2020 Outstanding Repair & Rehabilitation Project

# Park Avenue Tunnel Rehabilitation

*By Ashley Cruz*

The Park Avenue Tunnel, formerly known as the Murray Hill Tunnel, is a 1,393-foot-long (425 m), 16-foot-wide (5 m), 9-foot-tall (3 m) thoroughfare traversing six New York City blocks. The tunnel was originally constructed in 1837 as an open rock-cut, with a brick arch constructed over the cut in 1854 to create the tunnel profile. For the next 150 years, the tunnel would be plagued with issues ranging from mechanical system failures to liner wall leakage due to the soil volume above, which is where the idea of shotcrete stabilization was introduced within the project scope.

The structural scope using shotcrete as the roof liner, was first discussed at the beginning of the design phase due to the imperfect curves of the original brick archway. Cruz Concrete was brought in by the general contractor once the project was released for bid and worked closely with the design team. In this effort, Cruz's dedicated team developed the shotcrete installation sequencing and assisted with the development of the final concrete mixture design.

Cruz Concrete was ultimately awarded the sub-contract to perform shotcrete repairs at the original stone parapet walls and to furnish and install the 12 in. thick (300 mm) shotcrete liner spanning the entire arched roof of the tunnel. These scope items utilized 40 $yd^3$ (31 $m^3$) for concrete repair and 1600 $yd^3$ (1200 $m^3$) for the finished shotcrete liner.

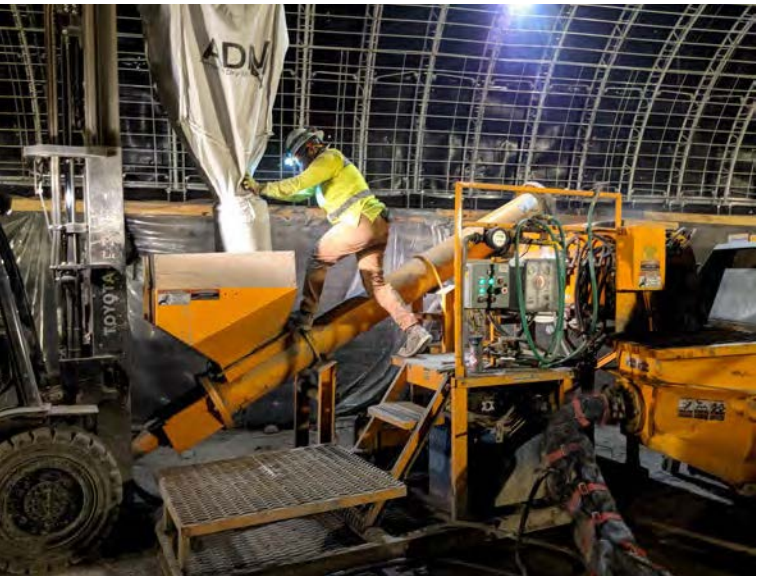

## A HISTORIC ARCHED CEILING IN A MODERN TIME

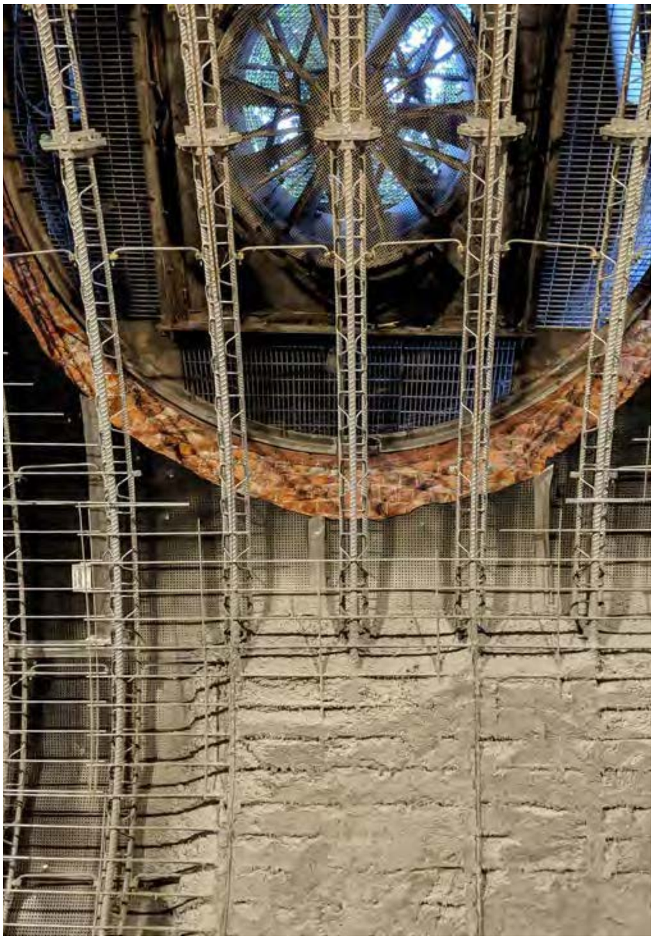
The design specification required the use of 6,000 lb/in$^2$ (41 MPa), pre-blended single component specially formulated Portland cement mixture with shrinkage reducing admixture, fibers, silica fume and carefully graded aggregate. This concrete mixture produced a high build, low absorption, machine-applied mortar. A crystalline permeability reducing admixture was also specified in the mixture design to decrease the overall permeability of the final product. All product testing yielded results that exceeded the material specification requirements.

The structural design of the new roof liner required building outward from the existing brick utilizing a waterproofing mat fastened to the brick, and structural steel reinforcement. lattice girders, comprised of two #11 (#36M) rebars and one #13 (#44M) rebar were placed 2 ft (0.6 m) on center and rested on top of the existing stone wall ledge. Sheets of wire mesh were also installed as additional support for the shotcrete placement.

The typical progression of this project was based on both the shotcrete technique and inspector approval. Each day, the crew applied shotcrete to the overhead arch in two lifts, progressing 25 ft (8 m) along the corridor. The base lift was approximately 6 in. (150 mm) to 9 in. (225 mm) deep, enough to fill in the lattice girders. The remaining thickness was

applied to the previous day's work. This served as the finishing lift, allowing for the use of less set-accelerating admixture, meaning the crew had more time to perfect the sponge float finish. Cruz mixed, applied, and finished approximately 25 to 30 yd$^3$ (19 to 23 m$^3$) of 3 in. (75 mm) slump concrete material per day.





Given the spatial limitations within a 16 ft (wide tunnel, Cruz was able to utilize a 3-team system: one nozzleman crew, one scratch and finish crew, and one pump and hose-maintenance crew.

## Mixing Shotcrete Onsite

Shotcrete was the major structural element, and determined the critical path of the project. The other three main elements being Road surfacing, repointing of the historic stone walls, and installation of new electrical and fire protection equipment comprised the remaining three main elements.

To successfully provide the specified shotcrete mix, which eliminated the use of ready-mix delivery trucks, Cruz was tasked with mixing the concrete materials on-site. To conquer this challenge, Cruz utilized a continuous mixer, brought in on a trailer and a pick-up truck, mounted on a skid for easy mobility via forklift. This allowed the team to move the set-up along the corridor each shift. Pre-bagged, dry concrete material came in the form of super-sacks (3,000 lb [1400 kg]), that were positioned over the dry-hopper of the mixer. Tractor-trailers delivered and off-loaded the 30 pallets of material every other week through the south entrance of the tunnel, which had a marginally taller clearance. These deliveries were strategically placed within the tunnel to mitigate any interference with other construction operations.

When working with shotcrete, it is imperative that the water-cementitious material ratio (w/cm) be properly maintained. When shooting overhead shotcrete, the precision of the w/cm becomes an even greater priority. Cruz's on-site concrete mix operator and inspector, were constantly monitoring the amount of water used for each batch of concrete. The slump was kept within +/- 1 in. (25 mm) of a 3 in. slump. As progress was made down the corridor, the water pressure

dropped, as the main source of pressurized water came from a fire hydrant located at street level, up to six city blocks away. To alleviate this problem, all but 100 ft (30 m) of the ¾ in. (19 mm) hose was replaced with a 2 in. (50 mm) water line, and other trades were only allowed to use this water source when there was no concrete mixing underway. A rapid set-accelerating admixture was also added at the nozzle throughout the project to ensure the adhesion of the concrete material once applied.

## THE DESIGN CHALLENGE

Another factor adding to the complexity of the project was the inclusion of work around 8 overhead exhaust fans. The fans ranged from 8 ft (2.5 m) to 10 ft (3 m) in diameter. During construction, the exhaust system required an upgrade, and with that, a redesign of the ceiling profile at those locations. The contract documents showed a roof design with a compression ring built inside each fan well. A change order was issued to construct the compression ring to hang outside of the fan. This added material to the original design with a compression ring that would protrude downward from the ceiling approximately 14 in. (350 mm) and 24 in. (600 mm) wide.

During the fan redesign process, Cruz continued to install shotcrete, forcing the crew to leave gaps in the archway around the exhaust fans, that were required to fully operate during construction. Shotcrete proved to be invaluable in the success of the compression ring work, as shotcrete does do not require formed construction joints, ultimately allowing the gaps to be placed with ease. The final approval of this redesign came as Cruz neared the end of the tunnel. The general contractor constructed a one-sided bulkhead at the inside diameter of each fan well to act as the limits of the shotcrete. This allowed the team to continue the systematic installation of shotcrete lifts. This ultimately added to the project timeline, however, the project was still completed ahead of the team's originally anticipated completion date.

Shotcrete was also extremely important to the overall aesthetic of the finished product as the engineer and architect required the finished concrete surface to follow the profile of the existing brickwork, which was far from perfectly level. The brickwork was built in 1857, and Cruz strived to conserve as much of the historical appearance as possible for future generations to experience.

## ENVIRONMENTAL AND ECONOMICAL SUSTAINABILITY

Given the efficiency of the shotcrete placement method, Cruz's team determined that shotcrete was 35 to 50% more time-efficient than the form-and-pour method would have

## 2020 OUTSTANDING REPAIR & REHABILITATION PROJECT

*Project Name*
**Park Avenue tunnel Rehabilitation**

*Location*
**New York, NY**

*Shotcrete Contractor*
**Cruz Concrete & Guniting Repair, Inc***

*Architect/Engineer*
**The LiRo Group**

*Materials Supplier*
**US Concrete Products*, Euclid Chemical Company*, & Penetron**

*Equipment Manufacturer*
**REED*, CANUSA***

*General Contractor*
**Tully Construction Company, Inc**

*Project Owner*
**New York City Dept. of Transportation**

***ASA Sustaining Corporate or Corporate Member**

been. Since shotcrete placement eliminated the need for erection and removal of complicated formwork, the owner enjoyed significant cost savings due to reduction of both labor and materials. Additionally, the elimination of formwork reduced the overall embodied carbons consumed throughout the project's lifespan.

Using the required on-site batching, Cruz was able to reduce the carbon footprint of concrete mixing and transport by over 50%, with the utilization of one 29 hp diesel engine with 430-running hours and 100 deliveries of material, as opposed to concrete batch plant operations and ready-mix delivery trucks in the Manhattan traffic. All storm drains in the tunnel were lined with filter socks to prevent sediment and lessen the slurry entering the sewer system, thereby reducing the pollutant load on the site's stormwater infrastructure.

Cruz Concrete completed the project, turning 1600 $yd^3$ of dry prepackaged concrete material into wet-mix shotcrete that was placed, finished and cured, in 70 working days. Water leaks have subsided and the archway still holds much of its 1800's character.

## ABOUT CRUZ CONCRETE & GUNITING REPAIR

Cruz Concrete and Guniting Repair, Inc. has been in business since 1984, incorporated in 1986. Cruz performs a multitude of concrete repairs and rehabilitation throughout the New York City and Tri-State Areas. Their services run the gamut from shotcrete roofs post-Sandy in Breezy Point, NY; "bath-tub" walls in the new World Trade Center, post-9/11; retaining walls of manufacturing plants; sub-roadway repairs to the George Washington Bridge; to historic restoration projects.

Cruz has been a corporate member of the American Shotcrete Association since 2010. Working on this project were two ACI-certified nozzlemen who both worked on portions of the overhead shotcrete contract. They also could not have successfully done the job without their team of finishers, laborers, and operators.

***Ashley Cruz** is an operating engineer and has been with the family-owned and operated business for three years. Ashley was both the project manager and concrete mixing operator for the Park Avenue Tunnel. Her attention to detail and understanding of concrete assured the mixed shotcrete was as specified. Ashley is the Director of Operations and aims to take Cruz Concrete to the next level in sustainability standards and blending creative design decisions with quality construction and bringing the foresight of our ecosystem into the spectrum.*