

# Qualifications of the Shotcrete Construction Team

By Charles Hanskat

**S**hotcreting is an efficient method for placing high-quality, durable concrete in a wide variety of concrete structures. Shotcrete has been successfully used in substantial number of projects for well over a century. As with cast-in-place concrete, the quality of the shotcrete placement is dependent on the quality of the materials, proper mixing and transport, substrate/subgrade preparation, the placing process, and protection until final strength is reached.

However, a comparison of the shotcrete process to the traditional “form and cast” process shows significant differences. Specifically, when using the shotcrete process:

- Formwork is eliminated or substantially reduced.
- It is necessary to identify the best shotcrete process (wet- or dry-mix) for the job.
- Special gunning equipment is required, including pumps, guns, hoses, nozzles, and admixture/water pumps.
- Knowledge is required to safely use and maintain the shotcrete equipment.
- A trained field crew that performs work totally unlike casting concrete in forms is required.
- Environmental conditions that are unsatisfactory for quality shotcreting must be identified.
- The nozzleman must be well-versed in shooting techniques, including proper air, water, and mix flow.
- The crew must be prepared to properly finish, protect, and cure freshly placed shotcrete.
- Knowledge of quality control procedures specific to shotcrete is required.

Based on these factors, it is apparent that a contractor offering to place quality shotcrete can only truly be considered a qualified shotcrete contractor if every member of the shotcrete construction team—from company management through the field team—has specific knowledge, equipment, training, and hands-on experience in the shotcrete process.

ACI 506R-05, “Guide to Shotcrete,” is a great primer on shotcrete design and application. ACI Committee 506, Shotcreting, is currently working on revisions to the “Guide to Shotcrete”; in the latest drafts, the committee developed an expanded section covering shotcrete crew requirements. The following provisions are summarized

to help establish field crew qualifications. The requirements for designating a contracting firm as a quality shotcrete contractor are then presented. A shotcrete team that meets or exceeds the presented crew and contractor requirements will be best qualified to provide a cost-effective, high-quality, and durable shotcrete application.

## Field Team Duties and Qualifications

*(based on input from ACI 506 Subcommittee developing updates to 506R, “Guide to Shotcrete”)*

### Composition and Crew Duties

The basic shotcrete crew may consist of a foreman, a nozzleman, a finisher or rodman, an assistant nozzleman, a wireman, a gun or pump operator, a mixer operator (if needed), and laborers.

Depending on the size and complexity of the project, one person may perform more than one operation. For example, the foreman could also function as the nozzleman; one person could perform as the rodman and finisher; an assistant can help the nozzleman by both pulling the hose and operating the air-lance/blowpipe; and, if necessary, the gun or pump operator and mixer functions could be combined and, with proper equipment, performed by one person. Larger, congested reinforced projects, on the other hand, may require more than one nozzleman and air lance operator and several finishers. Where several crews are operating, a foreman, superintendent, and engineer may be required.

**Shotcrete Foreman’s Duties**—The foreman plans, directs, organizes, and coordinates the work of each member of the shotcrete crew to obtain a safe and successful application. This includes ensuring the safety of the work area and following quality control procedures. The foreman is responsible for the inspection and maintenance of equipment, as well as ordering and expediting the delivery of materials. The foreman sets the pace of the work, maintains crew morale, ensures good housekeeping, and acts as liaison with the general supervisor or the owner’s inspection team. The foreman is usually a veteran nozzleman, finisher/rodman, or pump/gun

operator and should be able to fill any of the positions if required.

**Nozzleman's Duties**—The nozzleman is a key person in a shotcrete operation. He is responsible for applying the shotcrete and bringing it to required line and grade in a workman-like manner. The nozzleman's duties include coordinating the application with the foreman, finisher or rodman, and pump/gun operator. Before the shotcrete is installed, the nozzleman should ensure that all areas to receive shotcrete are clean, sound, and free of loose material and that anchors, reinforcement, and ground wires are properly placed and spaced.

In the dry process, the nozzleman controls the water content for hydration and ensures that the operating air pressure is uniform and will provide high velocity at impact for good consolidation. In the wet process, the nozzleman controls the air that increases or decreases the velocity to ensure proper placement, which includes proper encasement of the reinforcement.

The nozzleman provides leadership and direction for the shotcrete crew, which aids in the task of shooting high-quality shotcrete. The nozzleman is usually an accomplished finisher or rodman and gunman/pump operator.

**Wireman Duties**—The wireman sets elevations and thicknesses for the shotcrete placement, which may include the top and face of the wall. Grades set by the wiremen are the lines the nozzleman and finishers will follow. The wireman may use many devices for setting grades, such as piano wire, fiberglass-metal rods, plastic pipe, and so on.

**Finisher/Rodman's Duties**—The finisher rods, or cuts, the freshly placed shotcrete surface, bringing it to line and grade before final finishing. The finisher also locates and removes sand pockets, sags, and sloughs and guides the nozzleman to low spots that require filling with additional shotcrete. Before the shotcrete is set, the finisher brooms and prepares the surface for final application.

**Assistant Nozzleman's Duties (blowpipe/air lance control)**—The assistant nozzleman helps the nozzleman by dragging the hose and performing other duties as directed by the nozzleman. The assistant nozzleman relays signals between the gunman/pump operators and may also relieve the nozzleman for short rest periods. The assistant nozzleman may operate the air lance, if one is required, to keep the areas in advance of the shotcrete free of rebound and overspray. The assistant nozzleman may be a nozzleman trainee and place shotcrete under the direct supervision of a certified nozzleman.

**Gunman's Duties (dry-mix)**—The gunman provides a constant flow of properly mixed dry-mix material to the nozzleman. The gunman

operates and maintains a clean gun and assists in ensuring quality control. The gunman should be particularly attentive to the needs of the nozzleman to ensure that the mixture is properly prepared. The gunman generally oversees, controls, and coordinates the material mixing and delivery operation.

**Pump Operator's Duties (wet-mix)**—The pump operator regulates the pump to uniformly deliver the wet-mix shotcrete at the required rate. The pump operator is responsible for cleaning and maintaining the material hose and pump. The pump operator coordinates the delivery of the shotcrete mix and monitors the water content by observing or testing the slump of the mixture. The pump operator may change the delivery rate of the transit and ready mix trucks, including staging the trucks at the pump. The pump operator is also responsible for all the safety concerns of the pump and delivery line.

**Mixerman's Duties**—The mixerman's duties include, where applicable, the proportioning and mixing of the shotcrete mixture materials and maintaining and cleaning the mixing equipment. For field mixing, the mixerman is responsible for storage, care, and accessibility of the materials. The mixerman makes sure that the mixture is free of contaminated materials and debris and that the aggregates have the proper moisture content. He ensures a constant flow of shotcrete materials but is also careful not to mix more material than can be used within the specified time limits. The mixerman supervises the laborers who are supplying and loading the mixer.

**Hose Tender's Duties**—The hose tender's duties include moving tools, equipment, hoses, scaffolding, and materials. Hose tenders clean work areas, remove rebound and overspray, and provide support for the shotcrete application.

**Project Engineer, Project Manager, or Superintendent's Duties**—On large or complicated projects, a project engineer, project manager, or superintendent may be advisable. A shotcrete contractor usually employs engineers, project managers, or superintendents who may not be assigned to a single project full time. The project engineer, project manager, or superintendent is responsible for the material selection, mixture proportioning, preconstruction testing, qualifications of the crew, equipment selection, project planning, scheduling, logistics, materials handling, quality control, sampling and testing coordination, and troubleshooting technical problems during construction.

## Crew Qualifications

**General**—The quality of a completed shotcrete application results from the combined skills and knowledge of the shotcrete crew. The foreman



Fig. 1: Nozzleman with his air lance man and hose tender



Fig. 2: Nozzleman, air lance man, and finisher in the background



Fig. 3: Pump, nozzleman, and hose tenders

and crew should have performed satisfactory work in similar capacities for a specified period. The entire crew is responsible for the safety of each member on any particular project.

**Shotcrete Foreman**—The foreman commonly has proficiency in all crew positions and is in charge of the crew and the safety procedures. The foreman typically has at least 2 years of experience in the placement of shotcrete.

**Nozzleman**—The nozzleman should be ACI certified (refer to ACI CP-60, “Craftsman Workbook for ACI Certification of Shotcrete Nozzleman”) and have completed at least one application as a nozzleman on a similar project for the shotcrete contractor. In congested reinforced projects, the nozzleman should also be able to demonstrate, by preconstruction testing, an ability to satisfactorily perform the required duties and to apply shotcrete as required by specifications.

**Assistant Nozzleman/Nozzleman Trainee**—The assistant nozzleman/trainee should have 6 months of experience in a variety of shotcrete field operations that may include finishing, gun or pump operation, blowpipe/air lance control, and hose tending. The assistant should be able to demonstrate knowledge of proper shotcrete equipment setup (pump/gun, delivery hose, nozzle, and air/water supply). When shooting, the assistant must be under the direction of an ACI Certified Nozzleman.

**Blowpipe/Air Lance Control**—This person should have experience in finishing shotcrete and have proven successful manipulation of the blowpipe on previous jobs as directed by an ACI Certified Nozzleman, shotcrete foreman, or superintendent.

**Wireman**—The wireman should have at least 1 year of experience in setting grades on projects with shotcrete applications.

**Rodman and Finisher**—The rodman and finisher must have shotcrete experience and care must be taken not to create sags and loss of bond. Previous work experience that provided acceptable results should qualify him for this position.

**Gunman or Pump Operator**—The gunman or pump operator should be familiar with and able to operate the shotcrete delivery equipment, know the proper methods of material preparation and mixing, and be familiar with the chosen method of communication. The pump operator and gunman should preferably have at least 1 year of experience operating the intended equipment and be familiar with all manufacturers’ safety guides and operations.

**Mixerman**—The mixerman should know and perform the proper methods of material preparation and mixing to consistently mix and maintain the required mixture proportions, including the proper water-to-cementitious

content ratio (w/cm). The mixerman should have a minimum of 6 months running the specific (or similar) mixing equipment used on the project.

**Project Engineer, Project Manager, or Superintendent**—The project engineer, project manager, or superintendent should have at least 3 years of relevant field experience.

## Shotcrete Contractor Qualifications

The uniquely different needs of the shotcrete field crew and equipment, when compared to that for conventional cast-in-place concrete work, require the support, commitment, and positive attitude of the entire contracting organization for successful execution of quality shotcrete projects. Successful shotcrete projects demand full corporate support in:

1. Establishing and enforcing safety and quality control policies.
2. Purchasing and maintaining the proper equipment for each project's particular needs.
3. Committing to hire, train, and maintain the needed field personnel.
4. Handling the logistics of bidding, scheduling, and preconstruction requirements in an efficient manner.
5. Maintaining good client relationships, without which the shotcrete project may be less than successful.

The owner or specifier should always require an experienced and qualified shotcrete contractor team for executing quality shotcrete work. With this in mind, the following are suggested attributes for an owner or specifier to consider when selecting a qualified shotcrete contractor. By seeking out a contractor with the recommended qualifications below, the owner or specifier may rest assured that the **entire** shotcrete construction team—including a qualified contractor, ACI Certified Nozzleman, and experienced crew—has proven its ability to consistently place quality concrete by the shotcrete process.

Qualified contractors should have:

1. Five years of experience as a licensed contractor.
2. Five shotcrete projects of similar size, scope, and process (dry- or wet-mix) which were successfully completed within 5 years and have proper documentation, including full contact information for the owner/engineer/construction manager/general contractor, a project description, and the scope of work accomplished.
3. The ability to self-perform all shotcrete-related work and a minimum crew and staff listed as part of the company (either employees or substitutes with a work history under the current business name) consisting of the following minimum experienced field crew members:

- a. Shotcrete Foreman
  - b. Nozzleman (at least one ACI Certified Nozzleman on the project)
  - c. Dry-mix Gunman or Wet-Mix Pump Operator
  - d. Assistant Nozzlemen/Nozzlemen Trainees (blowpipe/air lance controller)
  - e. Finishers
  - f. Mixerman
  - g. Hose Tenders
4. Ownership of all necessary shotcrete equipment (pumps, guns, and hoses) to accomplish the job based on the specific project needs. The contractor must submit sizes and models of all shotcrete equipment to be used and should have a full equipment backup in case of equipment breakdown.
  5. A certificate as a Business in Good Standing from the state that the company resides in.
  6. A letter of bonding capacity from the bonding company or a letter of credit.
  7. Company insurance in good standing that meets all state minimum requirements, including, but not limited to, general liability and workers' compensation.
  8. ASA Corporate Membership.
  9. Ability to demonstrate that members of the company construction support staff (for example, safety, general superintendent, project managers, and construction managers) have educational session credits through an industry-appropriate continuing education program specifically addressing shotcrete design, construction, or administration (ACI certifications; ASA education sessions [including ASA Onsite Seminars]; seminars; or trade shows, such as World of Concrete, ACI conventions, and ASA meetings).
  10. An office or business base (with an address).
  11. References (including those from the five projects in Item #2).
  12. Affiliations.
  13. Full disclosure of any criminal or fraudulent rulings for shotcrete work against former or current company owners in a 5-year period.

## Summary

To consistently produce quality shotcrete work, the shotcrete contractor and key personnel all require proper qualifications through training in shotcrete materials, equipment, placement methods, curing, and protection to handle a particular project. It must be stressed that training in only one of these elements cannot guarantee success, and poor performance or lack of shotcrete knowledge by any member of the crew can cause a substandard finished product.

Simply specifying the use of an ACI Certified Nozzleman WILL NOT guarantee successful

shotcrete placement on a project. The ACI Nozzleman Certification program was designed to establish that the tested nozzleman is capable of shooting at an “entry” level. The nozzleman receives his certificate for each process and orientation if he succeeds in the written and the performance exam. However, the performance exam is not representative of the shotcrete application experience needed to consistently and properly place shotcrete. The shotcrete construction market has a wide range of project needs from basic, lightly reinforced, thin shotcrete sections to complex and congested structural systems requiring substantially more experience and sophisticated techniques. The wide spectrum of construction practices, shotcrete processes, performance requirements, and geographic differences can impact shotcrete placement in many ways. No certification program can address all potential variables. The ACI Nozzleman Certification program simply verifies that the certified nozzleman has basic shotcrete knowledge and has adequately shot a shallow, flat, lightly reinforced test panel. This establishes that the nozzleman has the **potential** to do a satisfactory job, once the experience required for a specific type of project is gained.

Only by selecting a quality shotcrete construction team composed of a qualified shotcrete contractor, a trained and experienced crew (including an ACI Certified Nozzleman), and the proper equipment and materials can you be reasonably assured your shotcrete project will produce the high quality, durable concrete structures that shotcrete is capable of creating.

### **Author's Note**

The basic content of this paper was reviewed and updated by a select task group of ASA Board members with many decades of shotcrete contracting experience. The paper was submitted to

the ASA Board of Directors (BOD) for consideration as an official ASA Position Paper at the Spring 2013 BOD meeting. After full Board review and approval, look for the official ASA Position Paper on our website [www.shotcrete.org](http://www.shotcrete.org).



**Charles Hanskat, PE**, is Managing Principal at Hanskat Consulting Group, LLC, a firm in Northbrook, IL, which he founded in 2012. He received his BS and MS in civil engineering from the University of Florida. Hanskat is a licensed professional engineer in 23 states. He has been involved in the design, construction, and evaluation of environmental concrete and shotcrete structures for over 35 years. Hanskat is an ASA Vice President, Board member, and Chair of the ASA Sustainability Committee. He is also a member of ACI Committees 301, Specifications for Concrete; 350, Environmental Engineering Concrete Structures; 371, Elevated Tanks with Concrete Pedestals; 372, Tanks Wrapped with Wire or Strand; 376, Concrete Structures for Refrigerated Liquefied Gas Containment; and 506, Shotcreting; and Joint ACI-ASCE Committee 334, Concrete Shell Design and Construction. Hanskat's service to the American Society of Civil Engineers (ASCE), the National Society of Professional Engineers (NSPE), and the Florida Engineering Society (FES) in over 50 committee and officer positions at the national, state, and local levels was highlighted when he served as State President of FES and then as National Director of NSPE. He served as a District Director of Tau Beta Pi from 1977 to 2002. He is a Fellow of ACI, ASCE, and FES and a member of ASA, NSPE, ASTM International, AWWA, NFPA, and ASCC.

<b>Shotcrete Contractor Qualification Evaluation Checklist</b>	
	Five years of experience as a licensed contractor.
	Five shotcrete projects of similar size, scope, and shotcrete process (dry- or wet-mix), successfully completed in those 5 years with proper documentation
	Shotcrete Contractor self-performs all shotcrete-related work and has provided an experience listing of the minimum crew to be used on the project (refer to additional checklist for the Shotcrete Field Team Qualifications)
	Owns all necessary shotcrete specific equipment (pumps, guns, and hoses) to accomplish the job based on the specific project needs. Shotcrete Contractor has submitted sizes and models of all shotcrete equipment to be used—including full equipment backup in case of equipment breakdown
	Certificate as a Business in Good Standing or equivalent from the state that the company resides in
	Letter of bonding capacity from the bonding company or a letter of credit
	Company insurance in good standing and meeting all state minimum requirements. (including, but not limited to, general liability and workers' compensation)
	Contractor is a Corporate Member of the ASA
	Contractor documents that company construction support staff (for example, Safety, General Superintendent, Project Managers, and Construction Managers) have continuing educational session credits
	Physical office, shop, or other business address
	References (preferably including those from the five shotcrete projects of similar size, scope, and shotcrete process)
	Company Affiliations (for example, ASA, ACI, AGC, and ABC)
	Contractor has disclosed any criminal or fraudulent ruling for shotcrete work against former or current company owners in a 5-year period

<b>Shotcrete Field Team Qualification Checklist</b>	
	Shotcrete Contractor has submitted names, positions, and experience of field team members as required for the project and generally including: <ol style="list-style-type: none"> <li>1. Project Engineer, Project Manager, or Superintendent</li> <li>2. Shotcrete Foreman</li> <li>3. Nozzleman (at least one ACI Certified Nozzleman on the project)</li> <li>4. Gun or Pump Operator</li> <li>5. Assistant Nozzlemen/Nozzlemen Trainee(s)</li> <li>6. Wireman</li> <li>7. Blowpipe/Air Lance Controller</li> <li>8. Rodman or Finishers</li> <li>9. Mixerman</li> <li>10. Hose Tenders</li> </ol>
	Project Engineer, Project Manager, or Superintendent—minimum 3 years of relevant experience
	Shotcrete Foreman—minimum 2 years of shotcrete experience
	Nozzleman—holds current ACI Nozzleman Certification appropriate for the work and has completed at least one similar application as a nozzleman on a similar project for the Shotcrete Contractor
	Gunman or Pump Operator—should have at least 1 year of experience operating the intended equipment and be familiar with all manufacturers' safety guides and operations
	Assistant Nozzleman/Nozzleman Trainee—should have 6 months of experience in various shotcrete field operations that may include finishing, gun or pump operation, blowpipe/air lance control, and hose tending. When shooting, must be under the direction of an ACI Certified Nozzleman
	Wireman—should have a minimum of 1 year of experience in setting grades and profiles on shotcrete work
	Blowpipe/Air Lance Controller—should have experience in finishing shotcrete and have proven successful manipulation of the blowpipe on previous jobs as directed by an ACI Certified Nozzleman, Shotcrete Foreman, or Superintendent
	Rodman or Finisher—has proven successful shotcrete finishing on previous shotcrete projects
	Mixerman—should have a minimum of 6 months of experience running the specific (or similar) mixing equipment in use on the project