Innovative Shotcrete Application Over Geofoam Structure Supporting Boston's Central Artery Tunnel

by David Jamieson

The objective of Boston's Central Artery/Tunnel (CA/T) Project is to ease the congestion of approximately 190,000 vehicles per day traveling through the city of Boston. This objective is being achieved through the total reconstruction of Interstate Highway I-93 as it passes through the heart of Boston, together with the extension of Interstate I-90 from its terminus at I-93 just south of downtown Boston to Logan International Airport in East Boston. The Artery replaces an elevated six-lane highway that opened in the late 1950s and originally carried approximately 75,000 vehicles per day. The focus of this article is on two transition structures and ramps in the C09C2 Construction Contract: the I-93/I-90 Interchange Ramps and Surface Restoration at Albany Street, where shotcrete facing has been implemented as a facing system for lightweight embankments.

The Challenge

As an outcome of a cost and schedule initiative, at the suggestion of the Federal Highway Administration (FHWA), an alternative solution was selected by CA/T project management for final design for most of the transition structures and ramps on the C09C2 Construction Contract. The design alternative called for constructing highway embankments using lightweight fill material consisting of blocks of expanded polystyrene (EPS) referred to generically as EPS geofoam.

Prior to implementing EPS, bridge structures requiring deep foundations extending to the underlying bedrock had been selected for the original design of the C09C2 structures. These structures included prestressed, precast concrete girder bridges and cast-in-place (CIP) reinforced concrete elevated slabs with precast curtain walls on both sides. After EPS was selected to replace the concrete bridges, the precast wall panels on the vertical sides of the embankments were not required to structurally support the EPS blocks and would have functioned basically as architectural elements performing an aesthetic function. With a thickness of 5 to 6 in., such wall panels would have also been relatively massive, and in most cases could not have been supported by the EPS blocks, thus requiring their own foundation. Under poor soil conditions, such a facing system may have required deep foundations such as piles and drilled shafts.

Proposed Solutions

The exposed sides of an EPS structure must be covered to prevent long-term surface degradation and incidental damage of the EPS, in addition to providing an architectural finish. An alternative was chosen for the facing system of the EPS embankments involving the use of what is called Exterior Insulation and Finishing System (EIFS). EIFS, often referred to colloquially as synthetic stucco, is a well-proven technology that has been used on buildings worldwide for decades. The CA/T Project design team, on behalf of the CA/T owner, the Massachusetts Turnpike Authority (MTA), developed a project-specific specification for the EIFS panels based on extensive research into existing EIFS standards from the American National Standards Institute (ANSI) as well as model specifications provided by several EIFS manufacturers in the United States. As best can be determined, EIFS had never been used previously for an EPS fill on a highway project, although it was suggested at a symposium on EPS geofoam as far back as 1993.

As project deadlines approached, however, some technical details had yet to be finalized on EIFS submittals. The scheduled Northbound opening of I-93 in February 2003 required two of the eight EPS transition structures on the C09C2 contract to carry traffic sooner than the outstanding EIFS technical details could be addressed.

Shotcrete Innovation

The Aulson Company of Methuen, MA, collaborated with project engineers at Bechtel/Parsons Brinckerhoff, managing engineering consultants to the MTA, and delivered an innovative solution for essentially covering approximately 10,000 ft^2 of EPS blocks using dry-mix process shotcrete. Working with CA/T Bridge Department Engineers and Architects, Aulson developed an effective system for preparation of the EPS substrate and

Fig. 1: Aulson ACI certified nozzlemen apply shotcrete to 4 ft test panels of EPS and wire mesh attached with bolster bars.

application of shotcrete. This system satisfied all project requirements including: fire resistance, weather and moisture proofing (due to direct adherence with the EPS material), aesthetic continuity, defacement resistance, cost-effectiveness, and completion within a short one-week time frame.

System/Process Test

Four-ft. test panels of EPS block were prepared for a system mockup and dry-mix process shotcrete (Fig. 1) was applied to the EPS blocks at a rate of 400 ft per s. The mockup assembly was evaluated for proper thickness, texture, color, and adherence. The test concluded that the system performed optimally and met or exceeded all specifications.

Project Implementation

Once testing was complete and the system was approved for use, Aulson personnel performed the following process to create a permanent exterior wall/facing system at the Central Artery Tunnel for ramps CC and KK.

EPS Preparation

Recessed notches measuring 1.5 x 1.75 in. were etched with a heat-welding gun every 12 in. along the permanent face of the EPS structure, in preparation for shotcrete adhesion (Fig. 2 and 3).

Wire mesh was attached to epoxy-coated bolster bars supported by epoxy-coated chairs using vinyl-coated wire ties (Fig. 4).

The mesh was then fastened to the EPS structure with Olympic NTB-2H glass-filled nylon fasteners including built-in 2 in. stress plates (Fig. 5). Hook bolts were used to attach the wire mesh to the permanent CIP concrete barrier along the top of the EPS structure.

Shotcrete Application

Specifications required that the contractor provide a controlling device to ensure that the thickness of the shotcrete be limited to 2 in. from the face of the EPS to satisfy durability and fire resistance requirements. Aulson met the specification by using guide wires on a turnbuckle system,

Fig. 2: 1.5 x 1.75 in. recessed notches are etched into EPS with heat-welding gun every 12 in., in preparation for shotcrete adhesion.

Fig. 3: Closeup view of recessed notches.

Fig. 4: Wire mesh is attached to epoxy-coated bolster bars with epoxy-coated chairs and vinyl coated wire ties, in preparation for attachment to EPS block.

Fig. 5: Olympic fasteners are used to fasten wire mesh to EPS block.

enabling control of shotcrete depth by shooting to the wires and cutting with a cutting rod.

Aulson ACI Certified Nozzlemen applied a 2 in.-thick layer of dry-mix process shotcrete at 400 ft per s (Fig. 6) over the approximately 10,000 ft^2 wall of EPS block.

Joints

Construction joints were created where the top of the EPS structure met the concrete slab above, parallel to the roadway and vehicle barrier grade. Joints were specified to be 3/4 in. deep and 1/4 in. wide, with appropriate backer rods and a one-part polyurethane sealant.

Expansion joints were created at every seventh vertical construction joint (± every 70 ft). These joints were specified to be 1/2 in. wide and cut through the full depth of shotcrete and mesh. A 45-degree chamfer was used on each side (Fig. 7 and 8). A level and straightedge were used to ensure a vertical line in the extremely dense shotcrete surface before saw-cutting with a diamond blade. Backer rods and polyurethane sealant were installed at each joint. Where the shotcrete installation met permanently exposed CIP concrete—at abutment walls, the underside of barrier shape, and similar intersections—a formed expansion joint was installed in the concrete with a temporary 3/4 in. batten to the full depth of the shotcrete. After shotcrete installation, the batten was removed and backer rods were placed and covered with sealant.

Fig. 6 (above): Aulson ACI certified nozzlemen apply 2 in. of shotcrete at a rate of 400 ft per s over EPS block.

Fig. 7: Aulson crews use a level and straight-edge to ensure vertical alignment in the extremely dense shotcrete surface before saw-cutting expansion joints every 70 ft with a diamond blade.

Fig. 8: Steel is attached to shotcrete face to ensure straight edges on expansion joints.

Aesthetics

Pressure washing was performed to prepare the shotcrete for final finishing. Two coats of a polymer-modified cementitious material were applied, creating an aesthetic appearance similar to rubbed concrete (Fig. 9 and 10).

Fig. 9: Pressure washing was performed before application of concrete refacing.

Fig. 10: A polymer-modified cementitious material was applied in two coats to create an aesthetic appearance similar to rubbed concrete.

Conclusion/Results

This innovative shotcrete solution enabled the Massachusetts Turnpike Authority to fulfill all project requirements and open the Central Artery Ramps on schedule. The Aulson Company also earned other Central Artery Project contracts for specialty services, including ultra-high-pressure water jetting and removal of asbestos, lead paint, and contaminated soils.

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