Shotcrete for Structural Repair of Key Light Rail Facility in Boston

by Henry A. Russell Jr.

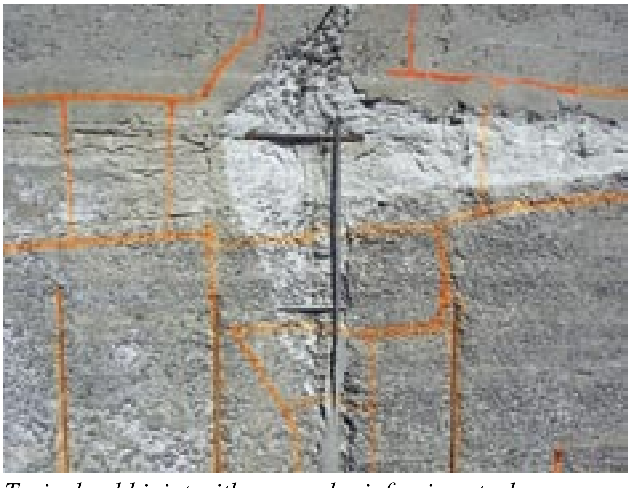
In 1922, the Boston Transit Commission built Shawmut Junction, a flyover located in Boston, MA. The flyover provided an overpass for the street car line connecting Mattapan, MA, with downtown Boston. The flyover was also located on the edge of an active cemetery. The structure is a box overpass with long abutment walls for the approaches for the rail line. The Flyover was constructed of cast-in-place concrete, mixed on site, and was not air entrained (air entrainment was introduced in the 1950s). The concrete structure had numerous cold joints and has deteriorated over the years.

In the early 1990s the railroad was abandoned and the rail tracks became a jogging and bike path. During recent inspections it was noted that the structure was in poor condition with extensive spalls, delaminations, and severe cracking. The Massachusetts Bay Transportation Authority (MBTA) retained Parsons Brinckerhoff Quade & Douglas Inc. to evaluate the structure and recommend either replacement or repair. The project had numerous restraints on the design. They included the requirement that the streetcar service could not be shut down, and that the jogging path could be closed for a period of only 4 weeks. In addition to these restraints, the Cedar Grove Cemetery also required "quiet times" during funeral services.

The inspection indicated that the structure was in very poor condition. In numerous places the reinforcing steel was exposed, and on the western side of the flyover the structural beams supporting the track had virtually lost their supporting seats. In addition to the severe deterioration of the floor beam concrete, the abutment retaining walls had extensive delamination and

Shawmut Junction

Typical deterioration of the supporting floor beams on the western side of the flyover



Typical cold joint with exposed reinforcing steel. Orange paint indicates limits of delaminations spalling. The delaminations appeared to be concentrated in the vicinity of construction cold joints that had experienced leakage. At many of these locations, the reinforcing steel was exposed. Approximately 50% of the structure required repairs.

The simplest solution was to remove and replace the flyover with a new concrete flyover. However, based on the condition survey and an analysis of the structure, it was determined that the flyover could be repaired by either cast-in-place form-and-pour concrete or by the use of dry process shotcrete.

Based on the restraints for rail operations, jogging path, and the cemetery, it was decided to repair the structure using a high-performance shrinkage-compensated, synthetic micro-fiber-reinforced, prepackaged shotcrete applied by the dry-mix shotcrete process. The selection of shotcrete over cast-in-place form and pour concrete was selected because clearances for the jogging path prohibited the use of forms. It was further decided to use hydrodemolition to remove the unsound concrete. The areas to be repaired were identified at the beginning of the project by sounding and were marked out with orange paint.

Hydrodemolition using 30,000 psi (207 MPa) water pressure was selected due to the ability to control the removal of unsound concrete and minimize the period of time required for surface preparation. The specifications required the use of a robotic machine to remove the unsound concrete. The use of a robotic machine facilitates rapid concrete removal while minimizing the quantity of water required. In areas where the robotic machine was unable to reach, hand wand hydrodemolition equipment was used. The hydrodemolition equipment also removed all rust and scale from the existing reinforcing steel. The water used for the demolition was recycled and reused.

The robotic machine was calibrated on site to remove only the concrete with strength of less than 2000 psi (14 MPa). During the project, the extent of delaminations was greater than originally expected and, in some cases, repairs were as deep as 10 in. (254 mm).

The design required the reinstatement of the structural integrity of the flyover for a design life of 50 years. The repair had to be compatible with the existing substrate. The design called for the cleaning of the reinforcing steel and replacement of any reinforcing steel with 30% or more loss of cross-sectional area. In order to assure a monolithic repair welded wire fabric (mesh) was used for the repaired areas. The welded wire fabric was galvanized after fabrication to protect it from corrosion. In addition, there were concerns about corrosion due to the

Hydrodemolition robot preparing to remove unsound concrete

Hydrodemolition robot removing unsound concrete

Deep repair after removal of unsound concrete


Final surface preparation


Shotcrete machine with prepackaged shotcrete


Installation of shotcrete over welded wire mesh at test section

creation of a galvanic cell between the new concrete and the existing structure. Therefore, the design required the use of galvanic corrosion inhibitors to be attached to the welded wire fabric approximately 30 in. (762 mm) on center around the perimeter of the repair and in the interior in areas of large repairs.

After hydrodemolition, the surface was cleaned with a high pressure power washer and the welded wire mesh and corrosion inhibitors were installed.

Proper surface preparation of the substrate was critical for proper bond of the shotcrete. The power washer was also used to premoisten the substrate. A dry process Reed Shotcrete gun with a 175 CFM compressor was used to apply the shotcrete. The majority of the work was performed from a man-lift.

The design required strict quality control and a shotcrete that would be shrinkage compensated and produce a high compressive strength due to the rail loadings on the structure. A prepackaged shrinkage-compensated, synthetic micro-fiber-reinforced, cement-based shotcrete was selected for the project. The material had the qualities shown in Table 1.

The high initial strength was required since the flyover was in constant use during the progress of the project and the demolition and shotcrete placement was phased to minimize any potential weakening of the structure as a result of concrete removal and replacement. Synthetic micro fibers were used to assist in reducing the potential for shrinkage-induced cracking and to improve the fire protection of the structure. In addition, there was a concern about dust generation and rebound from the operations. Based on our experience on numerous other projects the material selected for the project was U.S. Concrete Products 7101 D. The prepackaged material was provided in 50 lb (13.5 kg) bags and was delivered to the job on a daily basis to minimize impacts to the recreational use of the jogging path.

In conclusion, the selection of shotcrete for the subject project was the most economical and practical solution for the structural rehabilitation of the Shawmut Junction flyover. The work was satisfactorily performed within the extensive access and time limitations of the project, with no interference to rail operations or the jogging path. In addition, the project accommodated the Cemetery's requirement for the "quiet times" during funerals, which occurred at least twice a day. The use of prepackaged shotcrete was cost effective and is expected to provide the MBTA with an additional 50 years of design life for the structure. The project required the use of 5000 ft³ (142 m³) of shotcrete that was placed during a period of three weeks without requiring the rail

Table 1

Properties	1 day	7 days	8 days
Compressive Strength (ASTM C 109)	4000 psi (28 MPa)	7500 psi (52 MPa)	8000 psi (55 MPa)
Flexural Strength (ASTM C 348)	500 psi (3.4 MPa)	1000 psi (6.9 MPa)	—
Tensile Splitting (ASTM C 496)	700 psi (4.8 MPa)	700 psi (6.2 MPa)	—
Unit Weight	Less than 135 lb/ft^3 (2162 kg/m^3)		
Initial set time	2 hours		
Final set time	4 hours		

operations to be interrupted. Shotcrete provided a successful solution to a challenging remedial project and a satisfied owner.

Final finishing of the shotcrete repair. Note the 8 in. depth

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