Concrete Repair and Restoration at Franklin Falls Dam

by David Jamieson and Joseph Colucci

The Aulson Company of Methuen, MA, completed a major concrete removal, shotcrete repair, and restoration project for the U.S. Army Corps of Engineers (USACE) at the Franklin Falls Dam, a 60-year-old structure in Franklin, NH.

Dam Construction and History

The Franklin Falls Dam was built by the USACE as part of a coordinated system of reservoirs to provide flood control on the Pemigewasset River Watershed of the Merrimack River Basin in the state of New Hampshire. Authorized by the Flood Control Act of 1936, the project is located on the Pemigewasset River, the main tributary of the Merrimack River, approximately 2.5 mi upstream from the city of Franklin, NH. Construction of the project began in November 1939 and was completed in October 1943.

The reservoir is operated for flood control and has a total storage capacity of 154,000 acre-ft. The dam is constructed of rolled earth fill, with protective rip rap, rising 140 ft above the river bed. The spillway consists of an excavated channel along the westerly abutment of the dam and a concrete ogee weir with a crest length of 550 ft. Outlet works are on the westerly bank and consist of an intake channel and two 22 ft horseshoe-shaped conduits, each controlled by four service gates from the control tower and gatehouse above. Downstream of the outlet conduits, flow passes through a U-channel stilling basin and an outlet channel, finally winding its way back to the river.

Fast Facts about Franklin Falls Dam:

Approach channel to the gate tower: Approximately 99 ft wide, 840 ft long, excavated in rock.
Easterly wall: 470 ft long, rising approximately 35 ft above the invert of the channel.
Westerly wall: 85 ft long, varying in height from 37 ft to 14 ft above the invert of the channel.

Over a Half-Century Later...

Because the project was constructed in the 1940s, no air entrainment was used in the original concrete. The technology used to mitigate expansion and contraction of the 470 ft-long, 35 ft-high easterly wall and 85 ft-long westerly wall was to install horizontal and vertical joints. Because no weepholes were provided in the original design to allow drainage back to the channel, the flow followed the path of least resistance into and through the joints. This made the concrete structures particularly susceptible to freezing-and-thawing damage and deterioration in many of the horizontal and vertical joints along both the east and west walls of the approach channel.

Deterioration was particularly severe along the east wall because of a horizontal layer of impervious soil that formed part of the upstream dam embankment. The top of this impervious layer was located 12 to 15 ft below the top of the wall and concentrated the majority of storm runoff and snow melt along the second horizontal construction joint beneath the top of the wall. This situation provided a continuous source of water behind the wall and along the joint, which exacerbated the freezing-and-thawing damage with no weep holes to allow the water to escape. A portion of the remedial work included providing drainage

Aerial view of Franklin Falls Dam, Franklin, NH

Access to dam area, with safety protection

Aulson's electric swingtube pump

Shotcrete product pumped approximately 300 ft

from this area along the wall and back into the upstream channel beyond the beginning of the wall.

Photographs and other documentation from reports dating back to 1967 and 1975 indicate ongoing joint deterioration due to runoff and groundwater from the upstream dam embankment working its way toward the walls. By 1999, after several thousand freezing-and-thawing cycles, joint and surface deterioration had encompassed 10 to 15% of the walls' surfaces. It was concluded that due to the freezing-and-thawing damage and 60 years of exposure to the effects of carbonation, extensive rehabilitation work was needed.

The Restoration Challenge

Because of the long-term exposure to freezing and thawing and carbonation, it was concluded that isolated patching of areas would not be an acceptable long-term solution. It was decided that a minimum 1 in. depth would be removed over the entire area of the walls. Where unsound concrete was encountered, the removal would go as deep as necessary. The project engineers were confident that the repair material would provide the final surface desired, but, as in all repair projects, the primary concern was to obtain a surface preparation that not only removed all the deteriorated concrete but also provided a positive bonding surface. Therefore,

Surface prep via hydrodemolition method. Shoot wires stretched across area before wet-mix process shotcrete application

Wet-mix shotcrete application with less than 5% rebound

specifications required that all concrete removal be accomplished by the hydrodemolition method. This was the first time this method of concrete removal and surface preparation had been used in a New England District project of the USACE.

The Restoration Process

Aulson Project Manager Jim Marston chose to use an electric swingtube pump (refer to photo) that mixed the silica fume-enhanced structural shotcrete and dumped it forward into the pumping chamber before moving it several hundred feet through steel pipes and rubber hoses to the repair area (refer to photo).

This wet-mix process was chosen because the water-cement ratio (*w/c*) of the repair mortar is controlled at the mixing vessel instead of at the nozzle like in the dry-mix process. The correct quantity of water per bag of material was dialed in at the pump and the mixture remained consistent throughout the project. The high-velocity shotcrete was applied without the normal rebound and waste usually associated with this repair process.

(left) Rough cutting to shoot wires with Fresno float

Final shaping to shoot wires

Light broom finish after surface shaping of shotcrete

Marston estimated the rebound to be less than 5%.

The surface was prepared by water-jetting using high-velocity pumps leaving a rough profile to receive the shotcrete (refer to photo). The surface was then abraded with sand, washed thoroughly, and allowed to reach saturated surface dry (SSD) condition; then the product was immediately applied. This prevented the carbon dioxide in the air from contaminating the surface by forming carbonic acid at the bond line. Testing by either coring or hammering revealed a strong bond between the substrate and the silica fume-enhanced structural shotcrete mixture.

Thin, high-strength wires were stretched from top to bottom on the repair and adjusted by a turnbuckle system to provide an elevation guide during the shotcrete application process (refer to photo). The crews even rebuilt the face of the repair, which was around a curved area. The shotcrete was applied up to the top of the wires that were approximately 2 ft apart. The excess was cut out with a Fresno float (refer to photo). The surface was finished with a magnesium float. A light broom finish was applied to leave a lightly textured surface (refer to photos).

Because these silica fume-enhanced mixtures are 4 to 5 times denser than conventional concrete mixtures, the bleeding process occurs at a slower rate. It is important to not finish them with a steel trowel until all the bleed water is out of the mixture. If a steel trowel is used too soon, the bleed water can become trapped under the surface and blistering can occur, causing failure at the surface of the repair area.

Proper curing was achieved by using both sprinkler hoses and burlap to facilitate proper hydration of the cement and silica fume-enhanced structural shotcrete.

The Result

In the past, the USACE has experienced difficulties with several contractors regarding their ability to understand the nature of concrete repair as well as their lack of experience in the specialized application techniques required for this type of work. The Aulson Company, however, delivered results through its group of professionals who understood the challenge, had the expertise to perform the project, and took satisfaction in delivering quality work. The restoration solution achieved a repair that should keep the Franklin Falls Dam in peak operating condition for many years.

Since completing the Franklin Falls project, Aulson has won another significant concrete repair project for the New England District of USACE. The Aulson team has completed the majority of the work at Blackwater Dam in Webster, NH. The project was finished in Summer of 2003.

David Jamieson *is Vice President of Concrete Repair and Restoration for The Aulson Company, a full-service specialty environmental and industrial contracting company based in Methuen, MA. Jamieson has over 30 years of industry experience with the products, processes, and techniques of concrete repair—both as owner/operator of a contracting company and as senior project manager for manufacturers and contractors. He is an ACI Certified Shotcrete Nozzleman and an active member of the ASA, currently serving as Co-Chair of the Publications Committee. He may be reached at djamieson@aulson.com.*

Joseph Colucci *is a Senior Structural Engineer and Technical Lead Engineer for the New England District, USACE, located in Concord, MA. Colucci has over 30 years of technical experience in structural design, concrete repair, and oversight of various projects within the New England area.*