New RCC Dam Replaces 70-Year Old Concrete Dam

Geoffrey L. Cowan, P.E., Dewberry & Davis LLC, Keith A. Ferguson, P.E., Kleinfelder, Inc., and Fares Y. Abdo, P.E., Portland Cement Association

Big Cherry Dams soon after construction of the new dam.

The Old Big Cherry Dam is a 43-ft (13.1-m) high, 225-ft (68.6-m) long cyclopean concrete dam located in Wise County, Virginia near the Virginia/Kentucky state line. The dam impounds Big Cherry Reservoir, the water supply for the Town of Big Stone Gap, VA. The dam which was constructed in 1935, has been classified as a high hazard impoundment by the Virginia Department of Conservation and Recreation (VDCR). Dewberry & Davis LLC (Dewberry) has performed numerous engineering studies of the dam and reservoir during the past 20 years, including dam safety inspections, stability analyses, dam break studies, water supply, and rehabilitation studies. Past studies have determined that the old dam would be unstable during passage of the Probable Maximum Flood (PMF), the required spillway design flood. In addition, the Corps of Engineer's Phase I inspection report found the spillway capacity to be 20 percent of the required full PMF. Because failure during the PMF could result in loss of life, the dam had been operating under a conditional operation & maintenance certificate from VDCR since the inception of the Virginia Dam Safety Program.

Big Cherry Reservoir provides water supply to the town of Big Stone Gap water treatment plant. During dry spells, such as the summers of 1999 and 2002, reservoir levels have fallen to dangerously low levels prompting the Town to institute conservation measures and to examine alternatives for increasing the Town's water supply. Water supplies in neighboring Norton and throughout the region are also routinely stressed during dry periods, which points to a regional water supply problem.

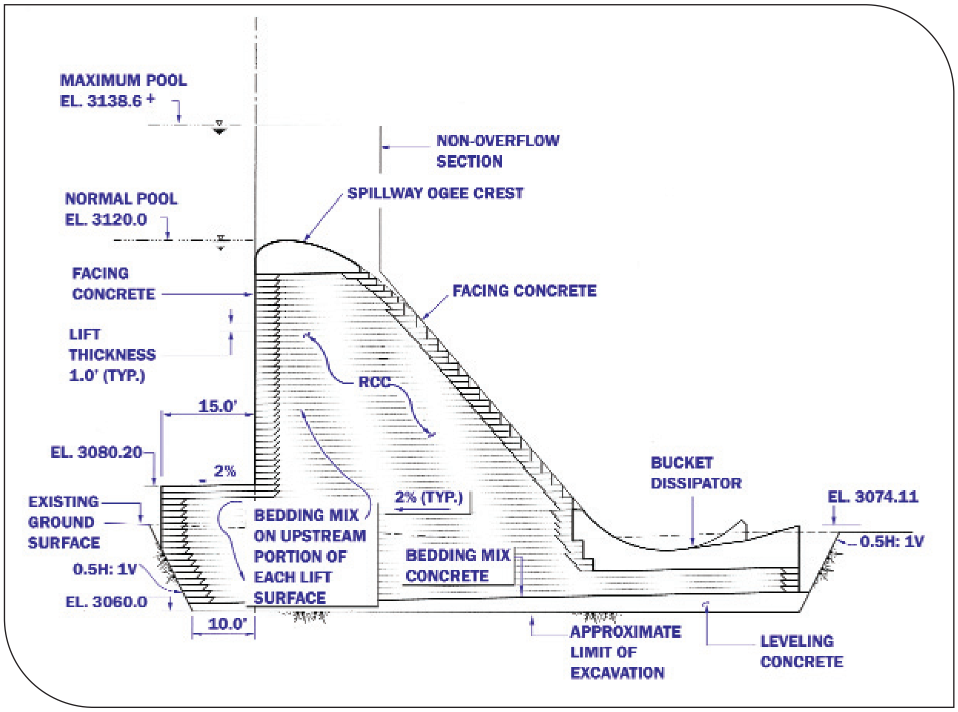
Before constructing the new roller-compacted concrete (RCC) dam, the 4 million gallons (15.1 million liters) per day capacity water treatment plant produced an average water supply of approximately 1.7 MGD (6.4 MLD) which was very near the safe yield of the old reservoir. The water treatment plant will be able to safely treat over 3 MGD (11 MLD) with the new dam and increased reservoir storage in place.

Preliminary engineering studies were performed by the engineering team of Dewberry and GEI Consultants in which the following options for both stabilizing the old dam and increasing reservoir storage were evaluated:

- Installation of post-tensioned anchors to stabilize the dam during passage of the PMF
- Construction of an RCC dam overtop of the old concrete dam
- Construction of a new RCC dam just downstream of the old dam and submerging the old dam

It was determined that construction of a new RCC dam downstream of the old dam and raising the permanent lake elevation 7 ft (2.1 m) to increase water supply was the preferred alternative to stabilizing and raising the existing dam. The New Big Cherry Dam helps reduce the region's water supply problem and the Town has negotiated agreements to sell treated water to neighboring municipalities once the increased supply becomes available.

Design of the New Big Cherry Dam was completed in June 2003 and plans were issued for bid in August 2003. The



Overflow Section of new dam

dam was designed to minimize long-term operation and maintenance concerns. Specifically, one of the primary design objectives was to eliminate the drainage gallery and both dam and foundation drains as well as to provide adequate stability of the structure without these typical elements. Stability evaluations indicated that this could be accomplished by the addition of an upstream buttress or heal section to the dam as shown in the adjacent overflow section.

Seepage control was provided by the use of a conventional concrete facing system, bedding mortar on RCC lift surfaces downstream of the facing concrete, appropriate foundation/abutment contact treatments, and control joints with water stops spaced at 12 ft (3.7 m) on center. The new dam foundation was located 165 ft (50 m) downstream from the existing dam at elevation 3,060 ft (932.7 m).

The design included an uncontrolled ogee type spillway to function as a combined service and emergency spillway. The downstream face of the spillway incorporated steps constructed as part of the RCC overflow section. These steps simplified the construction of the overflow spillway section and provided energy dissipation for flows down the spillway face. A spillway crest elevation of 3,120 ft (951.2 m) was established to provide a 7-ft (2.1 m) increase in reservoir elevation. An 80-ft (24.4 m) spillway crest length was used to provide for approximately 25,000 cfs (710 m^3/sec) discharge capacity at the spillway. The maximum elevation of the reservoir during the PMF was computed to be 3,138.6 ft (956.6 m). The top-of-dam elevation was designed at this elevation with freeboard provided by a 3.4-ft (1.04 m) high parapet wall located along the length of the dam.


Placement of lower RCC lifts

Energy dissipation was provided by a slotted-type submerged bucket with a bucket radius of 17.0 ft (5.2 m). The height of each training wall was computed from the depth of the full PMF flow along the spillway face.

An air-entrained conventional concrete was used for both the upstream and downstream facing systems to account for the severe freeze-thaw environment and expected frequent operation of the spillway.

Features and characteristics of the old and new dams/reservoirs are compared in Table 1.


Water stops and conventional concrete facing on upstream face of dam

Table 1: Comparing Features of Old and New Dams/Reservoirs

	Old Big Cherry Dam	New Big Cherry Dam
Regulatory Dam Height	43 ft (13.1 m)	70 ft (21.3 m)
Raw Water Storage	359 million gallons (1,359 million liters)	633 million gallons (2,396 million liters)
Reservoir Safe Yield	2.2 million gallons (8.3 million liter) per day	3.2 million gallons (12.1 million liter) per day
Spillway Capacity	2,500 cubic feet (71 m^3) per second	25,000 cubic feet (708 m^3) per second

RCC Mix Design

The RCC mix design for the project was prepared using an integrated concrete/soils approach. The intent of the mix design was to achieve a workable mix that would optimize the cementitious content required to achieve the required strength. The specified minimum compressive strength was 1,500 psi (10.3 MPa) at 90 days. Mix design studies were completed during the design phase and at the start of construction prior to completion of a test section. The mix consisted of 3,684 lb/yd^3 (2,189 kg/m^3) of a crushed basalt aggregate having a specific gravity of 2.70 to 2.75. Mix design and test section results indicated that the desired strength could be achieve with a total cementitious content of 258 lb/yd^3 (153 kg/m^3) at the proportions of 50% cement and 50% fly ash. This is equivalent to about 7% cementitious material by dry weight of aggregate. The water content was approximately 220 lb/yd^3 (131 kg/m^3).

Table 2 – RCC Aggregate Gradation

Sieve Size	Percent Finer by Weight	
	Specified Range	Project Range
1-1/2 in. (37.5 mm)	100	100
1 in. (25 mm)	94 - 100	100
3/8 in. (9.5 mm)	63 - 72	62.2 - 82.5
No. 10 (2.00 mm)	32 - 41	29.2 - 44.2
No. 40 (425µm)	14 - 24	16.2 - 25.7
No. 200 (75 µm)	6 - 12	9.7 - 17.2

RCC mixing plant and conveying system. Photograph was taken during cold weather shutdown

Construction and RCC Cost

In general, the construction scope of work included stream diversion during construction; excavation to bedrock; grouting of the rock to establish an effective seepage cutoff curtain; surface preparation of the bedrock and placement of dental and leveling concrete; and placement of RCC and air-entrained reinforced concrete facing.

The lowest bidder, Estes Brothers Construction, was awarded the contract for a base bid price of approximately $6 million. The dam's remote location and construction site

Spillway operating for the first time in April 2006

Table 3: RCC Cost*

Item	Estimated Quantity	Unit	Unit Price	Item Cost	Percent of Total RCC Cost
Aggregate	23,900	ton	$20.25	$483,975	37.73
Cement	955	ton	$99.80	$95,309	7.43
Fly Ash	955	ton	$31.31	$29,901	2.33
RCC handling, placing and curing	13,800	yd^3	$48.81	$673,578	52.51
RCC total	13,800	yd^3	$92.95	$1,282,763	100

Based on bid quantities and unit prices

topography presented significant construction challenges. RCC aggregate was not available within close proximity and only one steep-sloped, narrow, and unpaved road provided access to the site. The RCC was transported from the mixing plant to the point of placement using a conveyor belt and a crane equipped with a telescoping belt.

Construction began in April 2004 and the project was substantially complete by July 2005. The old dam was submerged and the first spillway overflow event took place in April 2006. Gears, Inc. was the RCC subcontractor for the project. The RCC portion of the work was substantially complete by January 2, 2005. Based on the bid quantities and unit prices, the project required 13,800 yd^3 (10,550 m^3) of RCC and 7,000 yd^3 (5,350 m^3) of conventional concrete. The average in-place cost of RCC (including cost of aggregate, cement, fly ash, mixing, transporting, placing and curing) was $92.95 per yd^3 ($121.57 per m^3). Cost information of individual RCC ingredients are listed in Table 3.

Summary of RCC Core Test Results

A core was drilled to sample the RCC from the dam crest to the foundation bedrock approximately 14 months following completion of the RCC construction. The purpose of the core hole was to document the quality of the RCC materials throughout the dam including the right chimney section, the contact of the RCC/abutment concrete, and the contact between the abutment concrete and the foundation bedrock. Overall, the quality of the RCC was very good.
A total of 7 representative samples were selected for unconfined compressive strength testing. The compressive strength test results ranged from 2,190 psi (15.1 MPa) to 3,530 psi (24.3 MPa) with an average of 2,800 psi (19.3 MPa). The compressive strength of tested specimens met the specified compressive strength of 1,500 psi (10.3 MPa) at 90 days and a desired long-term strength of over 2,000 psi (13.8 MPa).

RCC core extracted from the new dam

Credits

Owner: Town of Big Stone Gap, VA

Owners Representative: Lane Engineering, Inc.

Engineers: Dewberry , GEI Consultants, Inc., and Kleinfelder, Inc.

Contractor: Estes Brothers Construction, Inc.

RCC Subcontractor: Gears, Inc.

PCA

Portland Cement Association
5420 Old Orchard Road
Skokie, Illinois 60077-1083
847.966.6200 Fax 847.966.9781

500 New Jersey Avenue NW, 7th Floor
Washington, DC 20001-2066
202.408.9494 Fax 202.408.0877
www.cement.org

An organization of cement companies to improve and extend the uses of portland cement and concrete through market development, engineering, research, education, and public affairs work.