

Outstanding Shotcrete Project Award Winner

2007 Outstanding Underground Project

The MBTA Red Line Emergency Repairs

The Massachusetts Bay Transportation Authority (MBTA) is the operator of the Red Line Subway in Boston, MA. The Red Line connects the suburbs to the south side of Boston, the downtown Boston area, and the north side of Cambridge, MA. It is a major commuter link carrying over 200,000 passengers during a 20-hour operational schedule. The Red Line is approximately 17 miles (31 km) in length with 9 miles (17 km) of tunnels.

The tunnel system consists of three tunnels located in Cambridge, Dorchester, and downtown Boston.

Parsons Brinckerhoff (PB) was retained by the MBTA to establish an asset management program for the tunnel systems and, in particular, to evaluate the condition of the Red Line tunnels. The asset management program included the documentation of the mechanical, electrical, and structural elements of the tunnels.



Typical delaminations on Red Line tunnel at B Street



The bus transportation that was provided during tunnel shutdown



Delamination in arch of tunnel lining



The access location at JFK Station for high rail equipment

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During the visual inspection of the tunnels, it was noted by PB that a section of the Boston tunnel had severe delaminations and spalling in the vicinity of the B Street exit in South Boston. The delaminations and spalls were located in the roof and arch of the tunnel and posed a significant safety risk to the revenue trains. PB performed a “sounding” survey where the concrete surfaces were sounded with hammers to identify the extent of the delaminations. This survey indicated that there were approximately 4000 ft² (372 m²) of delaminations. The MBTA was notified, an emergency meeting was held, and a slow train operation order was initiated to minimize the potential risk to the revenue trains.

Within a week of the initial identification of delaminations, a contractor was given a work order and, under the direction of PB, was to mobilize equipment and personnel to remove the delaminations over the next weekend, which happened to be the weekend before Christmas 2006.

On the weekend of December 16, 2006, the Red Line operation was shut down between Broadway Station in South Boston and Ashmont Station in Dorchester. The unusually heavy passenger load, due to pre-Christmas shopping, was placed in busses that followed the route of the tunnel. The tunnel shutdown started on Saturday morning at 1:00 a.m. and was to be returned to operation on Monday morning at 5:00 a.m.

Access to the tunnel was from JFK Station in Dorchester, approximately 1.6 miles (2.6 km) from the work site and approximately 1/2 mile (0.8 km) south of the south portal of the Boston tunnel. This site was the closest location for placing the high-rail vehicles on the track. Prior to the placement of the high-rail equipment on the track, the power to the third (contactor) rail was shut down and properly tagged and locked out according to Occupational Safety & Health Administration (OSHA) requirements. In addition, a shield was placed over the third rail in the work area for protection from falling concrete.

PB identified the location of the delaminations prior to the arrival of the work crews who removed the delaminated concrete by the use of pneumatic chipping hammers, with laborers working from manlifts mounted on high-rail vehicles. To avoid the removal of sound concrete, the demolition work was performed using chipping hammers that weighed 30 lb (13.6 kg) including the bit. This limitation was to limit the amount of energy required to remove the unsound concrete while leaving in place concrete in excess of 3000 psi (21 MPa) compressive strength. In addition to the



High-rail equipment during removal of delaminations



Close-up of delaminated area after removal of the delaminations

roof and arch work, delaminated areas of concrete in the vicinity of the work were also removed.

On Sunday night at midnight, the removal of the delaminations was complete and all equipment was removed from the site via the access point at the JFK Station. The immediate safety issue was removed and PB was directed to develop repairs to the tunnel liner to restore it to its original condition.

The Red Line Boston Tunnel was built in 1912 to 1918; and at the B Street location, there was a cut-and-cover reinforced concrete box structure. The concrete compressive strength (F_c), due to the age of the tunnel, was between 5500 to 6500 psi (38 to 45 MPa). The restoration of the liner was required to restore the concrete to the original design lines. During PB's investigation of the delaminated areas, it was noted that the reinforcing steel was still in good condition with minimal loss of section.

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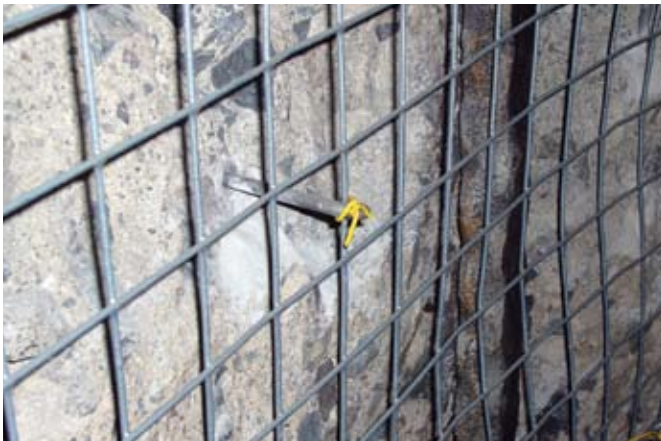
Due to the close clearances between the operating envelope of the Red Line trains and the concrete structure, the use of a traditional form-and-pour method of concrete placement was not feasible. To return the tunnel to operational use, it was necessary to minimize any dust generation from being pushed through the tunnel to the stations during operating hours.

Based on PB's experience in the restoration of tunnel liners, it was determined that a prepackaged polymer modified nonshrink wet process shotcrete with polypropylene fibers would provide a rapid installation; and the replacement shotcrete would add additional strength and fire resistance to the tunnel liner. The design called for the use of sacrificial corrosion-inhibiting anodes to be placed within the areas to be repaired and additional welded wire mesh, installed with J-hook anchors, to assist in the buildup of the shotcrete and to provide for a monolithic repair.

Between January 1 and February 18, 2007, the delaminated areas were prepared for the application

of shotcrete. The welded wire mesh was placed with J-hook anchors every 18 in. (457 mm) on centers and the reinforcing steel cleaned of all loose rust and scale. While the contractor was preparing the site for the shotcrete application, PB coordinated with the MBTA for storage of the prepackaged shotcrete in a heated warehouse. This was necessary to condition the materials because the shotcrete application was to be carried out during Presidents Day in February. The MBTA allowed the material to be delivered early and stored in the Red Line car repair shops. Coordination was also required between the distributor and the manufacturer of the shotcrete to arrange delivery times that met the MBTA schedule and available space in the car shop.

Early in February 2007, the nozzlemen to be used on the project were certified for use on the project by the MBTA Quality Assurance Laboratory and PB. This was done at the contractor's yard in a warehouse with similar temperatures to those anticipated on the site during installation. Mockups



Typical spall repair detail with galvanized welded wire and J-hook anchors



A shotcrete nozzleman certification test section



Shotcrete storage in MBTA Red Line car repair shop



Shotcrete being unloaded from railcars at shotcrete machine

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were made for overhead and vertical application of shotcrete and the chosen shotcrete material was to be placed using the Allentown Shotcrete Technology, Inc., shotcrete machine that would be used on the project. The test panels were taken to the MBTA lab and tested prior to the start of the placement of the shotcrete in the tunnel.

On the weekend of February 18, 2007, the Red Line was once again shut down and the passengers were ferried by bus around the work area. The contractor mobilized his forces and the power was shut down. The shotcrete was transported to the JFK site from trucks to rail cars and sent into the tunnel in two pallet loads. Once the pallet loads arrived, they were mixed on site and sprayed using manlifts mounted on high-rail vehicles.

The application of the shotcrete was performed in 30 hours using one machine and three nozzle men. The quantity of the shotcrete placed was 1000 ft³ (28 m³). After the placement of the shotcrete was completed, the tunnel was returned back to service ahead of schedule and revenue service resumed early on the holiday.

This project was a success due to the excellent cooperation of the MBTA operations crew, the MBTA Construction Department, the manufacturer

and distributor of the materials, the contractor, and the designer. All individuals worked as a team to alleviate a safety hazard and restore the tunnel liner to its original condition with minimal disturbance to the passengers of the MBTA.



Applying shotcrete to tunnel arch



Applying shotcrete to tunnel walls



Completed shotcrete placement on walls and arch

Outstanding Underground Project

Project Name

MBTA Red Line Emergency Repairs

Project Location

Boston, MA

Project Owner

Massachusetts Bay Transportation Authority
Domenic Anidi, PE, Project Manager

Architect/Engineer

Parsons Brinckerhoff
Henry A. Russell Jr., PE, Project Manager

Shotcrete Contractor

Jaycor
Steve Jacobs, Project Manager

General Contractor

J.F. White Contracting Corporation
Kevin Cole, Project Manager

Project Distributer

J Mac Building Specialties
Jim Macozek, President

Material Supplier

U.S. Concrete Products*
Ed Brennan, President

**Member of the American Shotcrete Association*