Shotcreting the East Side Access Program

Architect/Engineer: New York Metropolitan Transportation Authority Capital Construction

By Frank E. Townsend III

Prior to 9/11, all structural wall and tunnel concrete applications in New York, NY, used the form-and-pour concrete placement method. During this time, the dry-mix shotcrete process was being used in marine and bridge repair projects by Eastco Shotcrete throughout the region. The wet-mix shotcrete process was also being used in underground applications, primarily for initial smoothing of tunnel surfaces as a substrate for the sheet waterproof membranes. With support from George Yoggy and Bill Drakeley, Superior Gunite was brought to New York City (NYC) to help on a contract for the World Trade Center Reconstruction. The site was heavily congested with contractors and access from cranes was difficult due to the limited space. This project was extremely successful as Tutor Perini used Superior Gunite to stayform and shoot all the walls, hence eliminating carpenters, formwork, and crane time. The project came in under time and budget. From here, NYC was introduced to the wet-mix shotcrete process as an alternative to form-and-pour methods. Following this project, Superior Gunite had several other projects for the NYC Port Authority at the World Trade Center site assisting six different contractors with shotcrete placement in time-sensitive and difficult forming situations.

CM9 and CM19 Contracts

Superior Gunite was brought in to help on the Metropolitan Transportation Agency's (MTA) East Side Access project working on the four "well-ways" in the excavation contracts CM9 and CM19. The East Side Access project brings the Long Island Railroad into Grand Central Terminal and included dozens of separate construction projects. This project also adopted the term "pneumatically applied concrete" (PAC) in lieu of "shotcrete" to differentiate structural shotcrete placement in underground work from MTA's existing "shotcrete" specification that was geared exclusively towards smoothening shotcrete. PAC is shotcrete and complies with ACI's definition of shotcrete as concrete placed by a high velocity pneumatic projection from a nozzle. Though the term "pneumatically applied concrete" has been around for over 100 years and generically included the shotcrete process, the intent of MTA's PAC specification was to specifically include only the modern shotcrete placement materials, equipment, and techniques that meet the requirements for structural liner applications and to clearly distinguish it from smoothening shotcrete. PAC was used on the well-ways, which were inclined tunnels in rock and designed to house the access escalators. These well-ways were performed in a fraction of the time and cost of forming and placing these elements. After the well-ways were completed, word spread throughout the NYC construction community that the shotcrete process provided major efficiency and cost savings to the East Side Access program.

CQ39 and CQ32 Contracts

Following the well-ways, Superior Gunite was awarded the CQ39 project to shoot a 125 ft (38 m) long sequentially

Fig. 1: East Side Access overview schematic
(Photo courtesy of Evan Mason, CC BY-SA 3.0)

Fig. 2: CQ39 Tunnel section, prior to cutting out support columns

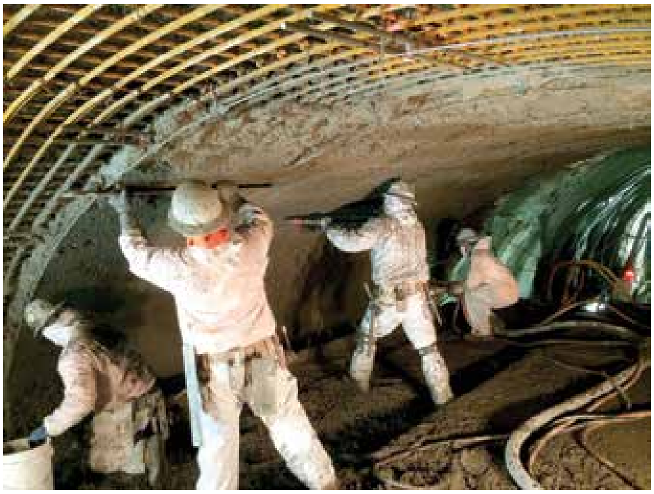

Fig. 3: Finishing at CQ39, cutting out pencil rod and starting to float

Fig. 4: First layer of shotcrete at CM006 showing scratch finish prior to installation of inside face reinforcing bar

excavated (SEM) tunnel between two 85 ft (26 m) deep access shafts. The tunnel was situated approximately 55 ft (17 m) below the water table and required freezing of the surrounding soils. A value engineered approach was given to the MTA to shotcrete this liner in lieu of the traditional form-and-pour method. This offered both savings in time and construction cost. Superior Gunite's scope was to expeditiously shoot the structural liner in 5 days, and then to quickly thaw the ground and transfer the load from the above ground structures. The tunnel was a 3 ft (0.9 m) thick structural liner with ring girders to help carry the load from above. Superior Gunite shot 1463 yd^3 (1119 m^3) of concrete in 4.5 days with a good portion of the placement in the overhead position.

Adjacent to CQ39 was CQ32, an 85 ft deep open cut with 5 ft (1.5 m) thick one-sided walls, 124 columns, and 1 to 2 ft (0.3 to 0.6 m) thick interior walls, adding up to 11,000 yd^3 (8400 m^3). The largest challenge on this project was the hydrostatic head on the exterior of the walls from the water table. Controlling the groundwater required constant use of weep pipes to relieve the water and/or pumps.

44th, 50th, and 55th Street Vent Shafts Project

Superior Gunite was then awarded several deep vent shafts in midtown Manhattan. These were 44th, 50th, and 55th Street vent shafts. These were one-sided exterior walls and, on the 55th Street vent, a large, 5 ft thick, 7000 ft^2 (650 m^2) overhead placement. This overhead was performed in 1 ft thick lifts using layering with prepared surfaces between layers. The exterior walls were 1 to 2 ft thick and totaled about 7000 yd^3 (5400 m^3).

CM006 Contract

The CM006 contract was the largest shotcrete project Superior Gunite performed with a contract value of over $20 million. This was for shotcrete surface smoothening and PAC work on the East Side Access project that included running tunnels, caverns, and cross passages from Queens to the midtown Manhattan station.

Fig. 5: Complete CM006 M-Cavern arches, end wall tunnels, and center walls showing rubber float finish

Fig. 6: Typical CM006 cross passage

At the start of the project, following the approval of nozzlemen and mixture designs, work began with overbreak smoothening. Smoothening layers were applied to the caverns' uneven and over-broken surfaces that had been drilled and blasted. Smoothening was considered complete by the surfaces meeting smoothness criteria, after which the waterproofing installation began. The structural arches in the lower-level caverns were completed in the following sequence: backfill/smoothening, waterproofing installation, outside face reinforcing bar installation, first layer of shotcrete with a rough scratch finish, inside face reinforcing bar installation, and second layer of shotcrete with rubber float finish. Most all overhead shotcrete was performed in layers. The first layer was "scratch" finished and saturated surface-dry (SSD) prior to shooting the subsequent final layer.

CM006 had a number of challenges that called for detailed coordination between the owner, multiple general contractors, and subcontractors. Above CM006 was CM014B, where Superior Gunite performed ceiling beam encasements in preparation for follow on walls. Shotcrete was also performed on exterior walls and additional smoothening. These were smaller dental placements of about 7 to 20 yd^3 (5 to 15 m^3) a shift, totaling about 1000 yd^3 (800 m^3).

Fig. 7: Rod-finished cavern at CM006

Fig. 8: Communications room with fishmouth, interior wall, and arched ceiling at CM006

CM005 Contract

CM005 was much like CM006 as it also included running tunnels, caverns, and most all of it was overhead work. The most challenging portion was at TT1, with a double mat of No. 11 (No. 36M) and No. 9 (No. 29M) reinforcing bars at 6 in. (150 mm) on center and four beam sections (Fig. 9).

Fig. 9: Reinforced beam section in upper level arch of CM005 TT#1 structure

Fig. 10: Upper level arch of TT#1 structure, tunnel, and cross passage interface

Fig. 11: Completed CM005 tunnel section

Due to the lap lengths, stirrups, and reinforcing bars transitioning from the inner to outer mats at the interfaces, the reinforcing layout forced the shotcrete to be placed in one lift. On most other overhead applications, layering of the reinforcing bars within concrete lifts of about 12 in. (300 mm) placements facilitated proper consolidation. A rubber float finish was provided on the 1500 ft^2 (140 m^2) surface area of these placements.

Fig. 12: Finished Access Tunnel 1 with rubber float finish

Fig. 13: Finished Grand Central Terminal 1/2 arch with rod finish; walls were rubber float finish

CM007 Contract

CM007 was the placement of the cavern walls, cross passages, and niches. Systematic patches 3 ft thick by 800 ft^2 (74 m^2), totaling 11,000 yd of concrete, were placed and finished. This allowed the general contractor to expeditiously place precast beams and progress through the two caverns. For this aspect, we drove the concrete trucks directly in from Queens and they rode the track invert directly into the main cavern.

Logistics of Concrete

Concrete service for the entire project was provided from three locations on street level in midtown Manhattan. The material was conveyed via 5 in. (125 mm) of slickline, up to 1500 ft (450 m) with up to 8 yd^3 (6 m^3) in the line before reaching the secondary pump that was located in the underground caverns for the placement of the shotcrete. Due to the volume of material in the slickline and the slower nature of shotcrete placements, the concrete used a retarding admixture to prevent the material from setting up in the slickline. The effect of the retarder was then negated at the nozzle using an accelerator.

Fig. 14: CM007 Cavern walls; this is one of two caverns

Fig. 15: CM007 Cavern walls; 3.5 ft (1.1 m) being placed

Logistics of Workers and Materials

Access of workers and materials was unique as the material access was 7 miles (11 km) away in Long Island City. At the access point, materials were loaded on to work trains and brought into the project on a designated schedule. This one point of access, along with the use of work trains, put an immediate 24-hour delay from when the materials arrive in the project yard to when they are available at the work location. Supply delays were further increased at peak project production times as availability of space on the working trains was quickly taken by the deliveries of steel, waterproofing, and equipment. As a result, general materials needed to be scheduled to be delivered no less than 72 hours before they were required. Large equipment needed to be delivered a week in advance. The track was shared by several subcontractors and the three general contractors. Coordination was challenging, and congestion significantly added to delays and created management challenges. The workers came in from several access points via rail, stairs down 110 ft (34 m), or construction hoists. This also shortened time available for doing productive work during the shifts. Getting to and from the work locations took up to an hour at times, but generally averaged about 30 minutes.

Shotcrete was used on two-sided walls, running tunnels, cross passages, niches, and as well as the cavern walls and arches. The use of shotcrete significantly aided the NYC East Side Access program, creating major cost and schedule savings by reducing the formwork and adding flexibility to the projects. Superior Gunite has installed over 84,000 yd^3 (64,000 m^3) of shotcrete throughout the program.

__Frank E. Townsend III__ is a Vice President for Superior Gunite. He received his bachelor's degree in civil engineering from Worcester Polytechnic Institute, Worcester, MA, and his master's degree from the University of Missouri, Columbia, MO. Townsend served the U.S. Army Corps of Engineers and his diverse military background has led to him being deployed around the world. He is an active member of ACI Committee 506, Shotcreting, and the American Shotcrete Association. He has been Awarded the U.S. Army Corps of Engineers' deFluery Medal and Engineer News-Record *New York's "Top 20 under 40" design and construction leaders in 2016. He is a member of the Moles and Beavers, which are fraternal organizations of the heavy construction industry.*