Successful Foundation Preparations in Karst Bedrock of the Masonry Section of Wolf Creek Dam

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Wolf Creek Dam Project Features

- Dam Embankment
- Switchyard
- Trout Hatchery
- Concrete Gravity Section
- 6 Unit Powerhouse

Lake Cumberland
Wolf Creek Dam Location and Purpose

- **Location**: Cumberland River in Russell County, Kentucky
- **Authorized Purposes**: Flood Control and Hydropower
- **Additional Benefits**: Navigation, Recreation, Water Supply, and Water Quality
- **Reservoir first impounded in December 1950**
Karstic Foundation
Dam and Foundation Profile
Masonry/Concrete Dam Upstream Profile

37 Monoliths

- 10 Tainter gates
  - 37’ x 50’ each
- Embankment wrap-around
- Stair-step foundation
- 6 sluice gates
  - 4’ x 6’ each
- 6 power intakes
to turbines
Exploratory Grouting (2011-2012)

Legend:
- 16 to 50 Gallons
- 50 to 100 Gallons
- > 100 Gallons
Dam Site Before Construction
Preliminary Borehole Exploration (1930’s) – 200 ft. centers
Additional Early Borehole Exploration
Preliminary Borehole Exploration (1940)

- Sandy clay filled cavity
- Weathered, fractured and cavernous; Cavity filled with clay, sand, and broken rock
- Weathered, fractured, and cavernous; Cavity filled with clay, sand, and broken rock
- Open cavity
- Partially filled with sandy clay
Early Borehole Exploration
Overburden Removal
Overburden Removal
Additional Drilling Post-Overburden Removal

Before rock removal was begun in an area, a study was made of all geological information pertinent to that area. This geological information consisted of the logs of the holes drilled during the preliminary investigations of the site as well as the various informative reports prepared by the Geological Section. From this information, it was usually possible to determine within reasonable accuracy the quantity and depth of rock to be removed in a given area to provide structurally sound foundations.

As the preliminary investigation drillings were made on one hundred (100) foot centers, it was decided that if a closer on-center pattern of drilling was made, a better knowledge of rock conditions would be afforded and rock removal would be confined to a minimum.
Additional Drilling Post-Overburden Removal

Beginning at the axis, two (2) inch percussion drilled holes were drilled on twenty (20) foot centers normal to and paralleling the axis until the entire area of the monolith or other structure had been drilled. These holes were drilled vertically, and were sixteen (16) feet deep. The drilling was carefully observed in order to locate possible subsurface solution channels, soft bedding of appreciable thickness, or other defects. A log was prepared of the results of the test drilling, and compared with the original geological findings. Upon completion of this review, the removal of the necessary rock was ordered.
Manual Removal of all Rock not “Firmly Bedded”
Bedrock Excavation Monoliths 37-30
Bedrock Excavation Monoliths 37-30

Mon. No. 32
Cleaning Out Solution Channel

Photo No. 89
Bedrock Excavation Monoliths 37-30

Mon. No. 32
Widening & Exploring Solution Channel

Photo No. 139
Large Solution Channel Excavated
Second Channel with First
Solution Channel Cleaning
Solution Channel Cleaning
Bedrock Excavation Monoliths 29-25
Contact Grouting

Monolith 25
Contact Grout System
Monolith 24
Upstream
Bedrock Excavation Monoliths 24-19
(Power Intake Section)
Bedrock Excavation Monoliths 29-19
(Power Intake Section)

Solution Feature

Solution Feature

Catheys Limestone
Monolith 20 – Grouting without Pressure
Bucket Excavation Monoliths 18-14
(Spillway Section)

PRELIMINARY EXPLORATION:

During the rock removal a solution channel was uncovered that extended along the entire downstream toe of the bucket. It was excavated to its full depth, and after its removal, percussion drilled holes on 10-foot centers were drilled 6 to 10 feet deep, into the area it occupied, and revealed the rock to be sound.
Bucket Excavation Monoliths 18-14
(Spillway Section)
Bedrock Excavation Monoliths 13-9
(Spillway Section – River Channel)
Bedrock Excavation Monoliths 8-1
(Left Abutment)
Bedrock Excavation Monoliths 8-1
(Left Abutment)
Bedrock Excavation
Monoliths 8-1
(Left Abutment)
Grout Holes and Drains
Masonry/Concrete Dam Foundation Profile

Bedrock profile along the axis of dam based on drawings mapped just prior to the placement of the concrete monoliths.
Original Dam Construction Cost

TOTAL CONTRACT COST $19,648,450.36

DEDUCTIONS:

The amount due the Government for Utilities and for credit assumed from S. A. Healy, Inc., the original contractor. In accordance with paragraph (f) of Article 29 of Contract No. W-40-058-eng-249

- $952,351.26

The amount equals to the number of yards of concrete placed multiplied by $0.40 for a given length of time. In accordance with paragraph (d) of Article 29 of Contract No. W-40-058-eng-249.

- 447,889.51

Payment for Government furnished cement used by contractor in erecting construction plants and facilities. In accordance with paragraph 1-C-10(b)(3) of the Specifications.

- 102,187.82

Deduction in accordance with Modification Number 6 dated 9 December 1946.

- 18,452.38

Deduction in accordance with Modification Number 15 dated 8 September 1947.

- 5,361.67

NET PAID CONTRACTOR $18,122,207.72

Original construction cost about $240 million in 2015 dollars

Recent remediations of embankment cost about $600 million

BUILDING STRONG®
Impervious Rolled Fill
Homogenous, well compacted, low plasticity clay.

Drainage Blanket
Choked with fines, difficult to distinguish from the alluvium in recent borings

Cutoff Trench
Compaction was likely variable. Placement and compaction, often by hand, occurred against rough vertical walls and under rock overhangs.

Alluvium
Predominately fine grained but with sand and gravel lenses

Cutoff Trench Design Philosophy (Core Trench Foundation Report, 1943):
“Overhangs and loose rock will be removed only where they cross the lines of the trench, since the earthfill in the sides of the trench will have the function only of stability and not of an absolutely uniform tight contact with the trench walls.”
Placement and Compaction of Cutoff Trench Fill
Distress Indicators Observed in the 1960’s

At the time, there were no instruments to monitor the project.
Turbid Discharge into the Tailrace in 1967
Sinkhole Observed near Switchyard in 1968
Sinkhole Observed near Switchyard in 1968
Emergency Grouting

Emergency Grouting 1968 – 1971
300,000 cubic feet of solids injected
1975 ICOS Combination Wall

- Embankment Barrier Wall
- Concrete
- Top of Dam EL 773
- Top of Rock
- Top of Alluvium
- Soft Zone
- Leipers
- Limestone Foundation
- Catheys
- End wall Sta. 57+50

- Seepage Barrier Wall
- Switchyard Wall
Since 1990 the extent of the wet areas has steadily increased, reaching the maximum extent in March of 2004.
Persistent Wet Areas
ACT Grouting (2007-2008)

1300 holes
900,000 gallons of grout
$70 million
Completed September 2008
Barrier Wall Construction (2009-2013)

Total Length of New Barrier Wall: 3,800 feet
Barrier Wall Construction (2009-2013)
Questions?