Kentucky Lock Addition
Downstream Middle Wall
Monolith Design

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Huntington District

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Presentation Outline

- Project Overview
- Downstream Float-In Cofferdam
- Monolith Design
  - Seismic Criteria
  - Stability Analysis
  - Thermal Considerations
- Construction Issues
Project Overview
Project Components

- New 110’x1200’ Lock Landward of Existing 110’x600’ Lock
- Relocations of KY Hwy 62, P&L Railway, TVA Powerhouse Access, and TVA Transmission Towers
Construction began FY98

Lock and DS Cofferdam Construction from FY08 through FY18 or beyond based on current funding stream

Total project costs are currently $639M
Existing Project Site
# Pool, Lock and Cofferdam Elevations

## Pool Levels
- **Headwater:**
  - Minimum Normal: Elev. 354
  - Maximum: Elev. 375
- **Tailwater:**
  - Minimum: Elev. 300
  - Maximum Design: Elev. 344

## Lock Elevations
- **Chamber:**
  - Top of Wall: Elev. 382
  - Lock Sills:
    - Upper: Elev. 335
    - Lower: Elev. 285
- **Approach Walls:**
  - Upper: Elev. Varies (Floating)
  - Lower: Elev. 345

## Cofferdams
- **Upper Cofferdam:**
  - Top of Protection: Elev. 375 (Top of Spillway Gates)
- **Lower Cofferdam:**
  - Top of Protection: Elev. 343.5 (25 Year Frequency)
Downstream Monoliths
PDT Members

- TVA – Owner
- Nashville District – Lock O&M and Project Management
- Bergmann Associates, et. al. – Downstream Cofferdam Design
- Huntington District – Design of DS Monoliths and Sills
- Many others involved in the overall design of the project
Downstream Cofferdam
◆ Design of the Downstream Cofferdam was contracted to a joint venture of Bergmann Associates and Ben C. Gerwick with D’Appolonia Engineering

◆ Design completed in FY03

◆ Combination of precast concrete float-in with tremie and cast-in-place in-fill, conventional sheet pile cellular, and tied Z-pile structures
Typical Cofferdam Section

- **EL 343.6**
- **EL 315.0**
- **EL 280.0**
- **EL 278.0**

**FLOAT-IN SEGMENT**

**TREMIE SEAL**
Monolith Design

- Seismic Criteria
- Stability Analysis
- Thermal Considerations
Seismic Criteria

Two sets of criteria for design

- TVA – “Federal Guidelines for Earthquake Analyses and Design of Dams” and USCOLD
- USACE – Earthquake Design and Evaluation for Civil Works Projects, ER 1110-2-1806
Seismic Criteria

◆ TVA Criteria

- Probabilistic Approach for MCE – 10,000 year event
- MDE = MCE
- OBE = ½ MDE
- Only Reservoir Retaining Structures to be designed to the MDE
USACE Criteria

- Deterministic Approach for MCE
- MDE/OBE based on Hazard Potential Classification – High, Significant, or Low
- High Hazard – MDE = MCE
- Significant & Low – MDE < MCE
## Seismic Criteria

<table>
<thead>
<tr>
<th>Agency</th>
<th>Hazard</th>
<th>MDE</th>
<th>OBE</th>
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<tbody>
<tr>
<td>TVA</td>
<td>Reservoir Ret.</td>
<td>0.25g</td>
<td>0.12g</td>
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<tr>
<td></td>
<td>High</td>
<td>0.25g</td>
<td>0.12g</td>
</tr>
<tr>
<td>USACE</td>
<td>Significant</td>
<td>0.13g</td>
<td>0.05g</td>
</tr>
<tr>
<td>USACE</td>
<td>Low</td>
<td>0.10g</td>
<td>0.05g</td>
</tr>
</tbody>
</table>
Seismic Criteria

**Downstream Monolith Hazard**

- TVA – Non-Reservoir Retaining Structure
  - Below Upstream Gates
  - Below Axis of Dam

- USACE – Significant Hazard Classification
  - Little or no potential for direct loss of life
  - Loss of a major public facility
Seismic Criteria

Load Cases to Consider

- OBE
  - TVA – 0.12g
  - USACE – 0.05g
- MDE
  - TVA – N/A
  - USACE – 0.13g
- Since MDE ≈ OBE, only OBE was analyzed
Monolith Design

- Seismic Criteria
- Stability Analysis
- Thermal Considerations
Stability Analysis

- 8 Load Cases Analyzed
- 3D Analysis on Miter Gate Monoliths
- 2D Analysis on Remaining Monoliths
- Monolith and Cofferdam treated as one structure
- Miter Gate Monolith and Monolith Immediately D/S analyzed as one Structure
Monolith/Cofferdam Combined Analysis

- Required for some load cases
- Tied together with #7 bars at 18” spacing vertically and horizontally
- Ties checked against seismic load case
Stability Analysis

STAGE 7: COMPLETE MONOLITH PLACEMENT
**Seismic Analysis of Ties**

- 1st Attempt – Non-Linear Time History Analysis using GTSTRUDL
- Ties Modeled as Non-Linear Springs
- Non-Linear Gap Elements at Concrete-Rock Interface
- 1st Runs Took 15+ Days and Produced Useless Results
- Next Attempt Exceeded the Computer’s Addressable Memory Space
Stability Analysis
Stability Analysis

◆ **Seismic Analysis of Ties** (Cont’d)
  - Abandoned the Non-Linear Analysis
  - Response Spectrum Analysis of Individual Structures (Cofferdam and Monolith)
  - Modal Analysis using GTSTRUDL
  - Assumed Worst Case of Peak Response of Each Structure Occurring at Same Time and Completely Out of Phase
  - Results Gave a FS of About 3
Stability Analysis
Stability Analysis

Dynamic Mode Shape
Mode 1
Freq 3.98E+00
Stability Analysis

◆ **Miter Gate Monolith Design**
  - Does Not Meet Criteria for Some Load Cases When Analyzed Alone
  - Determined What Additional Force Required at D/S Joint to Meet Criteria
  - Designed a Shear Key to Carry this Force
  - Monolith Joint To Also Be Grouted
Stability Analysis
Monolith Design

- Seismic Criteria
- Stability Analysis
- Thermal Considerations
Thermal Considerations

Two Options to Deal with Thermal Loads

- Separate the Structures with Bond Breaker and/or Insulation and Model Just the Lock Concrete
- Model the Combined Structure Accounting for the Heat Transfer and Restraint Provided by the Cofferdam

Second Option Required Based on Stability

Thermal Analysis Performed by Black & Veatch
Thermal Considerations

- Parametric Studies to Determine Lift Heights and Placement Restrictions
- Thermal Cracking Analysis
  - First Step Was to Model the Construction Sequence of the Cofferdam
    - 10’ Tremie Placement
    - 5’ Lifts Every 7 Days
  - Lock Construction Then Began on Day 365
    - Approximately 5’ Lifts Every 5 Days
Thermal Considerations

 Thermal Analysis Results

- Temperature and Shrinkage Steel Required
  - Around Culvert and Gallery
  - All Exposed Faces
  - Around the Chamfer at Top of Cofferdam

- Didn’t Account for Longitudinal Restraint from Cofferdam
  - Provide T&S Steel at This Face, or
  - Create Joints in Cofferdam
Thermal Considerations

KENTUCKY LOCK MC1 M25 X-STRESS (PSI), DAY 518, G=1g, 6/1 START
Construction Issues
Construction Issues

◆ Primarily Related to Foundation

- Excavation Adjacent to Cofferdam – Founding
  Elevation of Lock 2’ to 17’ Below Cofferdam
  Foundation

- Presence of Solution Channels – One Known
  Channel That May Extend to Below Upstream
  Corner of First Monolith
Construction Issues
Construction Issues
KY Lock Addition – D/S
Middle Wall Monolith Design

Questions?

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