

Shotcrete—The Repair Solution for the Memorial Tunnel

by Henry A. Russell

In 1953, the Memorial Tunnel in Standard, WV, was constructed as a two-lane, 2800 ft (853 m) tunnel with semi-transverse ventilation. The owner operated the tunnel until the mid-1980s when a four-lane bypass was constructed to upgrade the turnpike to current Interstate standards. The tunnel was abandoned until 1989 when the Federal Highway Administration (FHWA), in conjunction with the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), embarked on the Tunnel Fire Ventilation Test Program using funding from the Central Artery Project.

The test program consisted of performing controlled test fires up to 100 megawatts. These intense fires then provided valuable information for the design of ceiling wall partitions and the protection of facilities for power, ventilation, and lighting. In addition, it provided the opportunity to develop and evaluate methods of proper ventilation control of a tunnel under various fire scenarios.

Parsons Brinckerhoff was retained to perform the test program. As part of that test program, an evaluation of the structural condition of the tunnel was performed and structural repairs were designed. A critical part of the design was to insulate structural portions of the tunnel for temperatures in excess of 2000 °F (1143 °C).

The rehabilitation program for the reuse of the tunnel required the sealing of all cracks in the tunnel liner because the bedrock around the tunnel contained low-flashpoint cannel coal. In addition to sealing the cracks, extensive structural rehabilitation of the liner was performed to repair damage caused by the excavation for the bypass on the adjacent highway. Numerous products were evaluated to determine which would provide suitable fire protection for the structural elements of the ceiling and for mechanical equipment anchorages. The test program included the use of traditional ventilation with a tunnel ceiling and tests with the ceiling removed for the use of jet fans. The construction contract for the rehabilitation of the tunnel and the removal of the ceiling had a projected cost of \$10 million.

During the test program of 98 fires, routine inspection of the tunnel was performed to evaluate the performance of the fireproofing. Based on the performance of certain structural elements, changes were made in the use of structural fireproofing and code requirements for the protection of equipment. After the test program in 1991, the



East portal of Center for National Response (Memorial Tunnel)

tunnel was once again abandoned. This work was performed by Brinckerhoff and managed by Henry Russell. (Many of the lessons learned during this test program were included in the current International Tunneling Association [ITA] document on “Guidelines for Structural Fire Resistance for Road Tunnels” as edited by Henry A. Russell).

In 2000, the Department of Defense (DOD) expressed an interest in establishing a training site for management and counterterrorism training. The Memorial Tunnel was once again considered for the site of a training facility. Titan Corporation was retained as the facility operator with Brinckerhoff being the Engineer of Record for the rehabilitation of the tunnel. Brinckerhoff was retained to assist the operator in maintaining the structure and the design of the training mockups.

Today the Center for National Response serves as a training facility for first responders, local fire and rescue departments, law enforcement organizations, and various federal agencies including the DOD. The training center is used for counterterrorism training related to hazardous materials, highway, transit, and all underground structures including related explosive and collapse incidents. Please refer to the website for more details: www.centerforationalresponse.com.

The extensive fire testing required that structural changes be made to the structural liner, the ventilation buildings, and the tunnel itself. An in-depth condition survey was performed and, based on that survey, a prioritization of repairs was made for the structural rehabilitation of the tunnel.

Late in 2000, the operator went into an extensive training program requiring full utilization of

the tunnel. After September 11, 2001, the center was directed to conduct wide-ranging training programs. This necessitated development of a structural repair program that would not interrupt training operations.

The rehabilitation program required over 3600 ft³ (102 m³) of fiber-reinforced, shrinkage-compensating shotcrete to be applied on the interior of the tunnel to reestablish the structural support for the tunnel arch. In addition, over 1700 linear ft (518 m) of crack sealing for groundwater control and the waterproofing of the north portal area of the tunnel was performed.

Because the tunnel was now fully utilized, the repair contract required completion of the structural repairs within the last three weeks of January 2003 to maintain the DOD training programs. In a 3-week period in November 2002, the contract was developed and the bid package prepared. Based on its experience and qualifications, Brinckerhoff reviewed the bids and selected the bidder.

The successful bidder was Coastal Gunite Construction Company of Cambridge, MD. US Concrete Products of Baltimore, MD, manufactured the special prepackaged shotcrete as well as the cementitious waterproofing. DeNeef Construction Chemicals was selected to supply the material for the groundwater control. Extremely close coordination was required to have the total amount of the shotcrete, cementitious waterproof coating, and chemical grout on site on January 2, 2003. This coordination required rapid submittal, approval, and turnaround of shop drawings and an iron-clad commitment by the material suppliers to meet the schedule. The work started on January 3, 2003, and was finished within two weeks, one week ahead of schedule. The early completion allowed for the facility to be turned over to the operator ahead of the specified deadline.

The use of shotcrete was the only option for the owner to have over 3600 ft³ (102 m³) of repair material applied within this very tight schedule. Hand applying or forming and pumping the repair material would have added weeks to the schedule, creating an unacceptable delay in training.

Brinckerhoff specified the use of preblended material meeting specific performance criteria. The material specified contained fibers for shrinkage compensation and additional flexural and tensile strength. The material was also specified because of its low permeability, strength, and very low rebound. Rebound was less than 10% for this particular overhead application. In addition, Brinckerhoff and the tunnel operator required close control of dust and rebound during installation to minimize contamination to equipment and vehicles stored in the tunnel.

Using dry-processed, preblended shotcrete in bulk bags, Coastal Gunite went to work. First, the entire surface was prepared to the engineer's specifications. Application of the repair material



Counterterrorism training



Highway incident training area



Subway section training area



Collapsed tunnel training area

followed. Using a predampening system, the shotcrete was applied overhead to a nominal 3 in. (75 mm.) thickness in less than 10 days. The combination of experienced, certified nozzle men, careful surface preparation, and specific material selection kept the dust level to a minimum. Measured rebound for the overhead work was less than 10%.

This project was unique because this underground space has had three unique uses after being abandoned twice. The last rehabilitation required a fast-track effort between the owner, operator, design engineer, manufacturers, and contractor to provide a successful project on time and within budget. The cooperation between all parties

was exceptional and a vital element of Homeland Security was maintained with no delay in training.

The Center for National Response (Memorial Tunnel)

Location

Standard, WV

Owner

The Department of Defense
(West Virginia National Guard)

Operator

Titan Corporation

Project Engineer

Parsons Brinckerhoff

Project Manager

Henry A. Russell, P.E.



Henry A. Russell, P.E., is a Principal Professional Associate with 32 years of experience in Geotechnical Engineering and more than 20 years of experience in the inspection and

rehabilitation of underground structures. He is a Registered Engineering Geologist and Geotechnical Engineer and the Technical Director for the Rehabilitation of Underground Structures. Russell's project work includes the field investigation and rehabilitation design of underground structures throughout the world. Russell has authored numerous publications, including "The Rehabilitation of Boston's Green Line Tunnel, published in Concrete International, February 1992; and "The Policy and Procedures for the Inspection of Transit Rail Facilities, TCRP Report 24," published by the Transportation Research Board, 1996. He is the Chair of the American Society of Civil Engineers (ASCE)/ American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) Committee on Tunnel Rehabilitation, and of the International Tunneling Association's Committee on the Maintenance and Repair of Tunnels, and a member of the Moles. Russell's current assignment is in the Boston office of PBQ&D, where he is the Area Manager for the New England District's Geotechnical Service Center.