

ACI Nozzleman Certification and Underground Robotics

By Chris Zynda

I have been in the shotcrete industry for over 50 years. It all started with shoveling sand behind a gunite (dry-mix) machine and then moving on to foreman, superintendent, and ultimately owner of a shotcrete contracting firm.

I have been involved with wet-mix shotcrete for over 45 years. When we started with wet-mix, batch plants had no computers and the concrete mixture was never the same (except you could count on beer cans and large rock).

Fortunately, the shotcrete industry has steadily evolved over the last 30 years with computer-generated concrete mixture designs and state-of-

the-art batching equipment becoming the norm, rather than the exception.

The tunnel and underground industry is one of the world's largest users of shotcrete, both wet- and dry-mix processes. Figure 1 shows hand-nozzling with a dual-chamber dry-mix gun in an underground tunnel. Figure 2 shows hand-nozzling of an underground chamber and shaft with high reach lifts. (Note: No scaffolding required.)

Shotcrete placement with robotic equipment has become commonplace for installing rock support, final tunnel linings, and repair in the underground industry. Figures 3 and 4 show



Fig. 1



Fig. 3



Fig. 2



Fig. 4

Goin' Underground

robotic equipment being used for rock support and a tunnel lining. Improved technology with new systems includes use of accelerator injection systems (Fig. 5) that automatically adjust the amount of product to match the stroke of the concrete pump.

I have been involved with the ACI Nozzleman Certification program for over 15 years, being one of the founders of the program and one of the first ACI Shotcrete Nozzleman Certification examiners. With my detailed knowledge of the ACI certification process, I have explained to many tunneling contractors and engineers why they need ACI Nozzleman Certification for the underground shotcrete applications, both hand-nozzled and robotically placed.

Though the term “robotic” is widely used, it often introduces some misconceptions on what the equipment can actually do. In manufacturing plants, robots are usually programmed to endlessly repeat a defined set of operations. It may be welding an auto body or assembling a complicated piece of electronic equipment. In these manufacturing cases, the environment, material supply, and final assembly are well-defined. However, in shotcreted work, we don't have the “well-defined” final assembly—we have a host of variables:

- The underground receiving surfaces are normally quite variable;
- There is a varying amount of reinforcing;
- There may be varying thicknesses due to overcut of the rock;
- Concrete consistency may vary based on age of the mixture;
- Air and water volume and pressure may vary with the length of delivery hose; and
- Temperatures may vary and affect the thickness layers may achieve.

Really, in underground shotcrete, the robotic equipment is a tool for holding the nozzle, and the nozzleman remotely manipulates the nozzle position. This is similar in some ways to the concrete pump operator on a large boom truck who controls the pumping and placement at the end of the delivery hose, or maybe equivalent to a drone operator who controls the location and speed of the flying drone.

Though we use the term “robotic,” shotcrete placement is not preprogrammed or automated in a closely controlled environment. The quality of the final concrete in an underground application depends on the skill of the nozzleman and their knowledge of the various factors essential to quality concrete construction. Thus, the



Fig. 5



Fig. 6

nozzleman must be fully educated on the importance of material selection, properly sized and maintained equipment, proper placement techniques, testing requirements, safety, and finishing (Fig. 6). A quality underground nozzleman should have the basic knowledge and skill for hand-nozzling first, and then they can add the skill to remotely manipulate the nozzle with the robotic equipment.

ACI Shotcrete Nozzleman Certification helps to confirm in a standardized and rigorous way the nozzleman's knowledge of all aspects of basic shotcrete placement, and their ability to properly shoot the performance panel. The ACI Nozzleman Certification program covers the fundamentals for the shotcrete process

Goin' Underground



Fig. 7



Fig. 8



Fig. 9

using the CP-60(15), “Craftsman Workbook for ACI Certification of Shotcrete Nozzleman,” as the key reference for the program. ACI CP-60 has all the information needed to become familiar with topics such as water-cement ratio (w/c) and importance of aggregate gradations. I have mentioned only two topics from this workbook. Do you know how your crews would answer these two questions? Figures 6 and 7 show both vertical and overhead performance panels being placed for the ACI Nozzleman Certification Program.

Shotcrete for producing tunnel final linings is a fairly new application. Due to the availability and use of chemical admixtures, equipment, closely controlled concrete mixtures, and placing and finishing techniques, shotcrete is routinely used for structural reinforced retaining walls and heavily reinforced overhead sections (Fig. 8 and 9).

In summary, underground shotcrete is a huge market around the globe. Advances in shotcrete technology have improved materials and placement equipment, including “robotic equipment.” However, although robotic equipment helps eliminate the physical and safety demands of hand-nozzling, successfully placing quality shotcrete underground is still highly dependent on the knowledge and skill of the nozzleman. The best way for a specifier or contractor to confirm a nozzleman’s knowledge of the basics of shotcrete is to require them to hold a current ACI Shotcrete Nozzleman certification in the process and orientation to be used on the project. ASA’s website (www.shotcrete.org/education/index.htm) has an excellent compilation of nozzleman certification resources from both ASA and ACI.



Chris Zynda is a Past President of the American Shotcrete Association, current President of the Shotcrete Concrete Contractors Association, General Manager with JJ Albanese Concrete—Shotcrete Operations, and an ACI-approved

Examiner for Shotcrete Nozzleman Certification. He is a member of ACI Committees 506, Shotcreting, and C660, Shotcrete Nozzleman Certification, and ASTM Committee C09, Concrete and Concrete Aggregates. Zynda is also an approved Underground Examiner with California Transportation Agency.