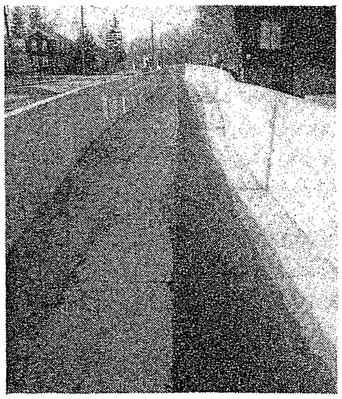

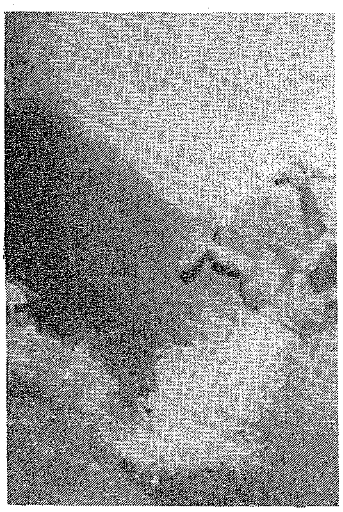

The REMR Bulletin

News from the Repair, Evaluation, Maintenance, and Rehabilitation Research Program

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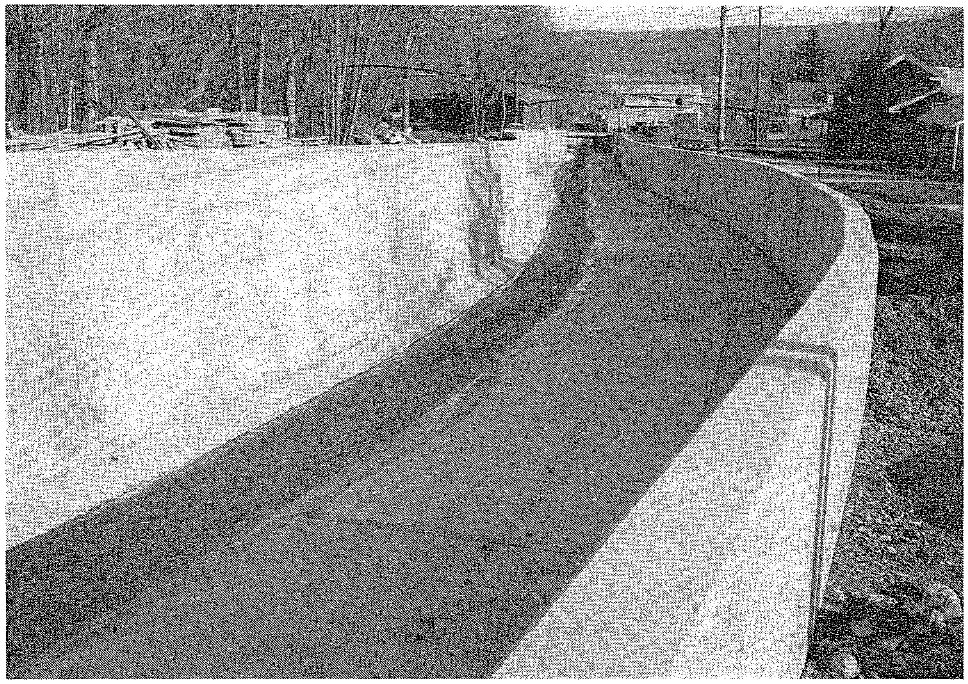

Hammondsport flume, showing replaced section after completion

Hammondsport Flume: A Case History in Rehabilitation and Repair

by
Russell E. Wege, P.E.
New York State Department of Environmental Conservation

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Glen Brook originates in the high country west of the village of Hammondsport and is located at the southern end of Keuka Lake in the picturesque Finger Lake Region of central New York State. The stream drains 5.24 square miles and is only 4.7 miles long. The stream drops 1,050 ft to the head of a concrete flume. Glen Brook enters the flume and abruptly turns left along the base of a mountain as it enters the village and terminates 2,200 ft downstream in Keuka Lake. Normal summer flow is only a few cubic feet per second. Prior to construction of the flume, efforts to maintain the channel with log walls and stone date back to 1820. On July 8, 1935, a cloudburst produced a 3,600 cfs peak flow. This storm produced the greatest flood on record when approximately 6 in. of rain fell over a 36-hr period. Approximately 80 percent of the total precipitation occurred during a 12-hr period. Glen Brook jumped its right bank and devastated the village by cutting a new channel 15-ft wide and 7-ft deep in Church Street. Direct damages to residences, businesses and utilities totaled $632,700.

Shortly after the 1935 flood, the Corps of Engineers designed a concrete gravity wall flume for the Works Progress Administration. Construction started in October of 1935 and was completed in 1936.

The design was based upon an arbitrarily selected design discharge of 5,000 cfs. The width of the flume varied from 24 to 32 ft, with a depth between 6 to 8 ft. The 2,200-ft-long flume had an 80-ft drop in elevation and terminated at Keuka Lake. The flume probably conveys super-critical flow at all flow rates.

Historic information indicates that the flume was constructed with hand labor. Large shale stones were used to key the walls into the footer. The aggregate was stream-washed stone which is mostly shale. The floor slab was constructed with a 6-in. wire-mesh reinforcement, but no reinforcement was used in the walls.

Glen Brook annually produces several hundred cubic yards of gravel (Fig. 1). The gravel moves by high velocity flow and erodes the floor of the flume. In 1950, the State sponsored some repairs through the Buffalo District Corps of Engineers by patching the floor and constructing a low flow channel. The State has been responsible for maintenance since 1950.

Gravel movement over poor quality concrete continued to erode the floor of the flume. Cycles of freezing and thawing, and cracking and efflorescence exacerbated concrete deterioration. The walls showed crumbling concrete in many areas. More serious was the continued deterioration of the floor. State maintenance crews periodically dewatered short sections of the flume and patched the holes which, in some cases, had eroded through the low-flow section of the flume, communicating flow to downstream cracks, joints or other holes. In addition, structure deterioration occurred at the terminus of the flume where wall sections and floor slabs moved several inches.

Department engineers and maintenance personnel became increasingly concerned over the potential of a catastrophic failure during a major runoff event. In 1980

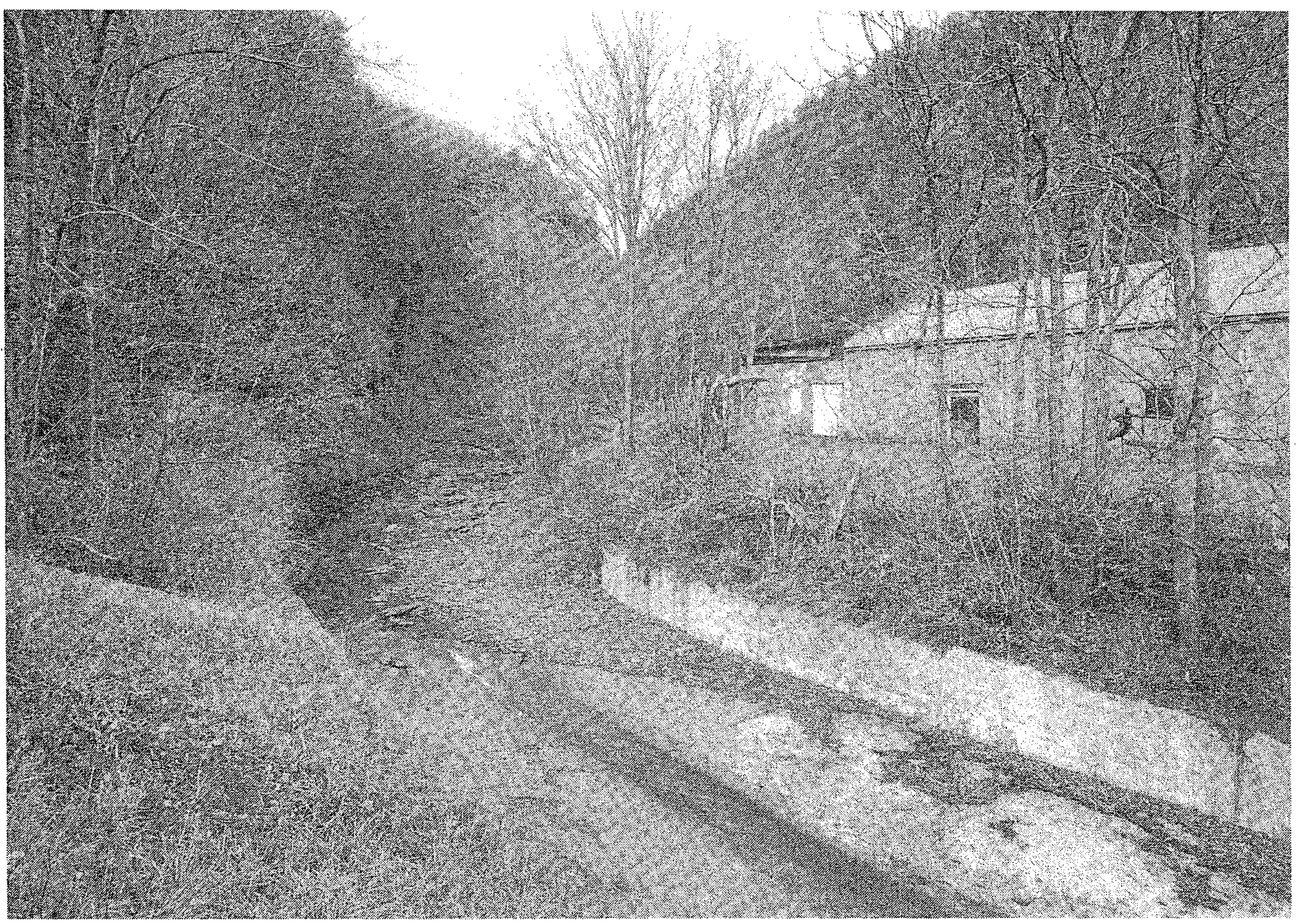


Figure 1. The upstream end of the flume before construction, showing gravel deposits

the State contracted with an engineering firm to study the feasibility of repairing the flume and managing gravel movement. Results of the study confirmed that the combination of a sharp bend and reduction in section from a 32- to 24-ft width, combined with a lessor slope, resulted in a significant hydraulic restriction in the critical upstream reach of the flume. The study further verified the poor condition of the concrete and the need to control gravel movement through the flume.

Three schemes for repair emerged for the study. The one selected addressed the hydraulic restriction with a 700-ft replacement section and an overlay of the remaining 1,500 ft of flume, at an estimated cost of $2.5 million. Also included was an upstream sediment trap (Fig. 2).

Shortly after acceptance of the study, the State asked the Buffalo District Corps of Engineers to review the study and assist in rebuilding the structure. The District verified the findings in the study that the flume was severely restricted and was in a deteriorated condition. Unfortunately, the Corps was unable to assist in making repairs due to an unfavorable cost/benefit ratio. The danger of the existing condition, however, prompted the State to correct the design problem and repair the deteriorating structure.

THE DESIGN

The State's design criteria, developed in 1986/87, was as follows:

- The minimum channel capacity shall be 3,600 cfs (100-year flow) plus 3.5 ft of freeboard in the upstream reach of the project in accordance with federal flood insurance regulations.
- The new channel must contain the 500-year flow rate of 4,800 cfs.
- The design must reduce the inflow of gravel into the flume.

The design contractor satisfied these criteria by:

- Proposing to extend the flume 200 ft upstream and expand the entrance from 32 ft to 85 ft.
- Protecting the flume with a 6 1/2-ft-high weir across its entrance. The weir would form a 1,600 cu yd sediment trap to stop the major portion of moving

Figure 2. Weir, sediment basin, and access road for maintenance are part of the new intake systems that helps control gravel intake

gravel. The weir would be constructed with five 2- by 3-ft openings in order to convey low flow through the structure.

- Replacing the upper 650 ft of the old structure. This would eliminate the hydraulic restriction by deepening the channel and reducing the sharp curve in the structure.
- Proposing to remove all deteriorated concrete in the 1,583-ft remaining section of the flume and by overlaying the floor and walls with a minimum of 6-in. of reinforced concrete. Reinforcing steel would be held in place with drilled and grouted dowels on 2-ft centers into the old concrete. In addition, care would be taken to honor existing construction joints (Fig. 3).
- Replacing the terminus end of the flume and stabilizing it with sheet piling and heavy stone.
- Including a 6-ft-wide low-flow channel in the design, to be constructed with a 3-in. overlay of abrasion-resistant silica fume concrete. It was believed that the majority of sand-to-gravel sized particles that pass through the rock trap move down the low flow channel. Therefore, it was unnecessary to overlay the entire floor with silica fume concrete.

The engineering estimate was almost $4 million, based upon July 1989 prices. From the face of the weir to the terminus near the lake, the total flume would be 2,450 ft long. The new flume would have a maximum slope of 5.61 percent, which would produce channel velocities of 38 fps at a 3,600 cfs flow rate.

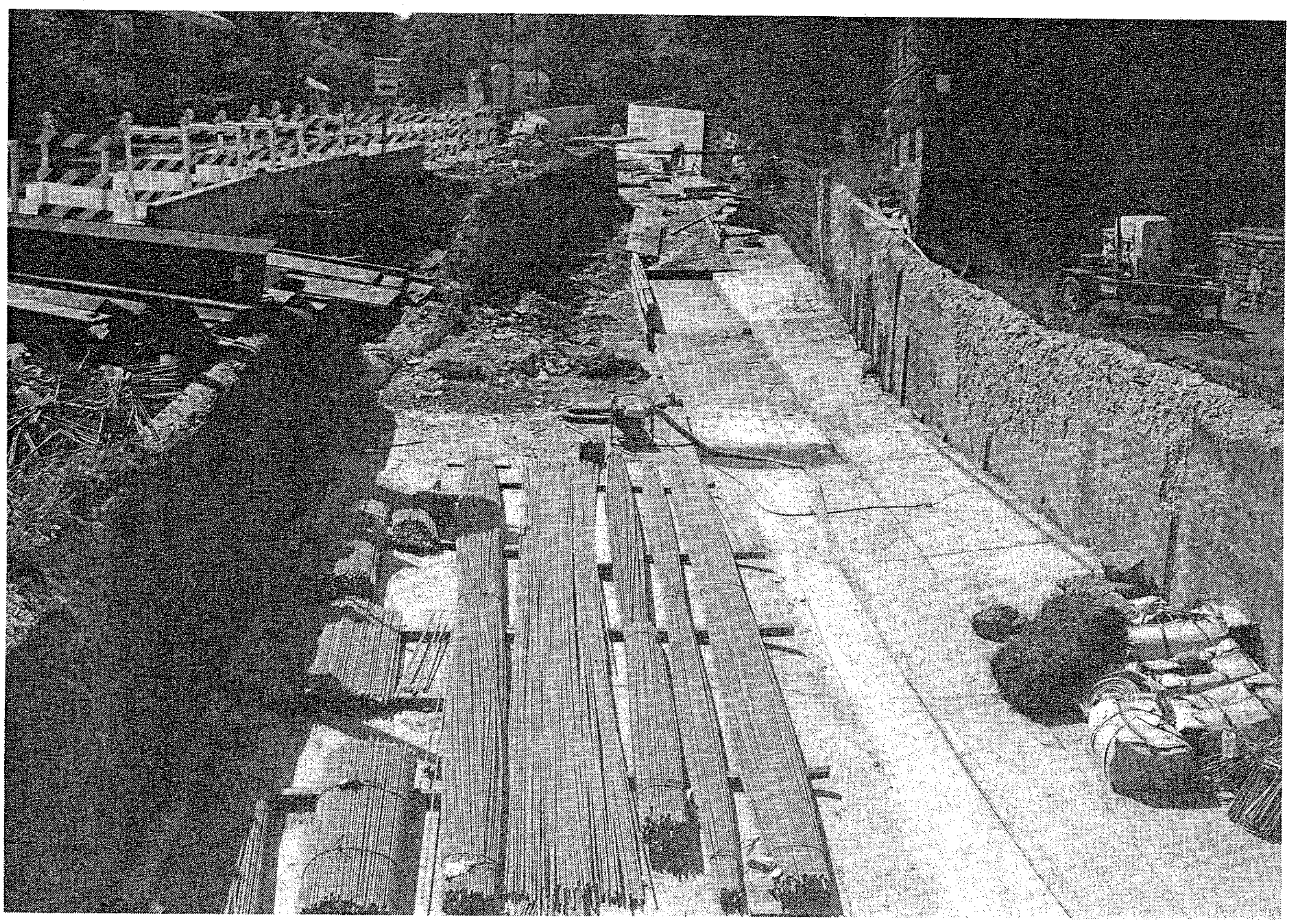


Figure 3. Upstream view, showing end of replacement section and beginning of overlay section during construction

CONSTRUCTION

A contract for construction was let in October 1989. The contract contained the following specific conditions of interest:

- The floor and low flow channel must be constructed in the dry.

- The project involved replacement of an access bridge over the flume, to be constructed immediately adjacent to an existing access bridge. The property owner required access to storage facilities on the far side of the flume at all times. Therefore, the old bridge could not be taken out of service, preventing construction of new flume walls prior to completion of the new bridge.

- Preparation of sections to be rehabilitated included that all deteriorated concrete had to be removed and all surfaces had to be sandblasted. Immediately prior to placement of the overlay, the old concrete surface was to be air cleaned, wet down and coated with a 1 to 1 mortar or neat cement paste, to insure maximum bond strength with the old concrete.

- The overlay was to match existing construction joints.

- Professional photography was to be performed monthly, documenting the construction progress.

One to three inspectors placed at the job site by the engineering firm insured quality construction. Surveyors periodically checked the building contractor's alignment and elevations for compliance with the plans and specifications. Joint meetings with State representatives on the job site occurred monthly. Walk-through inspections and problem solving flowed through these meetings. In addition, there were weekly updates from the engineering contractor to the State representative.

CONCLUSIONS

The design incorporated state-of-the-art technology from principles investigated in the Corps' REMR Research Programs: Specifically,

- the use of dowels placed in old concrete with non-shrink grout,

- placement of an overlay on carefully cleaned and prepared old concrete for maximum bonding and

- the use of an abrasion resistant concrete to reduce future erosion damage.

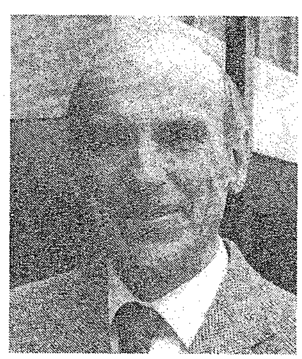
The Engineering contractor's research identified only two other locations in the country where the Corps had used silica fume concrete to minimize erosion. It is axiomatic that new construction is easier to achieve than rehabilitating old work. The new construction involved removal of much of the upper 650-ft section of the old flume, construction of the replacement flume section, access bridge, weir and sediment trap. This work went well. As a side benefit, villagers took advantage of the State project by upgrading the adjacent street drainage system and installing a water supply branch under the flume to better serve the opposite side of the structure.

A problem developed during preparation for the floor overlay in the rehabilitation section. Removal of some structural concrete in the low flow channel was anticipated. The small volume (60 cy) was expected to be removed with hand tools at a high unit price. However, the 6-in.-minimum base of new concrete plus the silica-fume overlay in the low-flow section could not be installed on the irregular floor without extensive concrete removal. In addition, some of the flume-floor concrete was found to be very poor, actually crumbling. This unexpected condition multiplied the cost. With perfect 20/20 hindsight, it would have been more cost effective to remove the entire floor of the flume, resulting in lower-per-unit cost for removal equipment.

The ability to trap the majority of gravel before entry into the flume prevents that material from eroding the new floor and provides a good source of gravel for the village. The village has agreed to maintain the sediment basin.

As of March 1, 1991, approximately 80 percent of the project has been completed. The contractor, engineer and State representatives have worked well together. Final result will be a high quality construction project that should safely convey 500-year, high-velocity flood flows.

More information is available from Russ Wege, (518) 457-3157.



Russell E. Wege, a registered professional engineer, is employed by the New York State Department of Environmental Conservation, Bureau of Flood Protection. He received a B.S. degree in petroleum engineering from the University of Missouri at Rolla. After working nine years in oil and gas production, Wege has accumulated more than 23 years of experience in operation and maintenance of flood control facilities.

Automated Knowledge Acquisition for Expert Systems

Expert systems fall into the broad category of artificial intelligence. They contain a collection of knowledge—written and textbook information along with an "expert's" knowledge—in a particular discipline. They lead users through a series of questions relating to that field. Upon completion of a querying sessions, expert systems give a conclusion/solution. Expert systems are designed to reinforce a gut feeling, facilitate the exploration of all factors involved in solving or pinpointing a problem, serve as a tool to enhance job performance, and train new or inexperienced field personnel.

As such, experts systems can link a problem solving process to a particular application.

At the US Army Construction Research Laboratory, scientists are working on a project that involves automating the knowledge acquisition process in the development of expert systems.

Presently, the development of knowledge bases for facilities and mechanical systems inspection, diagnosis, maintenance, and repair is very tedious, time consuming work. The knowledge engineer interfaces with the expert and the expert systems shell. This process can be compared to manually editing files in a data base system instead of using the data base manager.

The CERL developed prototype system called the Interactive Domain Model (IDM), is generic in nature. It can be used to extract information about inspection, diagnosis, and maintenance of facilities and mechanical systems for an expert directly rather than through a knowledge mediator. In the IDM, the nonprogramming expert can model a facility or mechanical system by building a graphical model of the system. This model is a hierarchical description of the various components, and subcomponents of the system. From this model, the program can interact with the expert to determine the diagnostic, maintenance, and inspection procedures used to identify faulty equipment and any needed maintenance and repairs to the system.

Use of the IDM to create expert systems has reduced the amount of time necessary to gather and organize the expert's knowledge by at least a factor of 10. Automated knowledge acquisition of this sort is a major breakthrough in what has become known as the knowledge acquisition bottleneck in expert system development.

More information about IDM is available from Debbie Lawrence at (217) 373-6755 (FTS: 958-7755).

Field Review Group Meeting

The REMR Field Review Group meeting is planned to take place at the US Army Engineer Waterways Experiment Station during August or September 1991.

Detailed information will be published when available. It will also be posted on REMRNET.

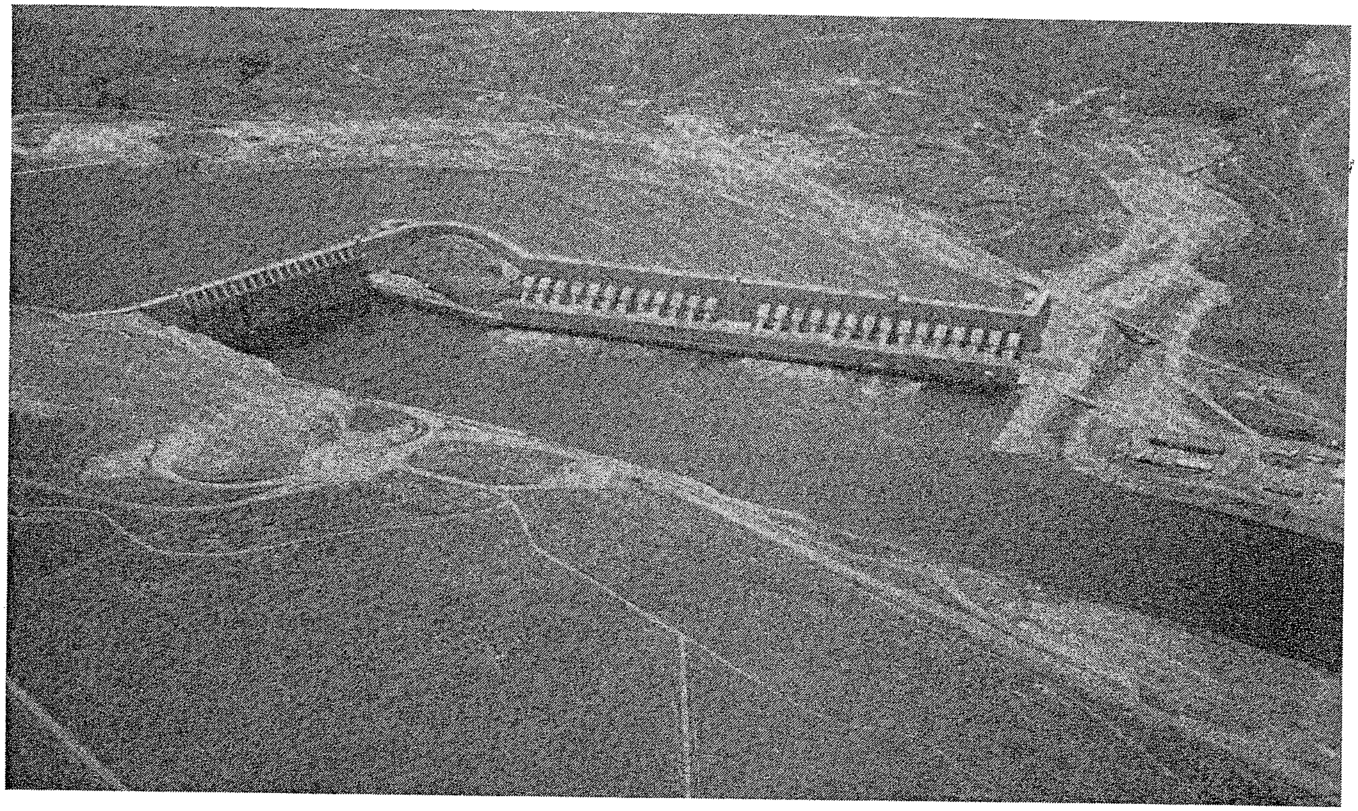


Figure 1. Aerial view of Chief Joseph Dam, Washington

Effective Underwater Joint Sealing at Chief Joseph Dam

by
Kenneth B. Sondergard
US Army Engineer District, Seattle

Chief Joseph Dam (Fig. 1) is a hydropower dam located near Bridgeport, Washington, on the Columbia River, approximately 50 miles down river from Grand Coulee Dam. The reservoir depth in the vicinity of the spillway is about 200 ft. Structural modifications made from the mid-1970s to 1981 allowed the reservoir to be raised to expand hydropower production. Immediately following the pool raise, the leakage inflow into the spillway sump increased dramatically. Inflow caused by leakage through the spillway structure joints exceeded the design capacity of the sump, and, on occasions, the capacity of the backup pumps. The amount of leakage was progressively increasing.

The sump was constructed with two 1,300-gpm submersible pumps and two 1,400-gpm turbine pumps as backups. Because of the high volume of inflow, two 1,000-gpm, portable emergency pumps were installed in the drainage gallery. On a few occasions, flooding of the drainage gallery has resulted from pump failures.

Historically, the peak sump inflow was below 1,800 gpm, well within the design limits for the sump (about 2,600 gpm). However, the sump inflow increased to approximately 3,600 gpm when the winter peak reservoir was raised in 1982, and the leakage volume increased to an estimated 6,000 gpm in the winter of 1988-89. The leakage volume appeared to be highly sensitive to very small changes in the temperature of the concrete; for example, a 1-deg-F change in concrete temperature could cause sump inflow to increase by hundreds of gpm. Therefore, large variations in sump inflow from one year to the next were possible, depending on the severity and duration of winter weather.

Leakage was the result of the structure's open horizontal lift and vertical monolith joints. Large volumes of water from the upstream reservoir entered the joint lines during the coldest period of the year when the concrete contracted and the joints opened. The annual variation in leakage ranged from less than 100 gpm in summer and early fall to over 5,000 gpm by the end of February to mid-March.

The spillway monoliths (Fig. 2) were constructed with five, equally spaced, vertical face drains, which collect leakage intrusion from the lift joints and discharge it into the drainage gallery. The monolith joints were constructed with two vertical, copper waterstops, spaced 36 in. apart (upstream/downstream) with an 8-in.-diam joint drain centered between them. This drain collects monolith joint leakage and discharges it into the drainage gallery. The discharge from the face and joint drains in the drainage gallery is collected in the spillway sump.

Construction activities to modify the dam aggravated leakage conditions. In addition, the erosional forces of high-volume, high-velocity water movements through the joint lines and the effects of slightly aggressive water quality caused further damage to the structure. Past efforts to moderate inflow were of a temporary nature; therefore, an investigation into site conditions and methods for permanent repair of the leakage was initiated.

1988-89 INVESTIGATION AND REPAIRS

The Soils and Materials and Instrumentation Section of the Geotechnical and Environmental Restoration Branch, Seattle District, provides the District design and consulting service for repair and rehabilitation projects, including use of specialty construction materials and applications. The Section has been actively involved in the repair of cracking and leakage problems in hydraulic structures since the late 1970s. Services provided for this project included assembling project resources at the dam, training the repair crew, selecting and procuring equipment and sealant materials, and supervising the operations to seal the leakage.

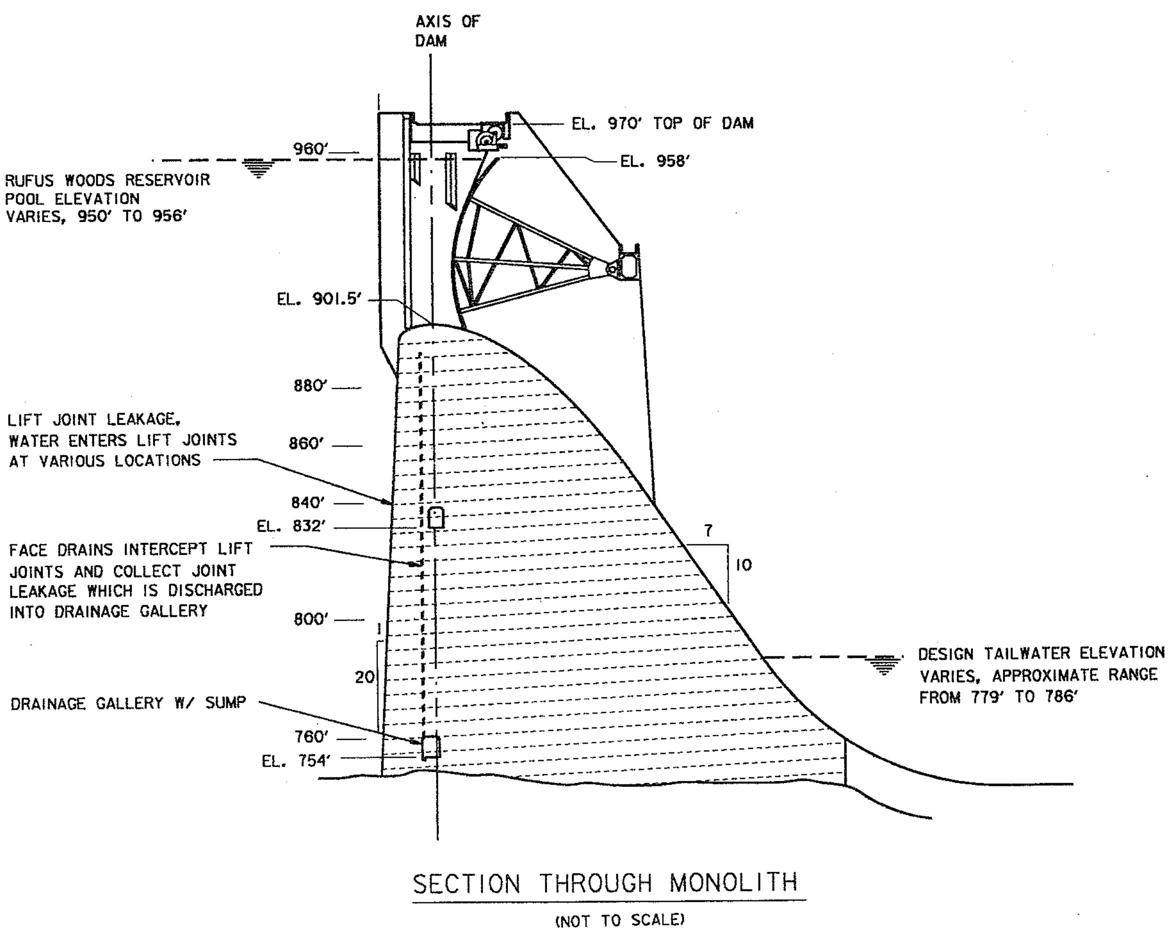


Figure 2. Monolith section showing leakage

In the winter of 1981-82, a variety of materials was tested in an effort to control leakage into the structure's joints. Materials tested included compressed wood particles (presto-logs), cinders, fibrous wood, and a water-activated polyurethane chemical grout, which was applied by remote control. In the winter of 1988-89, a variety of materials and techniques was investigated in a revised approach. Wood particulate (sawdust, with a varying size gradation) was deposited in the upstream reservoir near the surface of the spillway structure. Some of the particulates were drawn into the joints, reducing leakage significantly. In March 1989, after the application of the particulate, visual inspection of the joint entrances revealed large deposits of wood particles along the open joints. However, visual inspection in February through April 1990 disclosed that no wood particles remained. The absence of particles indicated that during the summer, when the joints close and water movement in the joints ceases, the attractive force holding the particles in the joint entrances is lost, and surface currents wash the particles away.

An alternate repair method appeared successful in sealing joint entrances and reducing water movement in the joints. Polyurethane and silicone sealants were applied to the joint entrances by remote-controlled, underwater methods. The water-activated polyurethane sealant bonded to the concrete surfaces and appeared to be a highly effective approach. Inspections in the winter of 1989-90 showed that the joint sealant remained bonded to the concrete surfaces and was still effective.

1989-90 AND 1991 REPAIRS

Repairs performed in the winter of 1989-90 and 1991 consisted of locating leaks, cleaning and inspecting joint surfaces, and applying a polyurethane joint sealant.

Preparatory work to install a valve system on the outlet of the face and joint drains of the monoliths to be repaired was completed in November 1989. The valve system was used to control water movement in the drains and joints and regulate velocities. Downhole camera inspections to locate sources of leakage into the monolith joint drains were accomplished in December 1989, January 1990, and May 1990. Suspect joint entrances on the upstream face of the spillway, ranging from 71.5 to 195.5 ft below the reservoir surface, were located, cleaned, and sealed during February through mid-April 1990 and 1991.

The repair procedure was based on past experience in the use of chemical grout injection for sealing cracks and joints. The initial phase of the repair for the lift and monolith joints was accomplished with remote-controlled methods (without divers), underwater video cameras, and pneumatic equipment adapted to suit the application. A 360-deg pan, 360-deg tilt, 8-power zoom camera mounted to a crane-supported frame was used for the underwater repairs and joint sealing. A pneumatic drive motor moved the cleaning-inspection-grouting equipment along the length of the frame to traverse a lift joint (Fig. 3). All camera systems were color videos with monitors and recorders. A downhole camera was used to inspect the monolith joint drains. A remotely operated vehicle (ROV), self-propelled (swimmer) camera was used for underwater inspections. Results of repairs on individual joints were readily discernible as the work progressed. As soon as a joint was sealed, leakage was reduced significantly as determined by measurement and visual inspection of drain outflows.

Points of leakage were detected on the upstream face by the use of dye injection. The concrete surface was cleaned with a 4-in.-diam, stiff-bristle, steel-wire cup brush powered by a pneumatic drive motor, a 3,000-psi water washing system, and steel scrapers. During the cleaning process, the concrete surface appeared to be soft and friable. The weak concrete surface material, algae and silt were removed to expose approximately 6 in. of clean, sound concrete centered on the lift joints.

Previous inspections indicated the spillway ogee surfaces were deteriorated to a depth of approximately 1/16- to 1/8-in. These surfaces had been continuously exposed to the reservoir water for approximately 35 years. The water is very pure and can reach temperatures as low as 34 deg F. These conditions create the potential for the calcium hydroxide constituents to be leached from the portland-cement paste. The result is a reduction in paste density and

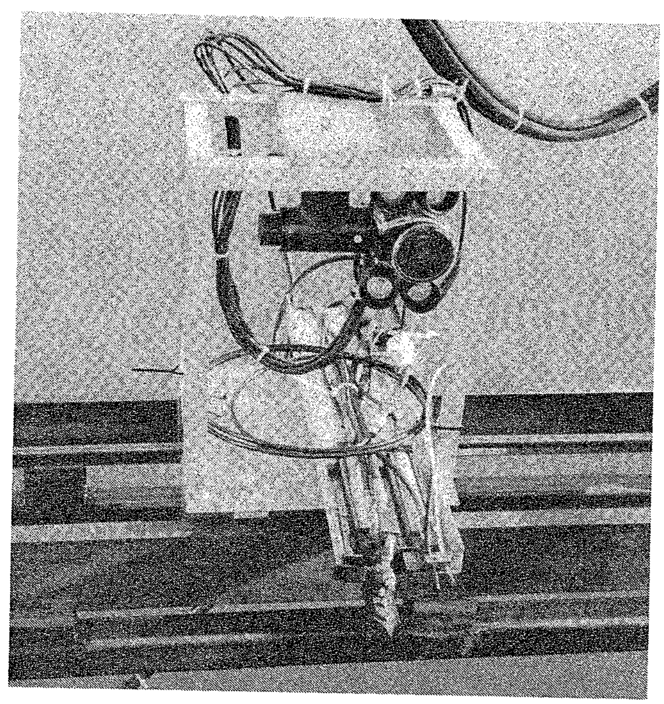


Figure 3. Pan-tilt camera with lights mounted on underwater frame, steel scraper tool with high-pressure water-blasting nozzle, grout hose (black) and dye hose (white)

strength, and ultimately a reduction of strength and an increase in the permeability of the concrete.

If the concrete surfaces exposed to the reservoir were being acted upon by aggressive water quality, then the concrete surfaces inside the joints were also likely to be affected and were subject to erosion when exposed to high velocity water movements. Therefore, it was highly desirable to reduce or prevent water movement into lift joints and to reduce movement velocity.

The repair procedure involved locating the leakage points and sealing them with a sealant designed for this type application. A pneumatic grout pump with a 30:1 ratio and up to 3-gpm delivery was used to pump the grout. Since the water movement into the joints has a significant attractive force, the sealant not only coats or seals over the joint entrance but is also drawn into the joint interior for a short distance (induction grouting).

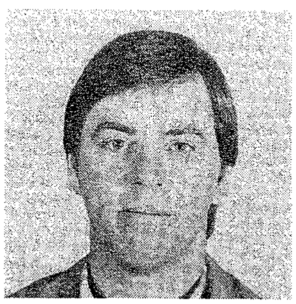
The repair methods used in this project appear to be effective on lift joints in general. Observations during repair of the monolith joints indicated that a few of the copper waterstops were ineffective along their entire lengths and other monolith joints appeared to have localized points of leakage. The remedial underwater joint sealing techniques in these instances were very difficult and cumbersome. However, significant leakage reductions resulted for all monolith joints where the repair procedure was used.

SUMMARY

The repair procedures implemented in the winter of 1989-90 and 1991 at Chief Joseph Dam have been effective in providing significant face and joint drain outflow reductions. Drain outflow has been reduced to a small fraction of pre-repair outflow. Repairs should be made with sealants specifically designed for this type of application.

The use of nonbonded solid particulates in structure joints is not a recommended or satisfactory treatment for providing a durable seal in moving joints in hydraulic structures. The use of pneumatic drive motors and pneumatically powered equipment was very awkward and inefficient. The system will be modified to use electrically powered all-hydraulic equipment in the future.

For further information, contact Kenneth B. Sondergard at (206) 764-3449.



Kenneth Sondergard, P.E., is a civil engineer in the Soils and Materials Section of the Geotechnical and Environmental Restoration Branch, Seattle District. He received his BSCE from the University of New Mexico and has done graduate studies in civil engineering at California State University, in engineering materials at Purdue University, and in soil mechanics at the University of Washington. For the past 10 years, Sondergard has worked in the area of engineering materials with military and civil works repair projects. During the past 7 years, he has been extensively involved in crack repair of dams and chemical grout applications.

REMR Overview Committee Chairman Promoted

Congratulations are in order for Mr. James (Jim) E. Crews, who recently was promoted to the position of Deputy Chief, Operations, Construction, and Readiness Division at the Office of the Chief, Engineers.

Crews will continue serving as the REMR Research Program Overview Committee Chairman at OCE. He also is the Technical Monitor for the Operations Management Problem Area. His new office symbol is CECW-O, new telephone number is (202) 272-0196.

Wanted: Articles that Describe REMR Activities

The REMR Bulletin will print articles about REMR technology application and other REMR activities.

Material is published with the author's byline. Contributions from all REMR problem areas are welcome. The bulletin has a circulation of approximately 2,800. Occasionally, REMR-published articles are reprinted in other publications, thus multiplying the readership considerably.

Manuscripts may be submitted in either draft format or on floppy disk (Word Perfect 5.0 or 5.1, Word Star 3, or ASCII). Photos and illustrations enhance any submission and are requested, although not as a prerequisite for acceptance. A biographical sketch of the author accompanied by a head and shoulders, passport style photo will also be needed.

For more information call Elke Briuer, (601) 634-2587, or send your manuscript to Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: CEWES-SC-A (TTS), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

COVER PHOTOS:

Completed section of Hammondsport flume rehabilitation, New York State.

Leakage discharge from monolith joint drain into drainage gallery.

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LARRY B. FULTON
Colonel, Corps of Engineers
Commander and Director

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