - Bond zones 10'
  - Load to, or near, bond failure
  - 4 lithologies tested
  - Parallel lab pull-out tests for comparison
Lessons Learned from the Field Anchor Study

- Corrosion Protection
  - Corrugated
    - Thickness
    - Handling
  - Sheathing
    - Polyethylene VS Polypropylene
    - Handling
Corrosion Protection

- Corrugated (Prinsco, Goldline)
  - 70-mil (measured at the crown)
    - 84-mil max
    - 56-mil minimum
  - 550 ft lengths
Corrugated collapses

- First lift 9 ft
- Second lift 30 ft
  - Collapses at 9 ft and travels up 8 ft
- All lifts reduced to 20 ft
Smooth Walled HDPE ½” Thick
HDPE Welded
Corrosion Protection
Corrosion Protection

- **Corrugated** (Prinsco, Goldline)
  - 4-mm (157-mil)
  - Manufactured in maximum 60 ft sections

- **Smooth Wall** (CPChem, Driscoplex 4100)
  - 0.5 inch
Corrosion Protection

◆ Smooth Wall Collapse

- First lift 10 ft
- Second lift 41 ft
- Third lift 119 ft (to the surface)
  - Collapse at 51.5 ft
Corrosion Protection

- Critical buckling pressure for 10” diameter, 70-mil corrugated: 19 PSI
- Critical buckling pressure for 10” diameter, 157-mil corrugated: 59 PSI
- Critical buckling pressure for 10” diameter, 0.50-inch smooth: 19 PSI
Corrosion Protection

Specifications call for a 100-mil corrugated

- Critical buckling pressure for 10” diameter, 100-mil corrugated: 39 PSI
Installation of Corrugated
Specifications call for a simple falling head test on the installed, but ungrouted corrugated.

Loss of less than 2.75 gallons in 10 minutes at 5 psi head shall constitute a watertight encapsulation.
Corrosion Protection

Field Fix of Polyethylene
Tendon Installation
One Corps, One Regiment, One Team
Corrosion Protection

Specifications call for a polypropylene hot-melt extruded coating. Polypropylene is much tougher than polyethylene sheathing but does cost more.
Alignment Tolerance Field Anchor Study

The scope specified a minimum drill tolerance of 1 in 150. Each drilled hole was surveyed for positional accuracy by the Baker-Hughes INTEQ using the Seeker™ Surveying System.

Survey accuracy

1 in 700 8-degree holes
1 in 300 45-degree holes
Starter Guide
Sub-Bearing Plate and Trumpet
Installation and Alignment
Installation and Alignment
Installation and Alignment
One Corps, One Regiment, One Team

US Army Corps of Engineers
Huntington District

15" Hammer
Alignment Tolerances

◆ Crest Anchors
  • 1 in 110 feet

◆ Anchors on downstream slope
  • 1 in 20 feet
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Up-Down Deviation from Intended Location
Due to Drift

- BDA 46-1 8° anchor
- BDA 46-2 8° anchor
- BDA 46-3 45° anchor
- BDA 46-4 45° anchor
- Tolerance: 1 ft in 150 ft

Depth Down Hole (ft)

Target Borehole
Actual Borehole
Alignment Tolerances

Each bidder was given a video documenting the lessons learned from the 2002 field anchor study and a copy of a report on directional drilling and bore hole alignment measurement technology.
Alignment Tolerances

Specifications call for each anchor hole to be surveyed using a rate gyrocompass, or equal equipment. If the hole alignment is not within these tolerances, the hole shall be backfilled and redrilled at the contractor’s expense.
Questions?

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Foundation Conditions

Construction Events

Fault was only partially removed from monoliths 13 and 14

* Fault was not removed from monoliths 10 through 12
DSA Project History

Fault was not removed from monoliths 10 through 12
One Corps, One Regiment, One Team

Up-Down Deviation from Intended Location
Due to Setup Error

Depth Down Hole (ft)

Up-Down Deviation from Set-up, $y_{set}$ (ft)

- BDA 46-1 8° anchor
- BDA 46-2 8° anchor
- BDA 46-3 45° anchor
- BDA 46-4 45° anchor
- Tolerance: 1 ft in 150 ft

Target Borehole
Actual Borehole

left, -
up, +
right, +
down, -