Fig. 1: Surface preparation complete; preparing for shotcrete placement

Lessons Learned on Spillway Shotcrete Overlay

By Billy Roy, P.E.

In early 2017, Knowles Industrial Services Corporation (KISC) was issued a contract by Great River Hydro, LLC (GRH) to perform a reinforced shotcrete overlay on an overflow spillway at Comerford Dam in Monroe, NH. The original Request for Bids specified that cast-in-place concrete be used, with no substitutions provided. After multiple site visits to better understand staging and access, debris removals, and placement logistics, KISC began to develop a value-engineered approach involving the use of air-entrained wet-process shotcrete to replace the cast-in-place specification.

The 58,000 ft^2 (5400 m^2) spillway surface is ogee-shaped at the crest. This curvature made design and construction of concrete formwork difficult. Additionally, the crest was located directly beneath the access bridge, making placement of forms with hoisting equipment nearly impossible without disassembling the bridge deck. Shotcrete placement was presented as a small-footprint option requiring little to no crane work throughout the duration of the project. This also made it easy to accommodate the existing surface curvatures.

The toe of the dam is a combination of ledge and wetland growth, making the construction of an access road difficult

and environmentally invasive. The owner was receptive to methods involving a smaller footprint. KISC proposed using cable climber scaffolding systems for elevated access and line pumps for conveying concrete. Shotcrete placement allowed elimination of heavy formwork, which in turn eliminated the need for cranes and fixed scaffolding. During the bid review process, several different repair methods and logistics plans were presented. KISC provided a unique, low-cost, reinforced shotcrete approach — and while shotcrete placement has proven to be the best option, we've learned some lessons along the way in ensuring a safe and strong spillway.

LESSONS LEARNED

PUMPING / NOZZLING SAFETY IS #1

No job is important enough to ever sacrifice the safety of the crew members and others around them. The shotcrete industry is often the underdog when compared to conventional form-and-pour methods. As such, greater visibility and scrutiny are placed on the safety measures employed in the shotcrete process. PPE is a necessary baseline, but more importantly, shotcreters must consider pumping and nozzling safety. Scaffolding systems must be built to provide firm and stable footing, free from the risk of falls. A comfortable and safe shotcrete crew shoots and finishes more effectively and is more aware of their surroundings. Pump operators must be experienced with various concrete mixtures and comfortable with anticipating plugs before they happen. Understanding pump pressures, hose accessibility, safe hose de-coupling techniques, replacement of excessively worn delivery lines and proper pump cleaning procedures can help ensure injuries are avoided.

A WELL-DESIGNED AND EXECUTED CONCRETE MIXTURE IS EVERYTHING

For all shotcrete projects, and specifically projects in remote locations such as this one, concrete mixture designs must be carefully considered and executed by a trusted vendor partner. With access on dams and spillways being so complicated,

Fig. 2: Typical steel reinforcing: #5 (#16M) L-dowels at 2 ft (0.6 m) spacing with a #5 rebar at 1 ft (0.3 m) on center each way

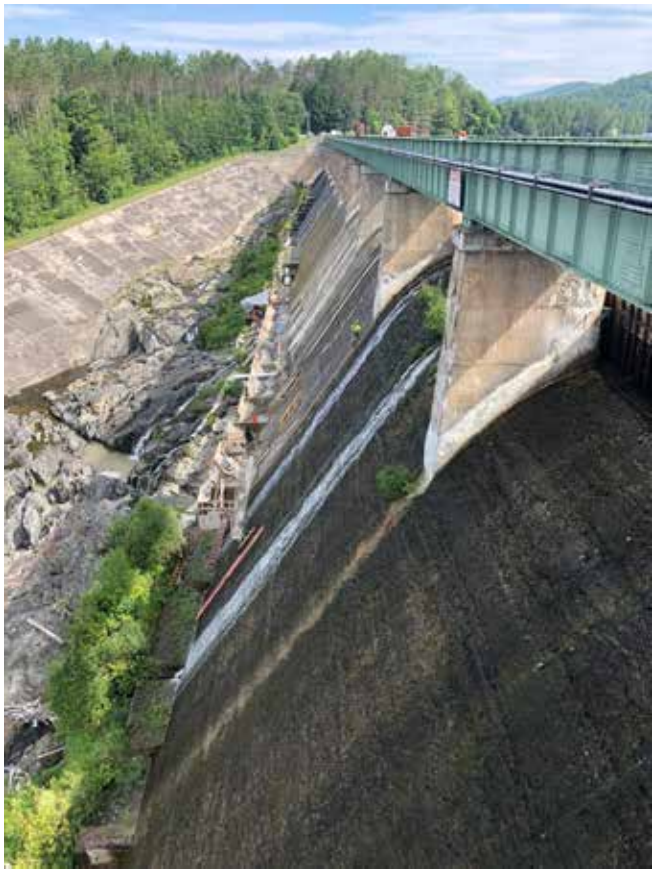

Fig. 3: View of the entire 850 ft (260 m) long overflow spillway

hose plugs and premature initial set can be catastrophic. It's imperative to develop a strong relationship with the local concrete supplier, founded on patience, good communication, and collaboration.

USE ADMIXTURES THOUGHTFULLY

Wet-mix shotcrete has come a long way from 1 to 2 in. (25 to 50 mm) slump mixture with uncontrollable initial set times. Mid-summer concrete placements are especially susceptible to quicker and potentially unexpected set times. Complex staging and access arrangements make rapid placement difficult, requiring additional time to place 10 yd^3 (8 m^3) loads effectively and safely. A hydration stabilizer was used to delay the initial set and to provide additional working time. A high-range water-reducing admixture was added to enhance workability and pumpability without compromising strength through excessive addition of water. A rheology modifier was added when the concrete arrived at the site to allow for deeper placements and more effective bench shooting. Microsynthetic fibers were dosed at a rate of 2.5 lbs/yd^3 (1.5 kg/m^3) for plastic shrinkage crack control. Site conditions must be carefully considered when designing the various ingredients to be put into a prospective mixture.

BE CONSISTENT BUT FLEXIBLE WITH THE MIXTURE

Not all concrete mixes are created equal, and the same mixture is not always optimal in different environments. It's easy to become complacent and go with what's simple from

Fig. 4: Completion of Bays 5, 6, 7, and 8 in 2019

a pumping and placement perspective. However, seasons change; including temperatures (highs and lows), humidity, wind, length of daylight, etc. It's important to remember that shotcrete mixes are not one-size-fits-all. They must be carefully considered and designed to meet the performance needs of the job as well as the environment in which it's being placed and cured.

USE ENGINEERING CONTROLS

Dams are especially susceptible to excessive surface evaporation due to wind and sun. As such, achieving Saturated Surface Dry (SSD) is imperative to combat drying and plastic shrinkage cracking. After shotcrete placement, we found it helpful to use a combination of finishing agent and evaporation control product to protect the concrete during the curing process. These products assisted with workability while finishing the concrete, while also providing significantly more protection against evaporation from wind and sun exposure.

NEVER UNDERESTIMATE THE NEED FOR PROPER EDUCATION AND TRAINING

As with many shotcrete projects, the repair method is site- and job-specific. Having crew members who fully understand the work is imperative to delivering a good project. To assist with this, KISC employed the services of RCS Consulting. Ray Schallom assisted with pre-job planning, concrete mixture designs, equipment selection, pumping logistics, and supplemental crew training. Investing in training and education for the crew was time and money well spent.

THE IMPORTANCE OF BENCH SHOOTING

Much of the shotcrete application exceeded 12 in. (300 mm) in depth. Our process involved bench shooting while mobilizing the scaffolding up the spillway to fill the section and prevent sloughing. The final 2 to 3 in. (50 to 75 mm) of shotcrete placement was achieved while mobilizing the scaffolding down the spillway. This allowed for proper cutting and finishing techniques to not damage the finished surface.

UNDERSTANDING YOUR FOOTPRINT AND SITE GEOMETRY

When specifying shotcrete placement as a substitute for conventional form-and-pour concrete, it's essential to highlight the laydown area and equipment footprint required for each construction approach. Shotcrete placement offers an incredible advantage for sites with limited access or small staging and laydown areas. The elimination of heavy formwork, in turn, reduces the amount of hoisting and heavy lifting required from cranes or other equipment. In the shotcrete industry, we continually strive to be safer, more economical, and more sustainable than conventional concrete and provide clear value for owners.

SUMMARY

KISC mobilized Phase 1 in 2017. Fast forward to 2025 and approximately 70% of the spillway has been successfully restored with a reinforced overlay using shotcrete placement. The project is scheduled to be completed in 2027 as the owner has elected to complete the work on a multi-year, phased approach. At completion of the project, KISC will have demolished and replaced approximately 1700 yd^3 (1300 m^3) of concrete. This collaborative, value-engineered approach demonstrates how shotcrete placement can effectively and efficiently meet the unique needs of complex projects. With licensed professional engineers and several ACI-certified shotcreters on staff, we developed a repair method and specification that met the intent and performance expectations of the original form-and-pour specification.

Several lessons were learned, but the most important was the concept of continuous learning. We found that success often requires thinking of new placement and finishing techniques, exploring new concrete mixture designs with appropriate admixtures, upgrading with better equipment and tool technology, and staying connected with other members of the industry. Adaptability and lifelong learning are key components to staying successful and guaranteeing future success in the shotcrete industry.

ABOVE: *Fig. 5: Typical shotcrete placement from a suspended scaffolding system*
BELOW: *Fig. 6: Shotcrete pumping and chemical dosing operation from the bridge overhead*

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