UNDERWATER HYDRODEMOLITION AT THE CANYON FERRY DAM STILLING BASIN FLOOR REPAIR PROJECT

BY FRANK IMMEL

The Canyon Ferry Dam is located on the Missouri River about 20 miles (32 km) east of Helena, Montana. The dam is a concrete gravity structure approximately 1,000 ft (305 m) in length along the crest with a structural height of 225 ft (69 m) and is located at an elevation of 3,750 ft (1143 m). The dam is a multi-purpose structure used to generate power, provide flood control, water for irrigation, and recreation. The spillway is an overflow section in the central portion of the dam controlled by four radial gates. Construction of the dam began on May 24, 1949, and was completed on June 23, 1954.

Fig. 1: Canyon Ferry Dam

Over time, the water flow (Fig. 1) over the spillway at the Canyon Ferry Dam, along with rubble, had eroded large areas of the stilling basin (Fig. 2) floor. Several of the eroded areas were up to 24 in (610 mm) deep and disrupted the flow of water across the basin floor. Since it was anticipated that the turbulence would lead to further erosion and damage, but at an accelerated rate, a repair program was implemented at the structure in 2004.

Fig. 2: Canyon Ferry Dam spillway, stilling basin and training wall

The Owner/Engineer issued plans and specifications to repair the floor of the stilling basin. The specifications called for reinforced concrete repairs using high strength, silica fume concrete. Concrete placement could not deviate from the specified elevations by more than ± ½ in (13 mm). In addition, the repair specifications did not provide for dewatering the basin. This meant that the work would be performed under 50 ft (15 m) of water. The underwater repair presented several unique challenges. Because the work was at an elevation of 3,750 ft (1143 m) and 50 ft (15 m) below the water, divers were required to follow the modified nitrox diving protocol.

Fig. 3: Airlift system used to vacuum debris from the basin floor

Water entered the stilling basin either by the flow over the spillway or through the hydroelectric generating station. The flow from these two sources is divided by a training wall. While work below the spillway could be done during the low water season, water was continuously flowing through the hydroelectric plant. As a result, the stilling basin was always full. Given the nature of the structure and the constant flow of water, it was impractical to dewater the basin to complete the repairs.

The specifications required that the repair thickness be a minimum of 6 in (152 mm) deep. Areas less than 6 in (152 mm) required removal to the minimum depth of 6 in (152 mm). The erosion of the floor consisted of large pockets that ranged up to 24 in (610 mm) deep in the center. However, from the center, the pockets sloped up to the original surface resulting in depths of less than 6 in (152 mm) along the perimeters of the deeper areas. In addition, other areas existed where the damage was less than 6 in (152 mm) deep.

The first step of the operation was to remove a large quantity of debris that had accumulated on the basin floor. Approximately 1.2 million pounds (544,311 kg) of loose stone and gravel were removed from the work area. This was accomplished using a 16 in (406 mm) airlift system that deposited the dredged material onto a barge (Fig. 3). The debris was transported to shore where it was used for fill (Fig. 4).

Limits of repair, baseline elevations, and final elevations were established through a combination of land based and underwater survey techniques. Using custom fabricated jigs, datum points were established at measured elevations to serve as "permanent" reference lines. A series of taut wires were then strung across the stilling basin area at a set elevation determined by the surveys. Divers used the taut wire system to take measurements throughout the various stages of construction to ensure compliance with the allowed tolerances.

Once the debris was removed, the difficult task of removing concrete to provide the minimum repair thickness was undertaken. The project specifications estimated 20 cubic yards (15.3 cubic meters) of concrete would have to be removed. The contractor selected hydrodemolition as the method to remove the concrete and provide a good bonding surface. The challenge was to do the removal under 50 ft (15 m) of water on a very irregular surface.

A special 6 ft x 10 ft (1.8 m x 3 m) frame (Fig. 5) was constructed that allowed for two dimensional movement of the waterjet over the surface. Each leg was hydraulically operated and could be extended 12 in (305 mm) to allow the diver to level the frame on the basin floor. Each leg could be operated independently by the diver using one of four control levers located on the frame.

All functions on the frame were hydraulically operated including the traverse, advance, and rotation of the waterjet nozzle in addition to the hydraulic legs. An electric hydraulic power pack was built to provide the hydraulic power and control of the hydrodemolition functions (Fig. 6). The hydraulic fluid used was vegetable-based biodegradable oil that would not pollute the water in the event of an accidental leak or damage to a hydraulic line. The control panel allowed the operator to program and control the functions of the hydrodemolition cutting frame.

The hydrodemolition pumps remained on shore while the hydrodemolition frame and hydraulic control unit were placed on a barge and moved to the stilling basin over the area to be hydrodemolished (Fig. 7). A crane

Fig. 4: Rubble removed from the basin floor

Fig. 5: Hydrodemolition cutting frame

Fig. 6: Hydrodemolition control panel and hydraulic power pack

Fig. 7: Work barge in basin

Fig. 8: Hydrodemolition cutting frame attached to crane

Fig. 9: Hydrodemolition cutting frame being lowered to basin floor at 50 ft (15 m) below the surface

Fig. 10: Diver's helmet contains air, communications, video, and lighting

on the barge lifted the frame and lowered it to the basin floor (Fig. 8 and 9). Water was transported to the hydrodemolition pump trailer via flexible hose (fire hose). Twin pumps on the unit pressurized the water to 36,000 psi (248 MPa). The water was transported to the cutting frame via specially designed ultra-high pressure (UHP) hoses which were rated at 40,000 psi (276 MPa) operating pressure with a burst pressure of 105,000 psi (724 MPa). The equipment's standard operating pressure of 36,000 psi (248 MPa) and 32 gallons (121 liters) per minute water flow rate were used during hydrodemolition.

The depth of cut in the repair area was controlled at the cutting frame. The UHP water passes through the waterjet on the cutting head, which is mounted on the traverse beam of the cutting frame. The cutting head can rotate between 0 and 1,500 rpm and was set to approximately 800 rpm for the removal. During the hydrodemolition, the depth of removal was controlled by four parameters that were regulated by the hydrodemolition operator at the hydraulic control panel on the barge:

- The speed of the traverse;
- The number of traverse times before stepping forward (away from the cut);
- The length of the step; and
- The speed of the rotation.

These parameters were adjusted during the test removal to provide the correct depth of removal. Once the operating parameters were determined from the test removals, they were generally used during the actual hydrodemolition production. However, based on the visual inspection of the removal area, the parameters could be adjusted periodically to account for increases or decreases in the deterioration of the concrete, compressive strength, aggregate size, varying removal depth, or any other reason that may result in a change in the depth of the removal based on the original parameters. The diver provided constant feedback and direction to the operator to ensure the proper concrete removal.

The diver was equipped with a diving helmet that not only supplied the nitrox air mixture, but also two-way communications and video feed (Fig. 10). Dry suits were used to protect the diver from the cold water (Fig. 11).

The diver was in constant verbal and visual communication with the support team on the barge. This included communications with the crane operator to position the frame over the removal area. Once in position, the diver would level the frame and direct the hydrodemolition operator to move the cutting head. Once the cutting head was in position, the operator would start the concrete removal. The diver would communicate the removal depth to the operator allowing the operator either to increase or decrease the traverse speed to either decrease or increase the depth of removal.

Safety was a key concern. The hydrodemolition subcontractor provided an extensive safety program covering the use of UHP water and mechanical tools. The divers received specific instructions and training on the dangers of UHP water.

One of the primary safety concerns during a typical hydrodemolition project is the control of flying debris. If the equipment or work area is not properly shielded, the high velocity water can easily project debris at speeds that can injure workers and damage equipment. For this application, however, no shielding was required. The surrounding water provided a perfect shield for the diver. Video of the actual waterjet removing concrete shows that the debris was propelled 6 to 12 in (152 to 305 mm) before falling harmlessly to the basin floor. Normally, the velocity and impact of the waterjet on the surface is so violent that it is almost impossible to record the actual demolition of the concrete. However, underwater demolition can be observed without injury to the diver or damage to the video equipment.

Other critical design features of this project included the requirement to maintain the existing construction joints in the original stilling basin floor and tying the new concrete slab to the existing floor using rock anchors. Over three hundred (300) 2-½ in (64 mm) diameter by 37 in (940 mm) deep holes were drilled into the floor using a hydraulic percussion drill mounted to a custom-designed frame (Fig. 12). In order to maintain specified concrete coverage over the rebar, it was necessary to counter bore these holes to allow for coupling rebar to the bolts. A No. 8 (1/2 in [13 mm] diameter) rebar mat was affixed to the anchors, mechanically bonding the two slabs together. In addition, the rebar mat was also tied to the existing training wall located in the center of the stilling basin using anchor bolts. Over one hundred sixty (160) 2-½ in by 20 in (64 mm by 508 mm) deep holes were core drilled horizontally into the base of the intermediate training wall using a hydraulic core drill for anchor installation.

Reusable steel form tops, which could be bolted together in various configurations, were constructed to conform to the dimensions of individual repair panels. The forms were attached using epoxy-threaded rod. The rod acted as hold down bolts and allowed the forms to be adjusted to the correct elevation and specified grade tolerances. The side panels of each form were custom fabricated to allow for irregularities in the stilling basin floor.

With the elevation set and the forms in place another unique challenge was addressed, the placement of high strength concrete into forms over 350 ft (107 m) from the river bank and 50 ft (15 m) below the water. A silica fume concrete mix was designed that satisfied the Owner/Engineer's concrete strength requirements and provided the high flow and self-consolidating properties required to ensure successful placement. The concrete, specified to attain a compressive strength of 12,000 psi (83 MPa) in 56 days, actually achieved compressive strengths of over 12,000 psi (83 MPa) in 28 days.

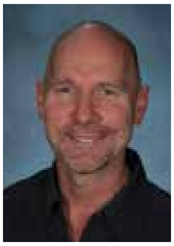

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Fig. 11: Diver suited and ready to work

Fig. 12: Custom 2-1/2 in x 37 in (64 mm x 940 mm) deep hydraulic percussion drill for rock anchors

Canyon Ferry Dam
Stilling Basin Floor Repair Project
Helena, Montana

OWNER/ENGINEER
Bureau of Reclamation
Billings, Montana

REPAIR CONTRACTOR
Global Diving and Salvage
Seattle, Washington

HYDRODEMOLITION SUBCONTRACTOR
Rampart Hydro Services
Coraopolis, Pennsylvania