2010 Outstanding Infrastructure Project

The Décarie Interchange Side Panel Repair Project

By Patrick Giguère and Philip Sawoszczuk

Highway 40's first segment was built in 1959 in Montréal, QC, Canada. The Décarie Interchange links Highway 40 to Highway 15 and was built between 1960 and 1964. The interchange is in a highly urbanized environment, which necessitated its design as an elevated highway. The complex structure has two main throughways and seven elevated ramps, most of which are two lanes wide without shoulders or about 21 ft (6.4 m) wide. The Décarie Interchange also consists of several smaller structures and covers roughly 0.1 miles^2 (0.26 km^2). It carries over 280,000 vehicles a day and is one of the critical transportation junctions on the Island of Montréal. The cross section of the interchange's deck is in a stepped trapezoidal box girder configuration, making it structurally efficient but difficult to repair using traditional cast-in-place repair methods.

The Project

The interchange was repaired several times during its 46 years of service using form and pump—mostly with limited success. Meanwhile, shotcrete had established an excellent reputation in Montréal, as it had been used to successfully repair various sections of Highway 40 over the last 20 years. A unique element of the structure was the placement of curved polymer panels to protect the underside edge of the interchange deck from the elements. This feature may have been effective originally, but it complicated the repair process, as parts of the panels were fastened to the deteriorated concrete. After several years, the panels failed to protect the concrete and the process of deterioration began to compromise the integrity of the structure. Québec's Department of Transportation (DOT) had the panels removed in 2009 and called for tenders to repair the deteriorated concrete.

Fig. 1: The 46-year-old Décarie Interchange in Montréal, QC, Canada was showing its age

After an initial bid, Teknika HBA, a Trow Global company, was retained as the engineering consultant for the project. Québec's Ministry of Transportation (MTQ) and the retained engineering consulting firm investigated several methods of repair, including form and pump using self-consolidating concrete. A number of factors led to the selection of the dry-mix shotcrete process to repair the structure. These factors included an unusual shape along the edge of the deck, which would be extremely difficult to form and costly to repair. The dry-mix shotcrete process allowed the design engineers to eliminate false work and follow the contour of the original concrete, saving considerable time and money. Furthermore, it allowed for greater flexibility due to the availability of prepackaged materials, which eliminated the need to wait for concrete trucks. In addition, the equipment was smaller and easy to move compared to the equipment used for the form and pump method. The crew was also able to shoot at any time without waiting for the forming crews. A public tender was called to repair the structure and Construction Interlag Inc. was announced as the lowest bidder. The selected company was awarded the contract and assumed the dual role of prime contractor and shotcrete contractor.

Construction Interlag Inc. was responsible for every element of the shotcrete repair. The project required roughly 500 bags of 3300 lb (1500 kg), which is equivalent to approximately

Fig. 2: More than 4600 linear ft (1400 linear m) of repairs were required

Fig. 3: Some repairs went up to 12 in. (300 mm) in thickness

445 yd^3 (340 m^3) of placed shotcrete. The material chosen for the project was the King MS-D1 Shotcrete provided by King Packaged Materials Company. The repairs totaled 4600 linear ft (1400 linear m), with some reaching 12 in. (300 mm) in thickness. In all, the contract was worth close to $2 million CAD.

The repair work was divided into phases to avoid the extra cost of construction during the harsh Montréal winter. The first phase began on August 2, 2009, and ended on November 1, 2009. The second phase began on March 21, 2010, and ended on May 16, 2010. The work consisted of preparing the site, carefully removing the old polymer panels, demolishing the deteriorated concrete, preparing the surface of the repair, applying the shotcrete, finishing it, and curing the material. The flexibility and speed offered by the dry-mix shotcrete process allowed Construction Interlag Inc. to complete 75% of the repairs in the fall and the remainder of the repairs in the spring.

Fig. 4: With more mobile equipment, the dry-mix shotcrete process was preferred

Fig. 5: Netting protected over 280,000 vehicles per day that use the interchange

The Challenges

Construction Interlag Inc. had to deal with several challenges common to transportation infrastructure projects located in heavily urbanized areas. First and foremost, the interchange serves a significant portion of Montréal's traffic and had to remain open during the repair activities. Most of the repair work was below the interchange deck, in open spaces not occupied by roads or highways, which made the placement of the smaller shotcrete equipment and material relatively simple. This notwithstanding, Construction Interlag Inc. was required to keep any stray demolished concrete debris, dust, or shotcrete spray from hitting passing vehicles and potentially causing an accident. Therefore, the MTQ required netting to be placed to shield traffic from the risk of stray material. The installation of the netting used involved fastening steel A-frame supports to the parapets of the interchange. The dark netting was attached to the A-frames and the parapet. Secondly, moving from one end of the site to another in a straight path was impossible, as one would cross several spans of road and highway. Therefore, the work was organized to avoid too much movement. King Packaged Materials Company's shotcrete materials were placed in several locations on site where repair

patches were located; this only required the movement of shotcrete equipment and personnel to the repair section. The material was always well protected from the elements with sufficient packaging and, when possible or necessary, by placing it below the elevated highway. Large infrastructure repair projects are always challenging with regards to public safety, but large structures such as interchanges also create unique environmental conditions.

The Décarie Interchange has hundreds of rectangular columns and a relatively thin deck that is coupled with open spaces located around and beneath its ramps, creating an ideal environment to channel wind and increase its speed. In other words, Construction Interlag Inc. had

Fig. 6: The nozzleman is battling the "wind-tunnel effect"

Fig. 7: A repair zone is blasted to clean the reinforcing bar and the substrate

Fig. 8: Welded-wire steel mesh conforms to the stepped trapezoidal cross section

to deal with the "wind-tunnel effect" as well. Higher wind speeds increased the difficulty in shooting quality shotcrete. A shotcrete mixture containing an excellent gradation, satisfying ACI Gradation No. 2, and including larger aggregates, such as 3/8 in. (10 mm) stone, helped increase efficiency, especially in windy conditions. Furthermore, an air compressor with a sufficient flow rate ensured that the material was travelling at the optimum speed to reduce dust production and rebound, and improve compaction.

The Work

By following ACI 506R-05, "Guide to Shotcrete," and having ACI Certified Shotcrete Nozzlemen, Construction Interlag Inc. was able to overcome the traffic and high winds to successfully repair the Décarie Interchange. The Allentown shotcrete equipment used was of the rotary barrel gun type, coupled with an Allentown predampener and an air compressor. The shotcrete was always shot between 50 and 77°F (10 and 25°C), as specified by Transports Québec. The perimeters of the repairs were saw cut to eliminate feathered edges. Deteriorated concrete was removed, using pneumatic hammers sufficient to remove any deleterious substrate, while minimizing damage to the sound concrete. The unsound concrete was removed leaving a minimum of 1 in. (25 mm) of space behind the first layer of reinforcing bar. The repair surface was cleaned with high-pressure water and sandblasting. A welded-wire steel mesh was securely fastened to the reinforcing bar and anchored to the parent concrete to eliminate vibration during shotcrete application. Prior to the shotcrete application, clean water was sprayed onto the surface to obtain a saturated surface dry (SSD) condition for improved bond strength of the repair.

King Packaged Materials Company's MS-D1 Shotcrete was then carefully applied according to ACI 506R-05, while also accounting for variable environmental factors such as wind and rain. The mixture design met all MTQ requirements, including the specified air void spacing factor of less than or equal to 300 μm, with no singular value exceeding 320 μm, as tested with ASTM C457. The air entrainment of the dry-mix shotcrete was critical on this project to provide superior freezing-and-thawing durability and also a high resistance to scaling caused by deicing salts—two major causes of concrete deterioration in a northern climate. A manlift was used to maintain the optimum distance and position between the nozzle and the repair—that is, between 2 and 6 ft (0.6 and 1.8 m)—and roughly perpendicular. The shotcrete was applied in the optimal number of layers to not exceed the plastic shear resistance

Fig. 9: Applying shotcrete from a distance of 2 to 6 ft (0.6 to 1.8 m)

Fig. 10: The rough finish was achieved with a steel trowel

of the material, thus avoiding fallouts or repair deboning. Good reinforcing bar encapsulation was also carefully executed. The rough finish of the shotcrete repair was done with a steel trowel and the final finish was achieved with a wood float. Finally, a liquid curing agent conforming to ASTM C309 was applied immediately after finishing to ensure adequate curing, as specified by Transports Québec for overhead repairs.

On the Road to Sustainability

Sustainability is of prime importance to the public and the industry. Shotcrete accomplished several positive environmental impacts during the construction with the materials and the energy used. First, the mixture design and specifically the cementitious mixture used in this project replaced part of its portland cement content with a supplementary cementitious material, thus reducing the amount of greenhouse gas emissions generated during portland cement production. Furthermore, this supplementary cementitious material is a waste by-product of other industrial processes that is recycled in the concrete industry, thus reducing landfill waste while still providing beneficial properties to the shotcrete mixture. False work and formwork, which require wood and steel, were practically eliminated; therefore, sustainability reduces the use of these materials. Careful effort during shotcrete application was also used to reduce dust production and rebound waste. In fact, Construction Interlag Inc. collaborated closely with the shotcrete mixture manufacturer, King Packaged Materials Company, to optimize the mixture to minimize dust formation. Finally, and most importantly, the shotcrete repairs extended the service life of the Décarie Interchange significantly, thus reducing the need to demolish it and build a new interchange. In addition, the increased durability of the shotcrete material will extend the time before future repairs are required, thus reducing resource use for future maintenance. It is clear that shotcrete contributed in many ways to the sustainability of the Décarie Interchange Repair Project.

Shotcrete for Today and Tomorrow

By carefully following the appropriate standards and procedures, Construction Interlag Inc. built a safe, economical, sustainable, and durable infrastructure repair project while overcoming several environmental challenges using the dry-mix shotcrete process in Montréal, QC, Canada. A key factor in the success of the project was the close collaboration between Construction Interlag Inc., Teknika HBA, Transports Québec, and King Packaged Materials Co. The Décarie Interchange Repair Project was not only an excellent example of shotcrete infrastructure repair and a practical demonstration of the sustainability of shotcrete, but it also ensures that shotcrete will have a bright future for many years to come.

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Project Name
Décarie Interchange Side Panel Repair

Project Location
Montréal, QC, Canada

Shotcrete Contractor
Construction Interlag Inc.

General Contractor
Construction Interlag Inc.

Architect/Engineer
Teknika HBA

Material Suppliers/Manufacturers
King Packaged Materials Company* and Allentown Shotcrete Technology, Inc.*

Project Owner
Ministry of Transportation, Québec

*Corporate Member of the American Shotcrete Association

***Patrick Giguère**, P.Eng., is a Project Manager and Estimator for Construction Interlag Inc. His areas of expertise include structural and road rehabilitation. He has over 15 years of experience in the industry and received his degree in construction engineering from Écoles de Technologie Supérieur, Montréal, QC, Canada.*

***Philip Sawoszczuk,** Jr. Eng., is a Technical Services Representative for King Packaged Materials Co. His areas of expertise include the rehabilitation and preservation of infrastructure, structural engineering, and durability of concrete. He received his degree in civil engineering from McGill University, Montréal, QC, Canada.*