Constructing a Cutoff Wall in Front of Walter F. George Dam in 100 Feet of Water

To combat seepage at the dam of the 130-MW Walter F. George Lock and Powerhouse in the southeastern United States, the U.S. Army Corps of Engineers built a 1,831-foot-long upstream cutoff wall. Installing this wall in water depths of as much as 100 feet without significantly affecting hydro operations taught several valuable lessons about working underwater.

y Donald E. Simpson, Marilyn Phipps, and Arturo L. Ressi di Cervia

The new 1,831-foot-long cutoff wall built in the Chattahoochee River in front of the Walter F. George Dam is the first of its kind constructed by the U.S. Army Corps of Engineers. This wall was built with the reservoir full and while the 130-MW hydro project generated electricity. This cutoff wall is the first to be built in water depths up to 100 feet and through multiple rock formations for another 100 feet. Construction was accomplished within 20 feet of the dam. Other hydroelectric project owners can apply the lessons learned during this challenging project, especially with regard to the underwater aspects.

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This article has been evaluated and edited in accordance with reviews conducted by two or more professionals who have relevant expertise. These peer reviewers judge manuscripts for technical accuracy, usefulness, and overall importance within the hydroelectric industry.

The situation at Walter F. George

Walter F. George Dam, completed in 1964 by the Corps' Mobile District, forms Walter F. George Lake (Lake Eufaula), on the Chattahoochee River between Alabama and Georgia. Along with recreational opportunities, the lake harbors an 11,160-acre wildlife refuge. The development consists of:

— A 1,496-foot-long concrete structure housing the spillway, the lock, and four generating units; and

— Two earthen dams that extend 5,810 feet along the Georgia border and 6,130 feet along the Alabama border.

The 82- by 450-foot lock accommodates barge traffic and allows commercial and recreational navigation of the river and lake. The powerhouse generates enough electricity to meet the needs of a city with a population of 40,000. Operators in the control room, which is staffed around the clock, regulate water flows and power generation for the lower Chattahoochee River.

Foundation rock for the concrete structure at Walter F. George is the three-layer Clayton formation. The 50-foot-thick upper earthy limestone layer consists of chalky to earthy material containing shell fragments. It shows no bedding planes, but there is a well-developed joint system oriented in a north-south direction. Compressive strength of this layer is 200 to 450 pounds per square inch (psi). The 40-foot-thick middle shell limestone layer consists of moderately hard, porous gray coquina type limestone. Compressive strength ranges from 300 to 1,000 psi. And the 35-foot-thick lower sandy limestone layer is variable, with strengths of 100 to 19,000 psi. It contains hard solid layers as well as non-cemented, highly compacted sand layers.

Immediately below the Clayton formation is the providence sand formation. The uppermost stratum of this formation is highly consolidated black marine clay. Sand content of the providence strata typically increases with depth.

The first indication of seepage problems at Walter F. George appeared when two sinkholes developed in October 1961 during the final stages of construction. The next year, boils appeared along the downstream toe on both sides of the dam, and the Corps performed repair work. Sinkhole activity continued, and the Corps again performed repairs in 1968, 1969, and 1970.

After the 1969 work, the Corps installed piezometers downstream from the dike on the Georgia side to collect information about erosion. In 1978, the Mobile District prepared a supplemental design memorandum that recommended constructing a 300-foot-long test section in the Alabama embankment before entering into any contract for a full-length cutoff wall. The continuing seepage condition and the need to ensure the safety of the dam required a permanent solution. A 24-inch-thick concrete cutoff wall was installed to the middle of the upper earthy limestone layer. In 1981, a similar cutoff wall was installed under the Georgia dike.

These cutoff walls were installed to stop the seepage in the alluvium and underlying earth limestone of the Clayton formation. Seepage under the concrete structures developed in the river channel area where penetration of the thin earthy limestone allowed lake water to access the underlying shell limestone. In 1982, a boil appeared immediately downstream from the powerhouse. This boil was caused by the water entering the shell limestone through an old construction piezometer that had been poorly grouted. The Corps plugged the exit point of the boil, placing 175 cubic yards of tremied concrete to fill the eroded channel under the powerhouse.

In the early 1990s, the lake water gained access to the lower strata of the shell limestone through joints in the earthy limestone that overlay joints in the shell limestone.

Choosing the best option to correct the seepage issues

In 1997, the Corps decided to construct a positive cutoff wall upstream of the main concrete structure. The wall would have to cross an existing lock structure and an underwater retaining wall. This was a difficult decision because the cutoff wall had to be built while the reservoir was full. In addition, power generation and lock operations could be interrupted for no more than 30 days at a time.

To begin the bid and selection process, the Corps issued a minimum set of specification requirements, extensive historic data, and soil information. Then the Corps invited bidders to submit two packages — one containing their qualifications, methods statement, and financial and safety records, and the second with the pricing proposal. The Corps convened a board consisting of engineers and a geologist to evaluate the first package. The Corps then matched acceptable packages to the bid and awarded the contract to the company whose proposal was in the best interest of the government, not necessarily the lowest bidder.

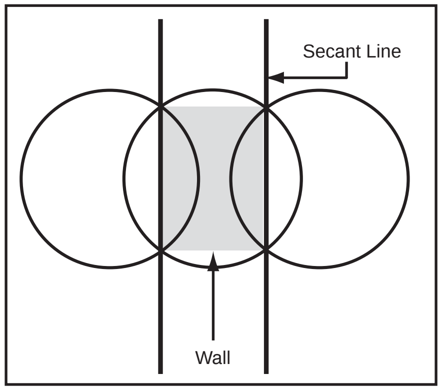

Figure 1: A secant wall consists of a series of overlapping circular shafts. The line connecting the intersection points is a secant line, and the thickness of the wall is the distance along the secant line between the two intersection points.

On August 14, 2001, the Corps awarded a $50.1 million contract to Treviicos-Rodio — a joint venture of Treviicos Corporation in Boston, Mass., and Rodio SpA in Milan, Italy — to construct a 24-inch-thick concrete cutoff wall.

The cutoff wall featured two types of construction:

— A panel wall built mainly over land. The wall is 306 feet long on the Alabama side and 164 feet long on the Georgia side. To build this wall, Treviicos-Rodio cut 3-foot by 9-foot vertical slots using a Hydromill, reverse circulation slurry wall equipment supplied by Rodio. The slots were cut as much as 200 feet deep, through various materials, including hard rock (15,000 psi). A submersible pump within the Hydromill removed the bentonite slurry and spoil material to a desanding plant, where the slurry was separated out and reused.

— A 1,232-foot-long concrete secant wall built in the water. This wall consists of 469 overlapping 52-inch-diameter concrete shafts (called piles) installed an average of 10 feet in front of the dam.

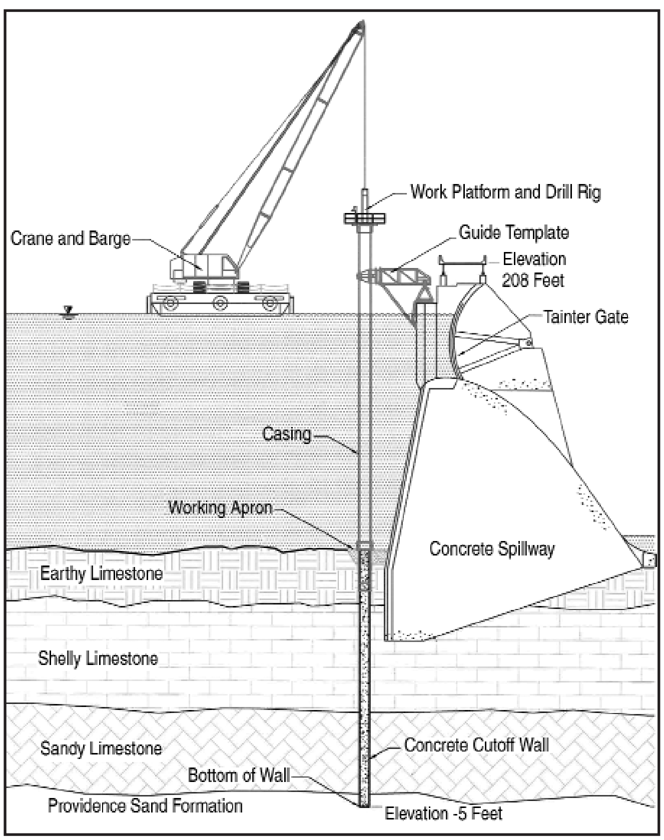

Figure 2: Installation of the secant cutoff wall in front of the dam at the 130-MW Walter F. George project involved placing 54-inch-diameter casings, then drilling down to an elevation of –5 feet above sea level and pouring concrete.

Workers use a barge-mounted crane to place the first of 469 54-inch-diameter casings for construction of the concrete secant wall in front of Walter F. George Dam. The wall is an average distance of 10 feet in front of the dam.

Because of the unique challenges involved in constructing a wall in water as deep as 100 feet, the contractor worked closely with subcontractor Vortex Marine Construction Inc. of Oakland, Calif., to accomplish and support the marine and underwater portions of construction. Divers from Specialty Diving Inc. in Hammond, La., and Pro Diving Services Inc. in Akron, Ala., were used for construction and inspection.

To visualize a secant wall, imagine cutting a cookie using a circular cutter. Then cut a second cookie that overlaps the first. The circles intersect at two points. A line drawn between these two points is a secant line. As you cut more cookies and connect their intersection points, a band forms between the secant lines. Adding depth to the cookies forms a secant wall. (See Figure 1.)

The Corps selected the Treviicos-Rodio proposal in part because it incorporated the secant wall construction method, which the Corps felt was the most economical method.

Divers made more than 150 dives to remove a steel coffer cell and other obstructions during construction of the cutoff wall in front of Water F. George Dam. Divers also assisted the project with construction and inspections.

Building the cutoff wall

Installation of the secant cutoff wall involved placing a series of 54-inch-diameter, 130-foot-long steel casings to guide the drills, then drilling down to an elevation of -5 feet above sea level, and finally pouring concrete into the drilled hole. During much of the underwater work, Vortex used a custom-modified Phantom HD2+2 remotely operated vehicle (ROV) from Deep Ocean Engineering in San Leandro, Calif. The ROV was used to determine the position of underwater features, without exposing divers to unknown hazardous conditions. The ROV also was capable of high-resolution video and sonar surveys.

Work on the secant wall was performed in seven phases:

Drilling and grouting

As the first activity under the contract, Treviicos-Rodio conducted an exploratory coring and grouting program to better define the geology formation and to fill large cavities in the path of the wall. The contractor completed 15 core holes down to an elevation of -5 mean sea level, or about 230 feet, with an average spacing of 150 feet. The contractor reduced the spacing between the holes when cavities in the limestone formation were found. Treviicos-Rodio grouted the core holes and cavities using a sand, cement, and water mixture.

During this drilling, the contractor discovered a massive concrete chunk (12 to 20 feet high by 3.5 to 15 feet wide by 80 feet long) along the proposed centerline of the secant wall. The Corps determined that the block, which contained miscellaneous embedded metals, was related to the original dam construction but was not identified in the plans and specifications. Before wall construction began in the area of the block, divers working for Vortex removed the block using a 12-ton chisel and clamshell buckets, which added $1.15 million to the cost of the project.

Constructing a working apron

Vortex first excavated an underwater trench directly in front of and parallel to the dam, extending a minimum of 5 feet from the concrete portion of the dam, with a minimum depth of 6 feet. To form the apron, Vortex then backfilled the trench with a flowable fill low-strength concrete using a tremie method of placement. The apron formed the work surface to install the cutoff wall.

Installing the templates and casings

Next, the contractor installed templates designed at Treviicos' engineering facilities in Cesena, Italy, on the dam buttresses. These templates were positioned so that the cross frames cantilevered out to miss the face of the dam below the water level. (See Figure 2.) Beams on the frames of the templates acted as guides to install the round steel casings that were used to guide drilling. Each casing was fitted with a collar that fit the template to ensure 33-inch on-center spacing and proper overlap of the secant piles.

The cranes used to install the casings were mounted on two 54-foot-wide by 180-foot-long by 12-foot-high barges anchored in front of the dam. The anchorage system was a series of steel cables so the barges could be winched into position. The massive cranes picked up the steel casings, weighing 34 tons, in a vertical orientation and lowered them to the bottom of the lake. Each casing was positioned using survey instruments on the perpendicular axis to ensure it was plumb. Finally, the casings were vibrated 8 feet into the working apron. This embedment was intended to isolate the concrete pile from the inflow of lake water during the drilling operation, particularly if cavities were encountered during excavation.

The casings provided the conduit from above the lake's surface to the bottom. The first casing acted as a guide for all future measurements and alignment. The contractor placed a series of primary casings first, followed by a series of secondary casings between the primary casings to form a continuous, overlapping wall.

Drilling and constructing the pile shafts

The contractor used two Wirth PB 612 reverse circulation drilling rigs to excavate the secant pile shafts. Each rig was positioned on top of the casings, and the shafts were drilled through the underlying rock to a depth of about 230 feet below the top of the casing, or the elevation -5 meters above sea level. (See Figure 2.) Water from the lake was used as the drilling fluid.

Maintaining water quality was a requirement of the contract. Therefore, the cuttings were airlifted through dredge pipe to a hopper barge and deposited on the lake bottom. And to reduce turbidity, the barge was fitted with a silt curtain around the perimeter that extended to within 10 feet of the lake bottom. Treviicos monitored water quality 24 hours a day using RUSS, a dial-in, computerized water monitoring hardware and software system supplied by Apprise Technologies Inc. in Duluth, Minn.

When drilling was complete, the contractor checked the shaft for verticality using a bi-axial inclinometer from Slope Indicator in Mukilteo, Wash., to ensure it had achieved the tight tolerances needed for a watertight cutoff. Treviicos plotted the results against the adjacent pile to ensure that a positive cutoff was provided.

The Corps encountered two major obstructions during this work. The first, a steel sheet pile coffer cell used in the original powerhouse construction, had to be removed because the drill rig could not cut steel. Divers had to cut out the members and raise the cell piece by piece.

Then, a piece of steel was encountered during drilling for placement of Pile 187. While trying to remove the steel, the contractor discovered other metal in the area. Hager GeoScience Inc. of Woburn, Mass., used a ground-penetrating radar, employed in depths of 100 feet for the first time, to identify a metal obstruction that extended 20 to 30 feet into the lake bottom. The object could not be removed, so the path of the wall was adjusted, with minimal delays or additional costs.

Pouring concrete for the cutoff wall

After each pile shaft was drilled, concrete was placed using a tremie or "open" pipe to form a pile. Concrete used to construct the cutoff wall was a plastic mix that produced a 28-day unconfined compressive strength of 900 psi. Lafarge North America in Herndon, Va., supplied the concrete from a batch plant erected on site.

Concrete was placed to a level corresponding to the bottom of the lake. When placement was complete, the casing was removed and reset in the next available position, and the operation started again. A total of 469 piles were installed, and more than 65,000 cubic yards of plastic mix concrete was placed.

Constructing the cutoff through the lock structure

The portion of cutoff wall going under the lock guide walls required special construction methods. Treviicos-Rodio used a diamond wire to cut slots in the upper lock guides to maintain structural integrity. After the cut portion was lifted out with a crane, the contractor used the Hydromill to finish cutting through the lock guide walls. The lock was closed for 60 days to allow for construction.

Tying the cutoff to the dam with a concrete cap

Before the 6-foot-wide by 6-foot-thick concrete pile cap was placed around and on top of the new wall, Vortex cut a 4-foot excavation into the apron on either side of the wall to remove any damaged concrete on top of the piles and to create the appropriate geometry for the concrete cap. The cap ties into existing concrete monoliths of the Walter F. George structures to seal seepage from the top.

Results

The scheduled completion date for this project was September 24, 2004. However, the wall was completed on January 31, 2004. The timeline was reduced by advance planning, cooperation between all parties, and workmanship that avoided lengthy remedial activities. In addition, this project had an amazing safety record. Construction ran 24 hours a day, six days a week. Even though this was hazardous work, safety procedures and special training put into place by the contractor and the Corps' Mobile District greatly reduced the risk. More than 535,000 man-hours were worked without a single lost-time accident.

In addition, more than 150 dives were made to remove the steel coffer cell and other obstructions. More than 100 of these dives required decompression. Total diving work for the project consisted of 120 deep-water dives requiring decompression and 69 shallow-water dives of 30 feet or less. By comparison, the Corps' Mobile District normally averages 22 dives a year.

Post-construction piezometer readings indicate that, after more than 40 years, the Corps solved the Walter F. George seepage problem. Because the work was done in a Corps multipurpose area, the Corps used meetings and outreach programs to keep the public informed about changes in navigation, power generation, or lake recreation. They were assured that the work would not affect lake levels.

Lessons learned about underwater work

Throughout this unique construction project, the Corps learned two important lessons:

— ROVs can enhance documentation and make work safer for divers. The Corps' safety manual recommends first using an ROV when possible to check the dive area for risk, such as dangerous current and diving obstructions. The ROV was used on this project for more than 1,000 hours

— Diving operations can occur during some discharges. Originally, the Corps would not allow diving while water discharge was occurring through the powerhouse spillway or lock structure. This limitation restricted either the amount of diving or operation of the structures during the construction process. To overcome this objection, the Corps' safety office worked with the U.S. Geological Survey, an arm of the U.S. Department of the Interior, to perform a current velocity survey. The Corps used different scenarios with gates open to identify the dangers to divers during discharges. As a result of this work, the Corps determined that it would be safe for divers to proceed during some discharges, with buffer zones of about 500 feet around discharges. This was a major consideration because work on the cutoff wall was able to continue while the powerhouse was generating, the locks were used, and the spillways were opened. ■

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