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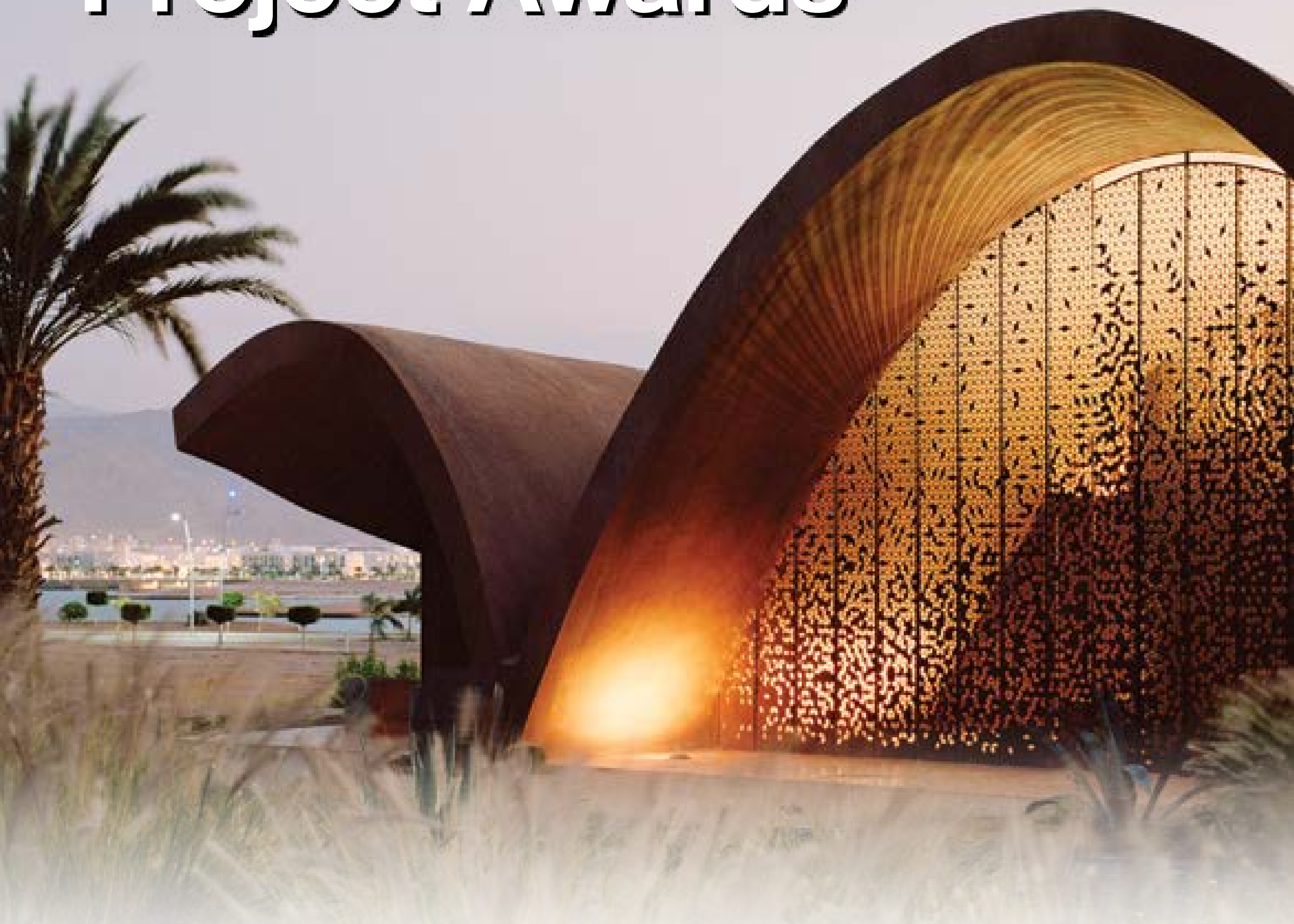
Outstanding Shotcrete Project Awards



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2019 Outstanding Repair & Rehabilitation Project

Falls Village Penstock #1 Structural Shotcrete Rehabilitation Project

By Billy Roy and Andrew Lawson

In early November of 2018, Knowles Industrial Services Corporation (KISC) was issued a contract by First Light Power Resources, Inc. (FLP) to perform a structural shotcrete liner within a steel-riveted penstock at the Falls Village Hydro Electric Plant in Canaan, CT. FLP's request for bids permitted contractors to provide a design-build approach for a structurally self-sustaining system to be built within the penstock interior. The existing 9 ft (2.7 m) diameter, 360 ft (110 m) long penstock was buried in its entire length on a steep bank and crossed underneath a live highway. Penstock replacement by excavation proved to be too costly, as much of the existing penstock beneath the roadway was encased in reinforced concrete requiring significant demolition and interruption to traffic in this area.

BID REVIEW PROCESS

During the bid review process, three different repair methods were presented, which included hand-laid fiberglass mat systems, structural epoxy liners, and structural shotcrete. KISC provided a unique, low-cost reinforced shotcrete approach. It was imperative that the awarded contractor provide structural calculations demonstrating that their method would be self-sustaining and could withstand all static and water hammer pressures while in operation, 13.1 lb/in.^{2} (0.09 MPa) and 2.2 lb/in.^{2} (0.015 MPa), respectively. Calculations were not to consider any strength contribution from the existing riveted steel shell, whose structural integrity was questionable and impossible to conservatively define. With two professional engineers on staff specializing in penstock shotcrete and steel reinforcement design, KISC was able to secure the contract by providing a series of structural calculations and submittals that met the strength requirements for the new penstock when operating at full capacity.

THE DESIGN

KISC worked with Kleinschmidt Associates, Inc., the Engineer-of-Record, to design a shotcrete liner that met the structural demands of the environment without significantly reducing the existing pipe's cross-sectional area, which would ultimately affect the overall power generation potential of the turbine units at the power station. In addition, a decrease in Manning's coefficient was desired to promote increased laminar flow. It was determined the Manning's coefficient for riveted steel is (0.19). KISC provided FLP and Kleinschmidt with substantial data proving that the new Manning's coefficient for smooth concrete would be (0.012) and the eventual epoxy coating would further decrease the Manning's coefficient to (0.010), ultimately providing less friction losses and higher water velocity to combat any losses due to reduced cross-sectional area.

Each structural shotcrete penstock liner is unique. The design process is complex and requires attention to various details and site conditions. External forces, such as soil overburden loads, bending and shear stresses, and highway loads, must be considered in the design process as well as internal hoop stresses, such as static and water hammer pressures and flow geometry.

This particular penstock design and construction was the tenth of its kind for KISC over the past 10 years. Over the years, KISC has worked with several engineering firms throughout New England to design and build reinforced penstock liners that have been approved and often favored by the Federal Energy Regulation Commission (FERC). KISC has assisted various owners and engineers on several penstock projects by compiling data and submitting packages for the shotcrete process which has, over time, become one of the preferred repair methods for water-filled pipes.

The original bid documents indicated that FLP would supply the awarded Contractor with a 6-week canal outage to perform the work. The approximately 2000 ft (610 m) canal diverts water from the Hoosatonic River which supplies three 9 ft diameter penstocks to the 9 MW power station. Penstock #1 was one of three penstocks that would be entirely de-watered during this station outage. KISC indicated the project duration would require a 12- to 13-week effort from start to finish. This condition was unacceptable to the FLP at that time, as the cost of leaving the canal dry and keeping the entire station (all three penstocks) offline for more than 6 weeks was not feasible for the owner due to the lost revenue from potential power generation. Furthermore, FLP's Safety Department was concerned with work being performed downstream of the existing Penstock #1 head gate if the canal was left at full capacity. KISC was charged with developing a work plan and method that could allow for the shotcrete work to be completed over a 12- to 13-week schedule without sacrificing lost power generation in Penstock Units #2 and #3.

The KISC Engineering team, comprised of Senior Vice President Andrew Lawson and Project Manager Billy Roy, began to value engineer an approach that would provide the necessary schedule time while not sacrificing FLP revenue. KISC committed to designing a temporary, secondary safety bulkhead upstream of the Penstock #1 head gate. The 1-1/4 in. (32 mm) thick steel safety gate would provide a secondary level of protection in the event that the existing penstock intake gate failed under the hydrostatic pressure of a full canal during construction. This approach would permit safe working access into Penstock #1 for KISC workers for 13 weeks without requiring a total station outage. This permitted FLP to continue generating power in Units #2 and #3 without interruption during the construction in Penstock #1. Additionally, this process allowed for the flexibility to work in winter months during historically lower river flows when water availability is not abundant enough to sustain continuous operation of all three units. This value-engineered approach resulted in KISC being awarded the contract for Penstock #1 at the originally requested 13-week schedule.

As part of the contract specifications, KISC was tasked with providing design calculations for the shotcrete reinforcing steel required to withstand the static and hammer water pressures in this penstock. The KISC Project Manager, Billy Roy, determined that the reinforcing bar configuration would be #4 (#13M) longitudinals spaced at 12 in. (300 mm) radially and #5 (#16M) prebent radial hoops spaced at 6 in. (150 mm) longitudinally. The reinforcing bar mat would be tied to a series of 1.5 in. (38 mm) slab bolsters welded longitudinally down the length of the penstock and spaced at 4 ft (1.2 m) radially. As with all water delivery pipes for power generation, it is imperative to design a shotcrete product that provides sufficient cover over the embedded steel while maintaining a small loss in overall cross-sectional area of the pipe. KISC elected to use Quikrete Shotcrete MS at 4 in. thickness around the circumference of the pipe. Rebound removal was difficult on this site due to limited access in and out of the work area, so a higher concentration of silica fume was desirable to minimize rebound and unnecessary cleanup labor.

Construction

KISC mobilized to the site on October 15, 2018. Construction began by excavating two areas through the soil overburden to expose the tops of the existing penstock to provide various points of worker access as well as to provide means of expelling shotcrete dust. Two large holes were cut in the existing penstock steel.

Fig. 1: Temporary safety bulkhead

Fig. 2: Excavated manhole access

Once the pipe was entered, the entire substrate was pressure washed with 5000 lb/in.^{2} (34 MPa) water blasting. All areas to receive 1.5 in. welded slab bolster were ground for cleanliness and to promote weld strengths. The project consisted of welding 2100 ft (640 m) of 1.5 in. continuous slab bolsters, installing 6.5 miles (10.5 km) of reinforcing steel, and applying 150 yd^3 (115 m^3) of Quikrete Shotcrete MS. Smoothness of the finished shotcrete was incredibly important on this project. As with all hydroelectric utilities, great care is taken to prevent any power generation reduction due to friction losses anywhere within the system. To maintain Manning's coefficient of (.012) for smooth concrete, cutting and finishing was a labor-intensive and necessary process. This would ultimately lead to increased laminar flow, higher water velocity, and subsequently higher generation capacity. KISC crew members spent considerable time finishing the entire 10,200 ft^2 (950 m^2) interior of Penstock #1.

Fig. 3: Welding steel transitions at upstream and downstream shotcrete terminations

Fig. 4: Reinforcing bar installed

Shotcrete Inspection

Specifications required the involvement of a third-party shotcrete consulting firm to provide unbiased commentary and inspection of the shotcrete process. Ray Schallom of RCS Consulting & Construction Co. Inc. was contracted to provide insight, education, and inspection services to assure that all shotcrete work and techniques were aligned with the project specifications. Among the topics inspected by Schallom were reinforcing bar layout and cover, silica awareness and mitigation, shotcrete finishing, and curing procedures. Final reports submitted by RCS Consulting reported no deficiencies in the shotcrete process implemented by KISC.

Project Challenges

Some of the challenges faced on this project included confined space entry and rescue, winter conditions with cold temperatures, shotcrete curing, and transporting large quantities of construction materials at great distances by foot. KISC provided all confined space permitting, air monitoring, attendants, and rescue services. To combat winter temperatures, all gunning and pre-dampening operations were confined to heated enclosures built near the work area. KISC crews exercised great diligence in protecting air-powered equipment from frequent freezing and provided ample protection for shotcrete materials stored outdoors at the site.

Conclusions

The project was completed on time in the original 13-week schedule. KISC crews worked 50 hours/week, including several weekends on and around holidays. The temporary safety gate was removed on January 4, 2019, and the penstock was placed back into operation later that afternoon with no startup issues. The owner expressed gratitude for the timely, cost-effective approach engineered by KISC which created very little power generation losses throughout the duration of the project.

In July 2019, KISC crews returned to Falls Village Hydro during the annual outage. The shotcrete liner was inspected after operating for approximately 7 months. No defects were found. FLP was pleased to announce that after collecting power generation data over that time period, no generation losses were reported due to the installation of the shotcrete liner. KISC finished the project by abrasive brush blasting of the entire 10,200 ft^2 penstock shotcrete liner and applying two 30 mil (0.76 mm) spray coats of high-build epoxy. The intent of the epoxy was twofold; to extend the service life for the shotcrete and to provide a lower Manning's coefficient to promote more laminar flow. The epoxy lining project was completed in the scheduled 2-week timeframe.

Fig. 5: Falls Village Penstock shotcrete

Billy Roy *is a Project Manager for Knowles Industrial Services Corporation based in Gorham, ME. He received his BS in construction engineering technology at the University of Maine College Of Engineering in 2013, and became licensed as a Professional Engineer in Maine in 2018. Roy specializes in design and management for various shotcrete, concrete repair, and grouting projects throughout New England. He is an ACI Certified Concrete Testing Technician, a NACE CIP Level 2 Inspector, and holds a Lead Abatement Supervisor certification with the State of Maine.*

Andrew Lawson *is Senior Vice President for Knowles Industrial Services Corporation based in Gorham, ME. He is a Professional Engineer in Virginia. He received his BS in civil engineering from Virginia Tech, Blacksburg, VA, in 1976. His 38-year on-going career with KISC began in 1982. He continues to serve the functions of Estimator and Project Manager specializing in shotcrete, concrete repair, and grouting services throughout the New England states, particularly with hydro-electric/water structures. He is certified in Maine as both an Environmental Design professional and Lead Abatement Supervisor and holds a NACE CIP Level 1 designation.*

2019 OUTSTANDING REPAIR & REHABILITATION PROJECT

Project Name
Falls Village Penstock #1 Structural Shotcrete Rehabilitation Project

Location
Falls Village, CT

Shotcrete Contractor
Knowles Industrial Services Corporation*

Architect/Engineer
Kleinschmidt Associates, Inc.

Materials Supplier
The Quikrete Companies*

Equipment Manufacturer
Allentown

General Contractor
Knowles Industrial Services Corporation*

Project Owner
First Light Power Resources, Inc.

*ASA Sustaining Corporate or Corporate Member

QUIKRETE TROWEL GRADE RE-CAP AND RAPID ROAD REPAIR – CA

QUIKRETE®, manufacturer of preblended commercial-grade cement and concrete products, strengthened its repair portfolio with the additions of its Trowel Grade Re-Cap, Rapid Road Repair – CA (Calcium Aluminate), and an updated version of FastSet™ Repair Mortar.

QUIKRETE Trowel Grade Re-Cap

A special blend of portland cement, sand, polymers, and other proprietary additives, Trowel Grade Re-Cap is a versatile shrinkage-compensated material ideal for repairing spalled, cracked, or pitted concrete surfaces from 1/16 to 1/2 in. (2 to 13 mm). It has a bond strength four times greater than the concrete itself. That means a concrete substrate will fracture or crack before its bond with Trowel Grade Re-Cap. With 30 minutes of working time, one 20 lb (9 kg) bucket will cover approximately 5 ft^2 (0.5 m^2) at 3/8 in. (10 mm) thick and up to 15 ft^2 (1.4 m^2) at 1/8 in. (3 mm) thick. Trowel Grade Re-Cap has a walk-on time of 3 hours and drive-on time of 24 hours.

QUIKRETE Rapid Road Repair – CA

Rapid Road Repair can be used for rehabilitating bridge decks, highways, runways, parking garages, parking lots, driveways, and other industrial concrete surfaces. Rapid Road Repair – CA is a new calcium aluminate cement-based formulation that also features fast-setting cements and alkali-resistant (AR) glass fibers. This new repair material provides contractors up to 30 minutes working time, greater high-early compressive strength, and increased tensile strength. Regardless of the jobsite environment or conditions, permanent structural partial-depth repairs up to 2 in. (50 mm) can be completed quickly. Rapid Road Repair – CA is available in 50 lb (23 kg) bags and reaches 3000 psi (21 MPa) in 90 minutes, 4500 psi (31 MPa) in 3 hours, and 8000 psi (55 MPa) in 28 days. For full-depth repairs greater than 2 in., a version of Rapid Road Repair – CA extended with gravel or stone is available in 80 lb (36 kg) bags.

QUIKRETE FastSet Repair Mortar

FastSet Repair Mortar was formulated to make structural repairs to any concrete, masonry, or stucco surface. The improved adhesion and reduced shrinkage make FastSet Repair Mortar even more ideal for vertical and overhead repairs. With 20 to 30 minutes working time and its unique properties allow for the sculpting of the material during placement, FastSet Repair Mortar can be used on damaged curbs, steps, prestressed panels, loading docks, retaining walls, and sewers.

For more information, call 800.282.5828 or visit **www.QUIKRETE.com**.

ACI ANNOUNCES NEW POSITION STATEMENTS

The American Concrete Institute (ACI) recently published its first six position statements. These position statements support policy positions and state, federal, and international programs, rules, and regulations.

The Institute's position statements are focused on advocacy efforts related to code development and adoption. Current positions statements include:

- Current Code and Standard Adoption—Encourage the adoption and/or use of current building codes and standards;
- Adoption of ACI Documents Without Modifications—Encourage the adoption and use of ACI products, including but not limited to codes and standards without modification;
- Acceptance of ACI Certification Programs—Support acceptance of sampling, testing, inspection, and installation of concrete and related products and materials; encourage the use of certification programs developed and administered by professional societies in lieu of programs developed and administered by other entities; and support mandates or otherwise place preference on accreditation of individuals and entities engaged in providing services related to concrete and concrete products;
- Concrete Knowledge—Support research, technological advancements, and dissemination of concrete technology; and channel through, directed to, or otherwise engage ACI and/or the ACI Foundation;
- Enhanced Resilience—Encourage or establish criteria related to enhancing the resiliency of the built environment; and where appropriate, engage ACI and/or the ACI Foundation to facilitate programs and activities related to the role of concrete technology in achieving enhanced resiliency; and
- Sustainability—Encourage or establish criteria related to enhancing the sustainability of the built environment; and where appropriate, engage ACI and/or the ACI Foundation to facilitate programs and activities related the role of concrete technology in achieving enhanced sustainability.

"These position statements provide a vehicle for the American Concrete Institute to advocate on issues of code development and code adoption in support of our expanded mission," states Steve Szoke, ACI Advocacy Engineer.

"The Institute has used and will continue to use these statements to align ACI efforts with other industry organizations to more effectively influence programs, policies, rules, and regulations related to concrete and concrete technology," continues ACI Advocacy Engineer, Kerry Sutton.

For more information, call 248.848.3800 or visit **concrete.org/positions**.