2013 Outstanding Underground Project

The Learning Curve

Nozzleman Qualification for New York City Subway Tunnels

By William T. Drakeley Jr. and Scott Rand

The MTA CC/Long Island Railroad/East Side Access Project is an extension and new installation of subway tunnels, shafts, and cross passages for the New York City metro area. These new subway systems and adjoining connections allowed the use of the shotcrete process, based on certain criteria specified by bid documentation. This was to be the first major infrastructure use of shotcrete within the boundaries of New York City.

Fellow shotcrete experts and co-author Bill Drakeley have watched this project unfold with a certain level of anticipation. Their primary preoccupation was to ensure proper shotcrete placement was conducted safely by a qualified workforce in an underground environment. Drakeley was hired to qualify workers for the project. Once the workers were qualified, he remained on the project as a consultant and led oversight to the work in progress at the request of the project owner. From the outset of the shotcrete production, the learning curve for proper application techniques had to be successfully undertaken at an accelerated pace. Given the unprecedented nature of the project, the stakes could not have been higher for the future use of the shotcrete process in the greater New York City metropolitan area.

Specifications

The design specifications required each person applying shotcrete to demonstrate acceptable proficiency, which was defined as application that met the requirements of both the specification and the proficiency requirements of ACI Committee C660, Shotcrete Nozzleman Certification. The contractor was also required to provide operators qualified to perform work conforming to requirements of ACI 506R, "Guide to Shotcrete," and ACI 506.3R, "Guide to Certification of Shotcrete Nozzlemen" (this document has been withdrawn by ACI because all nozzleman certification efforts now fall under ACI Committee C660), with operators certified according to the requirements of the ACI Shotcrete Nozzleman Certification program.

The ACI Shotcrete Nozzleman Certification program, developed and maintained by ACI Committee C660, is a program for certification of nozzlemen employed for the application of dry- or wet-mix shotcrete. While an ACI Certified Nozzleman would be able to demonstrate basic knowledge and skill in shotcrete application, there are other aspects involved in shotcreting in an underground environment that require specific additional training. There are many craftsmen in the underground construction community that have skill and experience in concrete, including some experienced in shotcrete application for ground support and familiar with the needs for safety and work-related qualifications in the tunnel environment. However, they are not ACI-certified nozzlemen, and, unfortunately, the educational curriculum and the performance test (structural test panel) do not directly relate to placing underground shotcrete. The test is therefore not necessarily useful in assessing the ability of a person to apply shotcrete in an underground construction application.

ACI Committee C660 is not presently considering a curriculum or certification specific to tunnel and mining applications. It is important to note that the original ACI 506.3R was a nonmandatory guide for an engineer who wished to design a program for nozzleman certification to include in a project specification. Even though many specifications list it as such, ACI 506.3R was never a certification program in and of itself. In fact, one of the reasons the guide was officially withdrawn was because of the confusion it often created when blindly referenced in a project specification.

Training

Due to the lack of official training programs for shotcrete applications in the underground environment and the overwhelming need for such education, we recommended that a program following the applicable training curriculum and examining procedure of ACI Committee C660 be established for the purpose of qualifying craftsmen for application of shotcrete specific to the require-

ments of each underground project. This was not and could not be an ACI-sponsored program, but it was deemed acceptable by the project engineer after a comprehensive review. The program was developed and presented by qualified, credentialed ACI C660 examiners and educators.

This new training and qualification program required background information describing previous shotcrete experience, which was submitted either by the individual or the union for each candidate. The shotcrete "résumé" was reviewed by the project engineer, the examiner/educator, and others as required.

This program incorporated classroom instruction of 4 to 6 hours, including topics such as basic concrete technology and practice, shotcrete application, equipment operation and maintenance (directly related to shotcrete), ground support in various conditions employing shotcrete in combination with rock bolts, lattice girders and other support components, quality control, safety specific to shotcreting, and project requirements. It also included field trials such as practice shooting, the shooting of test panels to demonstrate application skills, and lab testing to confirm quality of materials placed. Finally, the program required field supervision by a qualified examiner/educator during initial shotcreting by the nozzleman on the project.

One of the priorities of this program was to ensure the continued presence of quality assurance and inspection personnel employed by the owner and designer, as well as quality control efforts by the contractor. The ongoing quality assurance and inspection were provided by the same examiner/educator that conducted the educational portions of the program and observed the field trials. In this way, all parties involved in the placement and acceptance of shotcrete on the project were in harmony.

General Conditions

The new shotcreting program hit four initial obstacles. First, under Contract CM019, the east and west caverns, in addition to all adjoining cross passages, Y caverns, and shafts, were to be drilled and blasted. With each blast, material was excavated and moved to a crusher in the lower levels. It was then loaded onto an underground conveyor belt and transported north, from Midtown Manhattan past Northern Boulevard in Queens. This excavation activity involved a three-shift nonstop rotation. Each underground phase was scheduled by set internal timetables. Because we were "the new guys on the block," we were given low priority and had to fight for (time) space (refer to Fig. 1).

Secondly, this rock removal schedule also left us with the task of reaching nearly inaccessible

Fig. 1

Fig. 2

areas of rock wall and ceiling (refer to Fig. 2). We encountered overbreaks in the excavation up to 10 ft (3 m) and overall ceiling heights that extended beyond 50 ft (15 m). The difficult access inherent on this project made continuous shotcrete application impossible. We would start one section, only to have to stop and move elsewhere, due to terrain passable only on foot or by mountain goat.

A third obstacle, which emerged in the first quarter of shotcrete applications, was the fact that our crew—Sand Hogs provided by Local #147 and some #731 Laborers—as the shotcrete underground workforce, was not allowed to service the shotcrete equipment. Due to the scope and logistics of the project, this task was the responsibility of other union crews equipped with workers and tools and established to carry out a variety of maintenance tasks in all aspects of the project. Although this is efficient for most operations, electrical and mechanical services

were often not available when required on our project, which resulted in downtime and quick changes in procedure. Available maintenance crews had a variety of workers with vastly different talents. While the range of expertise was ultimately an asset to the project, in the short-term, it inhibited a uniform and productive shotcrete application. For example, if a large robotic machine went down and was in dire need of service, its maintenance received no priority but was added to the list on a "first-come, first-served" basis.

The final obstacle was that the areas to be shotcreted were also high-traffic sites, accessed by workers in many trades. It was a bottleneck for all those involved and made implementation of the shotcrete process and schedule very challenging.

Fig. 3

Fig. 4

Shotcrete

As the accepted training and qualification program was put into place, we began our journey along the learning curve. The crews and management settled on hand-nozzling with the aid of man lifts. This was an important stance to take in deference to the qualifications of the workers. We strongly believe that no matter how many classroom sessions we had (2 full days for each nozzleman, on average) or how many hours were spent perfecting technique on the robotic machines, the best way to learn quality shotcrete placement was to actually grab the nozzle and shoot by hand.

Under the observation of a qualified supervisor or previously qualified job foreman, we could start with the nozzle in a low-risk wall or bench shooting to acquire hours of practice. Full qualification came after an accepted number of hand-nozzling hours were documented by the approved qualification trainer. It was of great benefit for the nozzleman to have a qualified trainer by his side, giving tips while shooting or discussing key issues with the foreman so he, in turn, could relay advice to the general crew. It should be pointed out that our qualification was geared toward the entire crew and full shotcrete process, not just the workers holding the nozzle.

Both dry- and wet-mix shotcrete materials and equipment were used. With a 6 in. (150 mm) slick line, wet-mix concrete was sent from the street through a re-mixer down to the tunnels and into the Putzmeister Shotcrete Technology's shotcrete pumps. Despite both the harsh physical environment and the carelessness demonstrated by some tradesmen in moving equipment from one shooting location to the next, the pumps withstood the abuse and operated successfully.

According to the specifications, all the large-volume shooting was to be done with wet-mix (refer to Fig. 3). Some smoothing or short patching was handled with dry-mix. For the most part, the dry-mix placement on the project employed full skid-mounted guns with pre-dampeners from Putzmeister. The dry-mix material supplier used, after a thorough vetting process, was King Packaged Materials Company. King supplied MS-D1 Accelerated Shotcrete and MS-D1 Steel Fiber Shotcrete on both contracts. The 2205 lb (1000 kg) bulk bags were delivered by truck to a rail siding in the Bronx, where they were transferred underground to Grand Central Terminal's Madison Yards by railcar.

The crews had to understand more than just basic shotcrete (refer to Fig. 4). They used a sophisticated shotcrete mixture that included hydration control chemical dosing of concrete intended to sit for hours, yet remain plastic and pumpable without separation; be pumped up to

and beyond 2000 ft (600 m); and make it to the nozzle without plugs despite being fiber-reinforced. Especially in overhead areas, the shotcrete material needed to have an accelerated set once sprayed, yet retain some plasticity for shaping or rough finishing. Each nozzleman could see firsthand how important angle, velocity, mixture design, and equipment manipulation (such as man lifts) were to the overall success of the job.

The job was always made more difficult by the requirement to add reinforcement to some of the rock substrate (refer to Fig. 5). Welded wire was attached to the rock bolts, and, on occasion, a metal mine strap was adhered to potentially loose rock material. These reinforcement requirements (overly reinforced in our humble opinion) likely reduced the bond of the fresh shotcrete to the rock substrate. Nozzle movements had to be perfect in and around a mine strap and where welded wire sheets overlapped, but there was virtually no access to the rock substrate behind the reinforcing material. In those few areas where the mesh overlapped, the crew adeptly cut out the overlapping layer to allow proper shotcrete application and a good bond to the rock facing.

Fig. 5

Current Status

According to Sean Clevenstine, General Superintendent of Concrete at Schiavone Construction, who oversaw the shotcrete applications on the project:

"Simple mathematics can be used to show the effectiveness of the program. In early 2011, our production goal based on past performance before the program took effect, was 40 yd^3 (31 m^3) of shotcrete placement per day, spread over three 8-hour shifts. By project completion, we were capable of applying over 200 yd^3 (150 m^3) in a 24-hour period, per heading, with rebound hovering between 5 and 10%. For a project of this magnitude, it wouldn't have been possible to get those numbers without a comprehensive training and evaluation program in place. What I believe made our program effective was the fact that it was "graduated"—each individual was walked through the application process step by step, under a qualified supervisor. The end result was a highly productive, exceptional quality product. It also validated the craft members of Local #147

as 'expert' nozzlemen by the time they completed all of the steps for qualification."

As of June 2013, we have qualified over 35 nozzlemen for this and related projects. Most are from the #147 Sand Hog Union. The total amount of early ground support surface area sprayed is 1,000,000 ft^2 (93,000 m^2). The yardage installed for the MTA CC/Long Island Railroad/East Side Access Project regarding the early ground support phase of the project is nearly 46,000 yd^3 (35,000 m^3) of wet-mix shotcrete application and another 10,300 yd^3 (7900 m^3) of dry-mix shotcrete. Mid-June 2013 marked the completion of the bulk of the project, not including punch-list items. The current talent pool of nozzlemen in New York City should now be considered as competent and viable a labor force as any in the underground shotcrete world. It is said of New York City that "if you can make it here, you can make it anywhere." Now, for the shotcrete process, that promise holds especially true.

The Outstanding Underground Project

Project Name
MTA CC/LIRR East Side Access

Project Location
New York, NY

Shotcrete Contractor
Schiavone Construction Co., LLC

Shotcrete Consultant
Drakeley Industries*

General Contractor
Dragados USA/Judlau JV

Architect/Engineer
Metropolitan Transportation Authority

Material Supplier/Manufacturer
King Shotcrete*, Putzmeister Shotcrete Technology*/ Ferrara Brothers Building Materials Corp.

Project Owner
Long Island Rail Road (LIRR)

*Corporate Member of the American Shotcrete Association

The authors wish to acknowledge the contributions of George Yoggy (right) to this article

William T. Drakeley Jr. *is President of Drakeley Industries and W. Drakeley Swimming Pool Company. Drakeley Industries is a shotcrete consulting firm that is dedicated to the training and implementation of the shotcrete process in regards to building water-retaining structures, ground support, and underground shotcrete application. Drakeley Pool Company is a design/build construction and service firm specializing in in-ground, high-end commercial and residential pools. Drakeley is an active member of ACI Committee 506, Shotcreting. He is the first ACI Certified Shotcrete Examiner from the pool industry nationwide. Drakeley is also an ACI Certified Nozzleman, ASA Technical Advisor, Chair of the ASA Pool & Recreational Shotcrete Committee, and serves as Treasurer to the ASA Executive Committee. His writings have been published in national and international trade magazines, including* Shotcrete, Watershapes, Pool and Spa, *and* Luxury Pools *magazines. In addition, Drakeley is a Platinum Member of the Genesis 3 Group, a licensed member of the Society of Water Shape Designers, and a member of the Association of Pool and Spa Professionals (APSP). He is also the Concrete/Shotcrete Instructor at the Genesis 3 Pool Construction Schools and NESPA Region 1 Show in Atlantic City. As an Instructor/Trainer, Drakeley has given lectures on shotcrete applications for various pool trade shows and for World of Concrete. Drakeley is an Expert Witness regarding shotcrete applications for the swimming pool industry.*

Scott Rand *is the Sales Manager for the Construction Products Group at King Packaged Materials Company, a leading manufacturer and supplier of prepackaged cementitious products. Rand is responsible for the sale of King's shotcretes, concretes, grouts, and repair mortars, as well as mixing and placing equipment, to North American civil and mining markets. Rand has more than 25 years of experience in shotcrete and concrete markets in Canada and the United States, and is currently serving his second term on the Board of Direction for the American Shotcrete Association (ASA).*