Péribonka Hydroelectric Development Project

Contractor Converts Preblended Dry Components to Wet Shotcrete

by Simon Reny

Hydro-Québec is a world leader in the production of hydroelectric power. Over the past 50 years, it has been responsible for the design and construction of several large hydraulic dams throughout the northern areas of the province. The power supplied by these structures is sold to customers that include hydro utilities throughout Quebec and Ontario in Canada and in the northeastern U.S. The demand for more environmentally friendly sources of energy has lead Hydro-Québec to increase the production of hydro-electric power and, as a result, there are currently several new dam projects under construction to help meet this demand. The Péribonka Hydroelectric Development Project, launched in 2004, is one of the largest of these projects. At the peak of construction, the project had a total of 1350 workers on site.

The Péribonka project is located on the Péribonka River, 310 miles (500 km) northwest of Montréal, QC, Canada. The mean annual flow at the dam site is 15,470 ft^3/s (438 m^3/s) with a drainage basin of about 7500 $miles^2$ (19,450 km^2) and a fall of 230 ft (70 m). The output of the plant is 22,250 ft^3/s (630 m^3/s). The Péribonka dam is an earth embankment design with an underground power plant and generates a total power of 385 Megawatts (515,900 horsepower) and produces 2.2 Tetrawatts-hours (2948 million horsepower-hours) of energy annually.

Fig. 1: General view of the project on the Péribonka River, September 2004
(Photo courtesy of Hydro-Québec)

The project was divided into several different areas, including the earth embankment dam, the spillway, the diversion tunnel, and the underground power plant. In 2004, construction of the earth embankment dam was awarded to Excavation Chicoutimi of Chicoutimi, Québec. Excavation Chicoutimi started construction of the dam in 2005.

Before construction of the earth embankment, Excavation Chicoutimi had to expose the mountain bedrock surfaces on each side of the future dam location. The design called for the deepest section in the valley between the two mountains to be grouted using a process called deep-sealed wall. The grouted wall was produced by injecting a mixture of bentonite and portland cement using large drilling and grouting equipment guided by a global positioning system (GPS). The rest of the earth embankment required a watertight core to prevent water from bypassing the dam. This core (made of clay) would sit directly on the bedrock. After removal of the overburden, the Hydro-Québec engineers became concerned that cracks located throughout the surface of the bedrock could lead to future water loss from the reservoir or, in an even worse case scenario, create erosion that could cause the dam to fail.

To prevent this situation from occurring, the engineers elected to seal and smooth all nonhorizontal rock surfaces using wet-mix shotcrete. Excavation Chicoutimi subcontracted the shotcrete application to Construction Injection EDM of Quebec City, Quebec. Construction Injection EDM specializes in shotcrete application, grouting, drilling, and concrete repair. The fact that Construction Injection EDM was already on site, conducting drilling and grouting operations, made them an easy choice to subcontract the shotcrete work.

Construction Injection EDM investigated several options for the supply of the shotcrete material but elected to have a prepackaged, wet-process shotcrete mixture designed and supplied in 2200 lb (1000 kg) bulk bags by King Packaged

Materials Company. This option provided Construction Injection EDM with the flexibility of a high-quality prepackaged material that could be mixed on site, on demand. The prepackaged material (King MS-W1 Shotcrete) contained all preblended admixtures required to meet Hydro-Québec's specifications. The air-entraining admixture provided excellent freezing-and-thawing resistance and the silica fume provided improved adhesion, less rebound, and higher density (for higher compressive strength and added durability). No accelerator was required for this application. The mixture design allowed for application on both horizontal and vertical slopes. Mixing of the preblended material was achieved using a concrete truck, left on site for this purpose.

Several years of experience including projects with the Illinois Department of Transportation, The Ministry of Transportation of Quebec, and other Canadian mining projects provided King Packaged Materials Company with the experience required to perfect the dry to wet production of wet-mix shotcrete. Mixing procedures and mixture design development was completed during several large-scale research and development projects. Custom packaging, designed for use on large-scale, remote, and off-shore projects, allowed the preblended material to be stored on site without concern for moisture ingress that leads to premature hydration of the shotcrete mixture.

The wet-shotcrete mixture design specified by the Hydro-Québec Standardized Technical Specifications was very detailed. Performance requirements are listed in Table 1.

On-site testing in which the dry preblended materials were converted into wet-mix shotcrete was conducted and mock-up panels were shot by EDM's ACI-certified nozzlemen. To ensure qualification of the nozzlemen, Hydro-Québec shotcrete specifications required that all nozzlemen be ACI certified. Hydro-Québec engineers were satisfied with the results of the test panels and approved both the use of the material and the mixing process. The shotcreting operation started during the fall of 2006.

Fig. 2: Wet-mix shotcrete material production from bulk bag into a concrete truck

Fig. 3: Wet-mix shotcrete material discharge from the concrete truck into the pump

Table 1: Wet-Mix Shotcrete Performance Requirements

28-day compressive strength, psi (MPa)	Minimal weight of cement,* lb/yd³ (kg/m³)	Maximum water/ cementitious material ratio	Minimum proportion by weight of 3/8 in. (10 mm) aggregate, %	Air content, † %	Slump, ‡ in. (mm)
5000 (35)	690 (410)	0.40	25	10 to 15	4 ± 1 (100 ± 30)

* Binary Type GUb-SF (Type 1 with silica fume); Ternary Types GUb-F/SF (Type 1 with silica fume and fly ash), and GUb-S/SF (Type 1 with silica fume and slag).

† Air content is measure before pumping. In-place shotcrete has an air content of 5 to 8%.

‡ Slump is measured after the addition of high-range, water-reducing admixture. The tolerance specified is noted for quality control purposes only.

Fig. 4: Wet-mix shotcrete material application on the rock

Fig. 5: General view of the project on the Péribonka River, June 2007
(Photo courtesy of Hydro-Québec)

Fig. 6: Dam is completed and the reservoir is full, May 2008
(Photo courtesy of Hydro-Québec)

The dry, preblended materials were batched in an 10.5 yd³ (8 m³) concrete truck, usually at six 2205 lb (1000 kg) bags at a time (to ensure thorough mixing). The specified water/cementitious material ratio was achieved using a flow meter. This process provided Construction Injection EDM with access to fresh wet-mix shotcrete material during the entire shotcrete process. The use of three concrete trucks allowed them to have a continued, uninterrupted supply of material.

The surface of the bedrock was cleaned using a high-pressure water blast and the shotcrete was shot at a minimum thickness of 4 in. (100 mm). To obtain the required surface profile, some areas were covered by over 3 ft (1 m) of shotcrete. Shotcrete was wet-cured for a period of 7 days.

Quality control was completed daily by a laboratory hired by Hydro-Québec. Air testing was conducted to verify the air content of the fresh shotcrete and panels were shot to monitor the compressive strengths of the in-place product. Throughout the project, results of quality control testing exceeded the minimum requirements of Hydro-Québec.

The Construction Injection EDM crew consisted of a team of 10, including one nozzleman, a helper, a pump operator, three concrete truck drivers, one batcher, one technician, a foreman, and an administrative clerk. It was decided that the project stop during the winter months and the shotcrete was completed in the spring of 2007.

By the end of the project, Construction Injection EDM shotcrete crews had shot over 3800 yd³ (2900 m³) of King MS-W1 Shotcrete including several days in which more than 65 yd³ (50 m³) were mixed and shot. The dry-mix shotcrete process was also used in a ground support application during the construction of the diversion tunnel and the underground power plant.

The Péribonka Hydroelectric Development Project has been operational since July 2008.

Reference

"Devis technique normalisé béton, constituants et exécution des travaux d'ouvrage hydroélectriques," SN-26.1-2000 (révision mai 2005), Hydro-Québec Équipement, Montréal, QC, Canada

***Simon Reny**, Eng., is a Technical Representative for King Packaged Materials Company. His areas of expertise include applications, mixture designs, rehabilitations and durability, new technologies, and equipment for both dry- and wet-mix methods. He received his degree in civil engineering from Laval University.*