



A 22.3-meter (73-foot) plunge cut was made using the wire saw.





Mactaquac Generating Station, New Brunswick, Canada



Parts of the Mactaquac Generating Station were affected by Alkali Aggregate Reaction.

# Stress Relief for Big Dams

## Wire Sawing Relieves Concrete Stress Caused by AAR

Evidence of distress in a concrete dam at a Canadian generating station called for swift action to maintain safe working operations. Investigations determined that the end pier of the dam spillway was cracked internally and the cause of the problem was identified as Alkali Aggregate Reaction (AAR). A contractor was needed that could create large vertical slots through the concrete structure quickly and cleanly.

AAR is a deleterious chemical reaction in hardened concrete. The reaction occurs between reactive aggregates and alkalis in surrounding hydrated cementitious paste. The reaction produces an expansive gel formed at or near the paste/aggregate interface. With concrete at an internal relative humidity of 85 percent at 68 degrees fahrenheit, the gel absorbs water and increases in volume. This gel expansion disrupts the paste/aggregate bond and cracks surrounding paste.

Concrete afflicted by AAR results in expansion, causing increased internal stresses that eventually result in cracking. Many concrete dams and structures throughout the world suffer from AAR. Constant monitoring and continued remedial actions are required at these structures to judge the magnitude of expansions and counteract this expansion and prevent damage to joints or impair gate operation. One such counteraction employed by Mactaquac Generating Station, close to Fredericton in New Brunswick, Canada, is slot cutting concrete with diamond wire to relieve the internal stresses caused by this expansive reaction.



Detail 1

|                                   |  |          |  |
|-----------------------------------|--|----------|--|
| NB Power                          |  |          |  |
| CUTTING EDGE<br>ENGINEERING CORP. |  |          |  |
| DRAWN BY                          |  | CHECKED  |  |
| JLS                               |  | NI       |  |
| DRAWING NUMBER                    |  | REVISION |  |
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| DRAWING TITLE                     |  | Aug      |  |
| Intake 4-5 Slot Cut               |  |          |  |



The Mactaquac Generating Station, owned and operated by New Brunswick Power, is located on the Saint John River approximately 20 kilometers (12.4 miles) upstream from Fredericton. The station is the largest hydroelectric generating facility in the Maritime Provinces. Constructed in stages between 1964 and 1980, the facility has an installed capacity of 672 megawatts produced by six turbines. The facility consists of the intake structure, two concrete spillways, a diversion sluiceway and the intake spillway. Each structure contains five, 14-meter-wide, 16-meter-high (45.9-foot-wide, 52.5-foot-high) spillways.

Distress in the concrete structures at Mactaquac was first noticed in the mid-1970s with the increasing opening of a longitudinal joint in the powerhouse substructure. By the early 1980s, leakage through horizontal joints in the spillway, intake and diversion sluiceway structures was evident. At this point, New Brunswick Power decided to install instrumentation in the foundation rock and within the concrete substructure to check for the possi-

bility of a phenomenon such as rock swelling that may have been the cause of distress.

In 1985, spillway gate 10, adjacent to the intake structure, was found to be obstructed. A differential displacement of the spillway end pier toward the gate opening in excess of 25.4 millimeters (1 inch) was noted. It was at this point that the end pier of the spillway was found to be cracked internally. The cause of the detrimental expansion and subsequent cracking was then identified as AAR.

After the problem of expanding concrete was confirmed, it was decided that slot cuts would be made in the intake structures to relieve deformation of the spillway and piers. The first slot cut was made in 1988 within the intake structure. The slots disrupt the continuity of the adjacent expanding concrete, thereby reducing the magnitude of the deformations pushing at gate openings. Smaller deformations realized in the concrete adjacent to gate equipment resulted in improved operations.

A side effect of cutting the concrete is that cutting reduces confinement or restraint of



The contractor engineered a custom downhole pulley system for the work.



Wire sawing techniques were employed to cut and remove damaged sections of concrete.



the concrete, thereby allowing an increased expansion rate of the concrete. Depending on the width of the slots, re-cutting will be needed in the future to maintain manageable movements that do not interfere with gate operations. Instrumentation located throughout the structures record data that is used to determine the frequency of each re-cut. In general, the intake cuts are made on a three-year cycle, the diversion spillways on a two-year cycle and the powerhouse locations are cut on a six-year cycle. To date, 28 slot cuts have been made at the station. Cuts are positioned to ensure they are below any of the openings and embedded parts that may be affected by the expansion. Below this point, the mass of concrete is continuous. The increase of stress in this area does not cause any damage to concrete joints or moving gates.

CSDA member Cutting Edge Services Corporation of Batavia, Ohio, was contracted to return to Mactaquac and make a 25-meter-deep (82-foot) slot cut in the dam spillway that would range from 12 to 30 meters wide (39.4 to 98.4 feet). The CSDA Certified Company

had already performed wire sawing work at the station and the cutting team was familiar with the task presented.

"We had previously used a "pull" technique to re-open the slot in the diversion dam structure, advancing the saw along its track system to take up slack created by pulling the wire through the structure," said Joe Shebesta, project engineer for Cutting Edge Services. "We also used a "push" technique to re-cut the intake slot between monoliths 4 and 5." Push cutting or "downhole," is done by lowering pulleys into a cofferdam on the upstream face into pilot holes in the deck and by various pulleys located on the downstream face.

The 25-meter (82-foot) slot was cut in stages, from the top down. The first stage pushed the wire into the gallery and close to an active electric cable tray. This cut was carefully monitored to prevent severing of the cables and took approximately eight hours to complete. Then the wire was cut and the cables moved upward. More pulleys were added and the wire was reconnected for completion of the lower stage, taking 20 hours. When the wire reached

the minimum cut depth 25 meters (82 feet), the "down" pulleys were brought up. Cutting of the upstream stage was then performed, using downhole systems in the cofferdam and the pilot hole. The upstream cutting was completed in 30 hours.

Cutting Edge Services used a unique hydraulic-driven machine that was custom fabricated to feed 3.3-meter-long (10.8 feet) sections of aluminum tubing downward. The system is capable of plunging down to a depth of 33 meters (108.3 feet), but was only required to plunge 25 meters (82 feet) on this job.

All cuts at Mactaquac were maintained using 15-millimeter-diameter (0.6-inch) electroplated diamond wire supplied by Norton Pro Diamond. This was a directional rubber injected wire, providing added strength to the wire assembly and minimized breakdown of the wire caused by concrete slurry. The wire was constructed with 40 beads per meter and a 4.9-millimeter (0.2-inch) base cable.

The length of diamond wire used was approximately 100 meters (328.1 feet) and there was lots of contact area with the concrete, so

## What is AAR?

Alkali Aggregate Reaction (AAR) is an internal reaction that occurs when alkalis in cement react with reactive aggregate particles. There are two main types of AAR, alkali-silica reaction (ASR) and alkali-carbonate reaction (ACR). ASR is the more common of the two, and is the type of concrete expansion impacting the structure at Mactaquac Dam. During the process of ASR, a gel is formed around the aggregate. If the gel is exposed to moisture, usually if the relative humidity of the concrete is higher than 80-85%, it expands, causing the concrete mass to expand. The result of this expansion on large concrete structures can be unsightly cracking, although the structural integrity may not be impaired. However, major operation and maintenance problems may occur, such as binding of gates, cracking of piers and misalignment of equipment such as generators.

### Conditions Required for AAR:

High alkali content of the cement  
Reactive aggregate  
High moisture/water

### Remedial Efforts to Control AAR:

Concrete affected by AAR does not continue to expand throughout its useful life. This can be due to loss of moisture, but more commonly from the depletion of alkalis. The chances of a successful repair of structures that continue to exhibit AAR expansion are very low. Structures such as Mactaquac Dam can have its useful life expanded by implementing maintenance programs to alleviate the expansive forces resulting from the effects of AAR.

Since the 1980s, various remedial measures have been performed on the head works at Mactaquac, including:

- Modifications to the gates, guides and towers of the spillway, diversion sluiceway and intakes
- Chemical and cement grouting of the various structures to control leakage
- Reconstruction of bridge deck expansion joints at the spillway and the diversion sluiceway to re-establish eliminated clearances
- Slot cuts



The average speed of the wire saw was 1,200 meters (3,937 feet) per minute.

the average cutting speed was around 1,200 meters per minute (3,937 feet). Pressure on the wire was relatively low to maintain wire speed and deal with concrete slivers and debris in the cut line. Gauge pressure at the power unit was in the range of 2,500-3,000 psi. Connections in the butt joints of wires were monitored and replaced at 2-4 hour intervals and cutting was performed around the clock.

The use of wire sawing techniques increases overall safety, as operators can remain a safe distance from the cutting area and operate the saw by remote control. Cutting Edge Services made sure all operators were equipped with the correct personal protective equipment and tied off when working at height or near large drops.

"Diamond wire sawing systems are ideal for making slots in mass concrete structures. Maintaining slots at Mactaquac Generating Station is an effective way of dealing with expansion of concrete caused by AAR. Continued improvements in diamond wire and equipment technology are increasing the efficiency of performing this work, and it is hoped that we can continue to maintain safety and smooth operations at the station in the future," said Tim Beckman, owner of Cutting Edge Services.

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## COMPANY PROFILE

Cutting Edge Services Corporation has been in business for over 15 years and is based in Batavia, Ohio. Support operations are located in Houston and Seattle. The company offers primary services of engineered solutions, diamond wire sawing, underwater cutting and core drilling. Cutting Edge has been a member of CSDA since 1997, employs CSDA Certified Operators and is Level 1 Certified through the association's Company Certification Program.



## RESOURCES

### Customer:

New Brunswick Power

### Sawing and Drilling Contractor:

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Methods Used: Wire Sawing