Ice Harbor Lock and Dam

2024 Outstanding Infrastructure Project

Ice Harbor Dam Rewinds and Turbine Runner Replacement

Shaft for a turbine unit

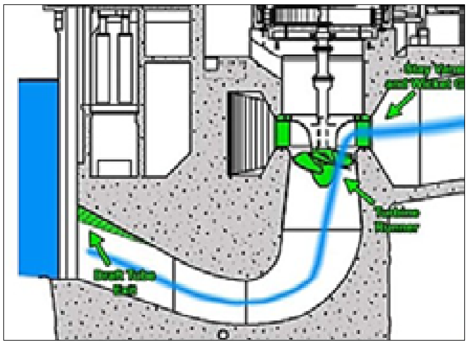


Illustration of the draft tube modification

By David Graham

Ice Harbor Lock and Dam was authorized by the River and Harbor Act of 1945. Constructed in 1956, the project includes a dam, a powerhouse, a navigation lock, two fish ladders, a removable spillway weir, and a juvenile fish bypass facility. It provides navigation, hydropower, flood risk management, fish and wildlife habitat, recreation, and incidental irrigation. The dam, located on the Snake River near the confluence with the Columbia River in Burbank, WA., is 2822 ft (860 m) long with an effective height of 100 ft (30 m). It is a concrete gravity-type dam with an earth-fill embankment section.

In 2016, the owner awarded a contract to rebuild three generating units to improve hydraulic conditions for fish passage and improved turbine electrical generating efficiency. This Contract included draft tube ceiling structural modifications, requiring the application of an accelerated wet-mix shotcrete with 100 lb/yd^3 (59 kg/m^3) of steel fiber, up to 6.25 ft (1.9 m) thick overhead. As overhead application of shotcrete to such thickness is seldom done, this posed a challenge for the designer and contractor.

PRECONSTRUCTION MOCK-UP / PROCESS AND SHOTCRETER QUALIFICATION

To qualify the shotcrete mixture design, accelerator type and addition rate, and the shotcrete application procedures by the ACI-certified shotcreters, several full-scale overhead mock-up sections were constructed with a thickness of up to 6.25 ft. These mockup sections replicated field conditions

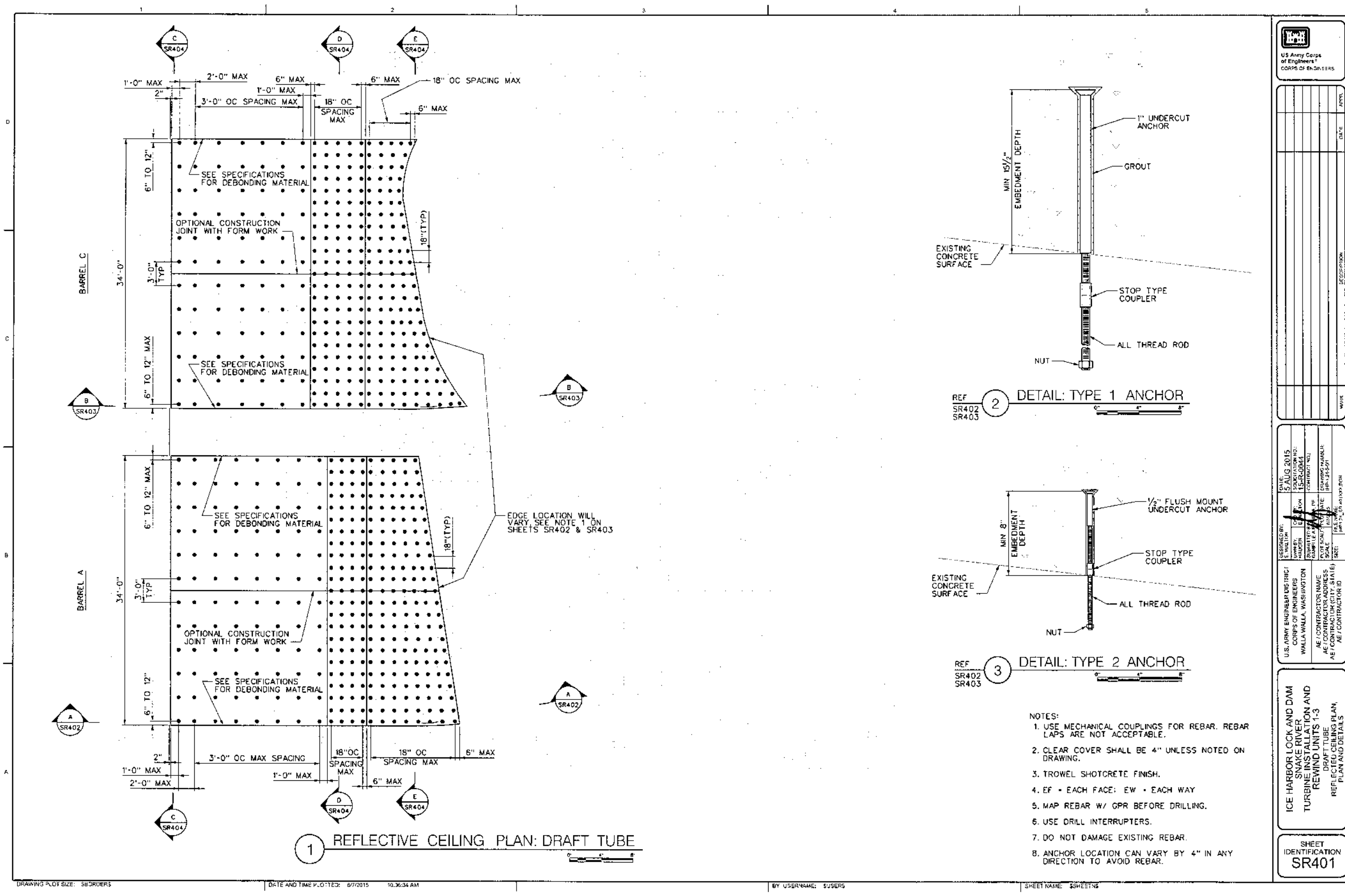


Fig. 1: Reflective ceiling plan for reinforced shotcrete modifications to draft tube

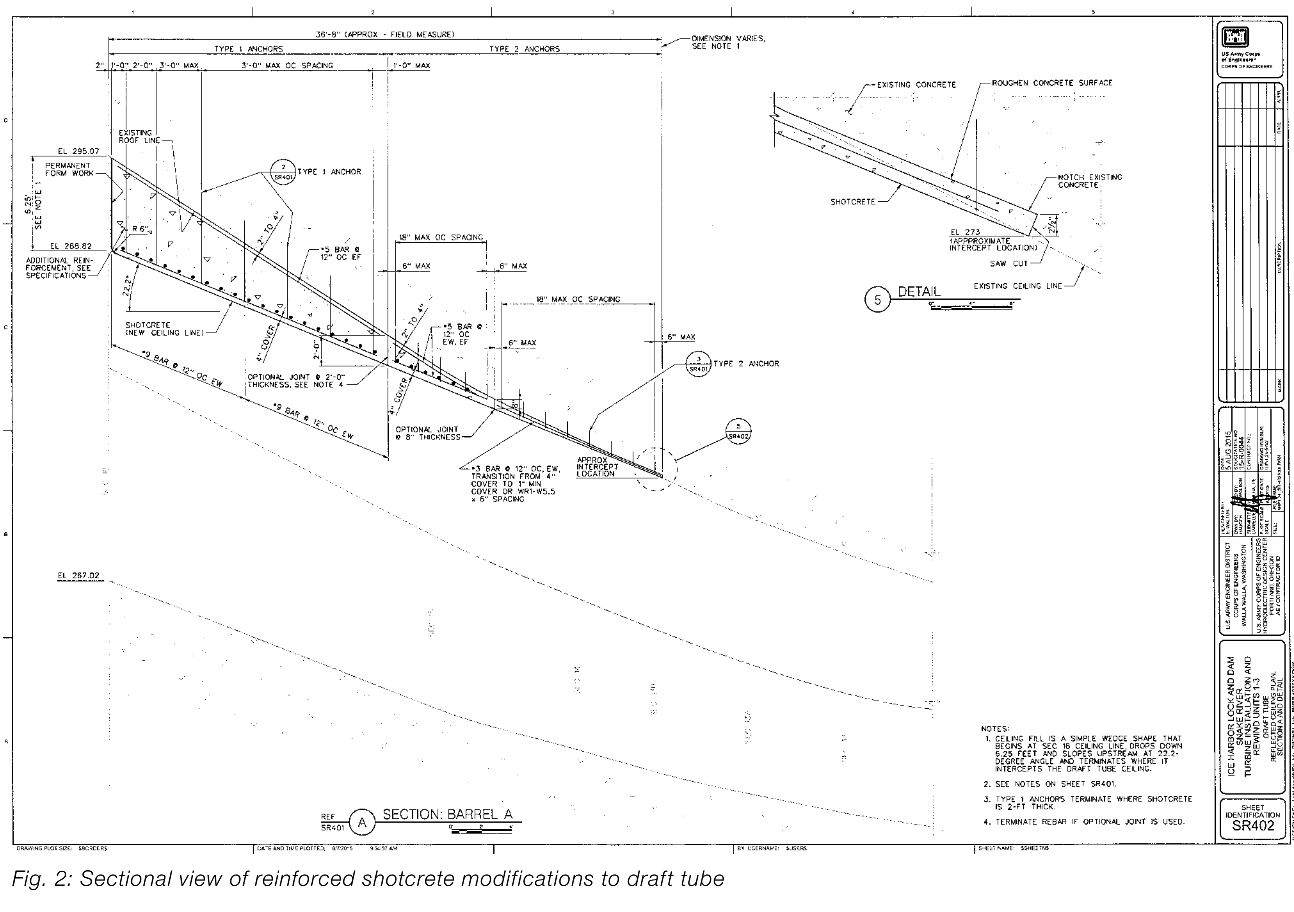


Fig. 2: Sectional view of reinforced shotcrete modifications to draft tube

Shotcreter shooting the full-scale mock-up

Mock-up block stripped and lowered to the ground for evaluation

A diamond wire cut section of a full-scale mock-up showing excellent shotcrete consolidation around rebar and saw cut prisms for bond testing

Permanent steel form, one-inch diameter anchors, and #5 reinforcing steel mat installed, secure and ready for shotcrete

Layer thickness was controlled to a maximum of 4" using steel piano wire

including 1 in. (25 mm) diameter undercut anchors, #9 (#29M) and #5 (#13M) reinforcing steel mat sections, and final finish. Each shotcreter qualified for use on this project was required to complete an acceptable preconstruction mock-up prior to jobsite shotcrete placement. After construction of the preconstruction mockup, each block was sawed in half to allow the design engineer to conduct a visual inspection of the cut sections and observe the quality of reinforcement steel encasement and consolidation of the multiple shotcrete layers placed overhead.

WORK AREA ACCESS

Sectional scaffolding was installed within the draft tube area from floor elevation to ceiling. The work platform elevation was lowered as required during construction as overhead shotcrete placement progressed.

SURFACE PREPARATION-REINFORCING STEEL-SUPPLEMENTAL ANCHORS

Prior to shotcrete placement, all existing concrete surfaces to receive shotcrete were prepared using an abrasive blasting technique to ICRI CSP 7. The leading edge was sawcut and concrete removed to provide a minimum of 2.5 in. (63 mm) thick shotcrete section. A 6.25 ft high permanent steel form was installed straight and plumb providing 2 in. (50 mm) spacing from the temporary stoplog bulkhead. Supplemental anchors were installed that included 0.5 in. (13 mm) and 1 in. diameter undercut anchors. The #5 and #9 reinforcing steel mats were installed per plan.

SHOTCRETE PLACEMENT AND FINAL FINISH

Accelerated wet-mix steel fiber reinforced and silica fume modified shotcrete placement started after all surface preparation, supplemental anchors, and reinforcing steel were installed and passed inspection. Shotcrete was placed in consecutive layers up to a maximum of 4 in. (100 mm) thick until the full section was complete. Steel piano wire was used for grade control between layers. Material for the final 2 in. layer was constructed using ACI 506R gradation #2 aggregate, silica fume, and polypropylene fiber dry-mix shotcrete. The final finish was light broom with a tolerance of 0.25 in. (6 mm) in 10 ft (3 m).

PRODUCTION QUALITY CONTROL AND QUALITY ASSURANCE

The work was monitored full time by qualified inspectors. After each days' production, inspectors filled out inspection checklist reports which were submitted daily. Field testing was conducted to record the ambient temperature, concrete delivery temperature, as-batched and as-shot air contents, and initial and final set times. Beam molds were shot to determine early-age compressive strength development using an end beam tester.

The contractor shot one production shotcrete test panel for every 50 yd^3 (38 m^3) of shotcrete placed, or one per day, whichever occurred more frequently. Cores were extracted from the test panels to determine:

- Compressive strength at 7, 28, and 56 days
- Boiled absorption and volume of permeable voids to ASTM C642 at 28 days

Shotcreter shooting overhead on a scaffold platform in an upright position to the No. 5 rebar and the one-inch anchors

Excellent quality of encasement of the No. 9 rebar was observed by the shotcrete inspector

Final broom finish of the draft tube ceiling modification

Beam molds shot for determination of early age compressive strength using end beam tester

Bond pull-off testing was performed to determine shotcrete bond strength to the prepared concrete substrate. Bond strength testing was conducted after the shotcrete applied to the original prepared concrete substrate had cured for a minimum of 7 days. Bond strength tests were also performed to evaluate the bond between shotcrete layers.

PROJECT CHALLENGES

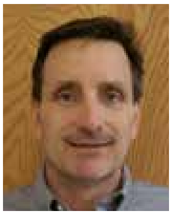
- Difficult access due to the work location being deep within the dam structure
- Overhead crane limitations and shared use requirements
- Waste material removal
- Leaking stoplog seals
- Weather: Hot summer and cool winter conditions
- Multi-year contract, 2016-2024
- Construction activity delays, eight-month COVID shutdown
- Portland cement changed from Type I to Type IL in 2023
- Fly ash source change in 2021 proved detrimental to the concrete mixture design strength development; as a result, fly ash was removed from the mixture design during the 2024 phase
- Confined space, temporary ventilation, dust/vapor controls, lighting

SUMMARY

Construction of Unit No. 2 (2017), Unit No. 3 (2020), and Unit No. 1 (2024) proved that a high quality, accelerated, wet-mix, steel fiber reinforced, silica fume modified shotcrete up to 6.25 ft thick overhead can be applied successfully. The structural modification to the draft tubes was completed using wet-mix shotcrete, except for the final 2 to 4 in. (50 to 100 mm) finishing shotcrete layer, which was constructed using dry-mix shotcrete.

REFERENCES

1. Radomski S., Morgan D.R., Zhang L., Graham D., Structural Modifications to Hydroelectric Turbine Draft Tube Ceiling, Shotcrete Magazine. Summer 2019, pp 22-34.
2. Zhang L., Radomski S., Morgan D.R., Graham D., Structural Modifications of Draft Tubes Using Overhead Wet-Mix Steel Fiber Reinforced Shotcrete, Concrete Repair Bulletin, International Concrete Repair Institute, Inc. July/August 2022, pp 20-28.



***David Graham**, Project Manager/Estimator for PCiRoads, LLC. With over 40 years of experience in the shotcrete industry, he has managed numerous projects nationwide that include the use of shotcrete on buildings, bridges, tunnels, dams, silos, tanks, and soil stabilization.*

2024 OUTSTANDING INFRASTRUCTURE PROJECT

Project
Ice Harbor Dam Draft Tube Modification

Project Location
Burbank, WA

Shotcrete Contractor
PCiRoads, LLC*

Architect/Engineer
U.S. Army Corps of Engineers, Walla Walla District

Equipment Manufacturer
Gary Carlson Equipment* / Putzmeister*

Materials Supplier
Master Builders Solutions*

General Contractor
Voith Hydro

Owner
U.S. Army Corps of Engineers, Walla Walla District

Other Project Members
LZhang Consulting & Testing, Ltd. / WSP Canada, Inc.

**ASA Sustaining Corporate or Corporate Member*