Western U.S. and International Water Projects Using Shotcrete

by Warren Harrison

Shotcrete is used for many different hydraulic projects in the arid western part of the U.S. Projects include water tank repair, spillway repair, water channel repair, temporary shoring for water tank construction, and water features.

Concrete Water Tank Repair

For water districts, water tanks have been repaired where, for many different reasons, the original concrete has deteriorated. In the resort town of Vail, CO, the underside of a 20 ft (6 m) high roof of a water tank was repaired using dry-process shotcrete. The repair was necessary to cover and protect exposed reinforcing bar that was placed too close to the bottom of the roof slab placement. The exposed rusted reinforcing bar was sand blasted, the roof was power washed to bring the existing concrete to a saturated surface-dry condition, and dry-process shotcrete was applied to the roof of the structure. The tank was ventilated with air-powered fans. The unique point of the project was the supply of material down the ski slope to the tank from an upper access road. It was too dangerous to use a concrete truck, so a 2-ton (2 tonne) truck was used and slid down the ski slope from an upper access road.

Water Diversion Structures

The Bureau of Reclamation is in charge of diverting water from the western side of the U.S. continental divide to the eastern portion of the U.S. One of these major projects is the Frying Pan-Arkansas Project where west slope water is diverted through a series of collection points and tunnels and then sent to the eastward-flowing Arkansas River. A diversion structure called "lily pad" collects water from a series of springs in the early part of the summer and directs the water to a shaft connected to one of the diversion tunnels. The original structure was built with burlap sacks filled with concrete that hydrated in place. The structure was 750 ft (229 m) from the nearest truck access road and 250 ft (76 m) above the road in elevation. The construction estimate was based on placing the repair shotcrete with helicopter-lifted material shot from a pump airlifted to the diversion channel site. The original design required a 4000 psi (26 MPa) compressive strength shotcrete mixture with 130 lb/yd^3 (35 kg/m^3) of steel fibers. The repair included cleaning out the old flume and

Lily pad pump

Lily pad diversion structure

Lily pad pump setup

encasing the existing concrete sack structure with 4 in. (102 mm) of shotcrete.

At bid time, commitments could not be obtained from helicopter companies because the work had to be done during the high-fire months of August and September. A value engineering proposal was therefore submitted to use No. 3 epoxy-coated reinforcing bar in place of the steel fiber in the same proportion (lb/yd^3 [kg/m^3]). A Reed C50 HPS that had a 1750 psi (12 MPa) concrete face pressure capability was also used and was turbo-charged to work efficiently at the job-site elevation of 12,000 ft (3660 m).

The expected face pressure was calculated from the data given by researchers, and many sources were consulted to develop a pumping and piping method that would work in these extreme conditions. A 2-1/2 in. (64 mm) pipe size with a 2-1/2 in. (64 mm) hose and nozzle for placing was chosen. The line was reduced to 2-1/2 in. (64 mm) at the pump, and the lower end of the pipe was anchored so that the reducers could be removed safely. A shut-off sliding gate valve was also installed so that if the line was full during or after pumping the pump and reducers could be disconnected from the delivery line. Prior to pumping shotcrete, the delivery line was lubricated with a water and bentonite mixture. The line valve was closed and the hopper was cleaned of bentonite to prevent dilution of the shotcrete mixture.

The mixture design had 659 lb/yd^3 (390 kg/m^3) of Type I/II cement, 117 lb/yd^3 (69 kg/m^3) of Type F fly ash, 560 lb/yd^3 (332 kg/m^3) of pea gravel, 2180 lb/yd^3 (1293 kg/m^3) of sand, 23.3 oz/yd^3 (900 mL/m^3) of water-reducing agent, 46.6 oz/yd^3 (1800 mL/m^3) of hydration inhibitor, 295 lb (134 kg) water, and air entrainment as needed. The mixing site was a 90-minute travel time from the pumping site. Set time was delayed using a hydration inhibitor. The mixture was pumped at 4 to 5 in. (102 to 127 mm) slump with 8 to 10% air measured at the truck. At the outlet end, the slump was 1 to 2 in. (25 to 51 mm) with air at 5 to 5.5%. The contract required that test samples be taken at 28 days from the structure. A gas-powered drill was used to core-drill in the snow and samples broke at 5320 psi (37 MPa) at 28 days. Test panels were shot and cored on site, and the test samples tested 4270 psi (29 MPa) at 28 days.

Spillway Repair

At a large dam near Denver, CO, shotcrete was applied to the spillway for repair. The shotcrete was immediately applied after demolition and excavation to protect the slaking claystone bedrock material. The substrata were sealed from weathering while the contractor installed caissons, reinforcement, and the final spillway concrete.

Spillway repair

Shoring for expansion of water treatment plant

Water and Waste Water Treatment Plants

Normally, new structures to metropolitan facilities must be placed nearby existing structures. By placing the structures so close together, shotcrete must be used with soil nails or micropiles to underpin and support the existing structures and shore the walls of the new structure. Many projects must involve shoring to protect existing pipe lines.

Pumping Station Chamber Repair

In Israel, shotcrete was used to repair a charging pump chamber to make it relatively waterproof, allowing it to rehabilitate 900 high-power charging pumps. The charging pumps took the intake water from below the Sea of Galilee and charged a 30 MW pump that pumped the water

Tunnel repair at pump station in Israel

Dry shotcrete at pump station in Israel

Water distribution system in Israel

from –722 ft (–220 m) elevation to the outlet at +148 ft (+45 m) elevation. The chambers had an inflow rate of 3000 gal./min. (11,000 L/min.), which was reduced to 45 gal./min. (170 L/min.), making the chambers safe for the rehabilitation workers.

The dry-shotcrete process was used to seal around the gates and incoming water flow, which directs water to the pipes. Eventually the pipes were also grouted to provide an additional seal. The work took 2 months during December and January. The dry-shotcrete material was formulated in Israel and supplied by a flooring material supplier who used local sand, chert 3/8 in. (10 mm) aggregate from Turkey, Israeli cement, and silica fume from South Africa. The shotcrete machine was shipped from the U.S. and a local supplier was used for the diesel air compressor.

References

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