

SHOTCRETE NOZZLEMAN CERTIFICATION AND QUALIFICATION IN NORTH AMERICA

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ABSTRACT

This paper provides an overview of shotcrete nozzleman certification and qualification in North America. It traces the history of development of a shotcrete nozzleman certification program by the American Concrete Institute (ACI). It also describes the contributions of the American Shotcrete Association to the development and maintenance of the program.

The ACI shotcrete nozzleman certification program caters to hand nozzling only. It is currently not designed for certification of shotcrete nozzleman for application of shotcrete with remote controlled manipulator arms although it could be adapted for this purpose. ACI currently certifies nozzlemen in the following categories: wet-mix vertical, wet-mix overhead, dry-mix vertical and dry-mix overhead. Finally the paper describes the procedures used in North America for qualification of nozzleman and the entire shotcrete team for application of shotcrete on specific projects.

1.0 INTRODUCTION

The year 2007 marked the one hundredth anniversary of the founding of the dry-mix shotcrete process (referred to then as *gunite*) by Carl Akely in Chicago. The wet-mix shotcrete process was first introduced into North America shortly after the Second World War. Thus shotcrete has a long history of use in a wide range of different applications in North America. It was quickly recognized that the skills and competence of the nozzlemen (in addition to having suitable materials, mixture designs and application equipment) were a key to achieving a successful shotcrete project. Thus even in the early years considerable emphasis was placed on the training of the shotcrete nozzleman as a *craftsman*. Prior to the 1990's there was, however, no formal shotcrete nozzleman certification program in North America.

In 1991 the American Concrete Institute ACI 506 Shotcrete Committee published ACI 506.3R-91 *Guide to Certification of Shotcrete Nozzlemen*. The Synopsis to this Guide stated: *This is a guide for a means of certifying wet and dry-mix shotcrete nozzlemen for application of several but not all types of shotcrete. The certification procedure includes a learning and training period, a written/oral examination and a workmanship demonstration.* This publication was, however, only a *Guide* and there was no organization in North America actually providing formal shotcrete nozzlemen certification to this *Guide*. As such it created some confusion in industry. Some specifiers were requiring nozzlemen to be certified in accordance with this ACI 506.3R-91 document, but no organisation was actually providing such certification services.

2.0 AMERICAN SHOTCRETE ASSOCIATION NOZZLEMAN CERTIFICATION PROGRAM

In 1998 a group of dedicated contractors materials and equipment suppliers, engineers, testing companies, academics and others interested in the shotcrete process got together to form the American Shotcrete Association (ASA). The *Vision Statement* of the ASA is *to have the shotcrete process understood and used in every beneficial application*. The *Mission Statement* of the ASA is *to encourage and promote the safe and beneficial use of the shotcrete process*.

The ASA recognized the need for a viable shotcrete nozzleman certification program and so one of its first priorities was to establish an *ASA Shotcrete Nozzleman Certification Program*. This was done with the understanding that if the American Concrete Institute developed a *Shotcrete Nozzlemen Certification Program* as part of its certification activities that the ASA would withdraw its program and support the ACI Program.

The ASA also recognized the need for comprehensive training for nozzlemen planning on taking the certification examination. Thus an early priority of the ASA Education Committee was development of a *Shotcrete Nozzleman Training* program. This training program was based on development of PowerPoint CD training modules for use in classroom instruction, but also includes hands-on training in the field in either the wet or dry-mix shotcrete process, or both. All nozzlemen had to take training for application of shotcrete to vertical surfaces. Training in shotcrete application to overhead surfaces was optional.

ASA rolled out this program in 1999 and some 42 nozzlemen were certified under the ASA banner between 1999 and 2001.

3.0 AMERICAN CONCRETE INSTITUTE NOZZLEMAN CERTIFICATION PROGRAM

In 1997 the American Concrete Institute established ACI Committee C660, Shotcrete Nozzleman Certification, with the mandate to develop, maintain and update programs for use in the certification of persons performing as shotcrete nozzlemen. The ACI Committee C660 developed a thorough certification program with strict policies, guidelines and procedures that responded to the needs of the shotcrete industry. It prepared the examination material for both classroom and practical field examination. It also vetted knowledgeable persons in the shotcretes industry to act as ACI approved examiners.

In January 2001 ACI rolled out its first Shotcrete Nozzleman Certification program at the World of Concrete in Las Vegas and ASA terminated its program. The ACI Shotcrete Nozzleman Certification program was greatly aided by the precedence of the ASA program. Much of the certification format and indeed much of the examination material was adopted directly from the ASA program. This provided a kick-start to the ACI program. The ACI program is now only some seven years old, but already there are over 800 ACI Certified Shotcrete Nozzlemen and many more nozzlemen being certified each year, as more owners, engineers, architects and government agencies specify the use of ACI Certified Shotcrete Nozzlemen on their projects.

4.0 DETAILS OF THE ACI PROGRAM

As with any ACI certification program, examination sessions are conducted by Local Sponsoring Groups (LSG's). In the case of Shotcrete Nozzleman Certification there are currently two ACI recognized LSG's:

- a.) American Shotcrete Association, which administers examinations in English and Mexican Spanish.
- b.) Laval University, Laval, Quebec, Canada which administers examinations in French and English.

ASA agreed to take on the role as an LSG for ACI for Shotcrete Nozzleman Certification on the understanding that all examination candidates would first take the ASA Shotcrete Nozzleman Training School before taking the ACI Shotcrete Nozzleman Certification examination. This decision was made in part:

- a.) To improve the chances of nozzleman passing the ACI examinations (It was ASA's experience that there was a high failure rate, particularly in the written examination, of nozzleman who did not take the ASA Training School).
- b.) To impart a consistent message regarding *best shotcrete practice* to all persons in the shotcrete industry.

The ACI Shotcrete Nozzleman Certification program has a prerequisite of a minimum of 500 hours experience as a nozzleman or nozzleman-in-training before a nozzleman is eligible to take the ACI exam. In addition, in order to achieve certification from the ACI program candidates must fulfill the following requirements:

- Part 1: Demonstrate knowledge of all the items covered in a pre-shooting performance checklist
- Part 2: Shoot a standard reinforced panel for the methods (wet and dry-mix) and position(s) (vertical and/or overhead) to be certified. The test panels are cored through the reinforcing steel at five predetermined locations and the cores are evaluated for *Core Grade* according to the criteria detailed in the ACI CCS4 Shotcrete Craftsman publication.

Figure 1 shows the standard reinforced shotcrete test panel and core locations. In order to pass this phase of the certification program, the nozzleman must not get more than two Core Grade No. 3's. Also, a single Core Grade. No. 4 or No. 5 would result in a failure. Figure 2 shows a typical set-up for an overhead test panel.

Answers to all the examination questions can be found in the ACI CCS-4 Shotcrete Craftsman publication. Prospective examinees are encouraged to self-study this publication as well as questions presented in the ACI CP60 (02) Shotcrete Nozzleman Certification work book. Topics covered in the examination include:

- Basic concrete technology, including the cement hydration process and importance of the water/cementing materials ratio with respect to compressive strength, permeability and durability
- Shotcrete cementing materials including Portland cement types, supplementary cementing materials (fly ash, silica fume, slag, calcined metakaolin etc).
- Gradation and durability characteristics for coarse and fine aggregates
- Chemical admixtures for use in shotcrete, including set accelerators added at the nozzle
- Shotcrete mixture designs and plastic and hardened shotcrete performance requirements.
- Shotcrete supply and application equipment for either the wet or dry-mix shotcrete processes, including:
 - Shotcrete batching and delivery systems
 - Shotcrete guns for the dry-mix process
 - Shotcrete pumps for the wet-mix process
 - Ancillary shotcrete equipment such as: predampening units and water booster pumps (for the dry-mix process), air compressor hoses, nozzles and blow-pipes.
- Preparation of surfaces to receive shotcrete and the use of devices to control line and grade such as shooting wires, depths nails and edge forms.
- Proper shotcrete application techniques including the correct procedures to fully encase reinforcing steel and other embedments.
- Proper shotcrete trimming, screeding, trowelling and other finishing operations.
- Importance of proper shotcrete curing and protection during and after shotcrete application and finishing
- Hot and cold weather shotcreting procedures
- Shotcrete quality control (QC) and quality assurance (QA) inspection and testing procedures, including acceptance/rejection criteria for installed shotcrete and remedial works for defective shotcrete.

5.0 ACI RECERTIFICATION POLICY

The *ACI Shotcrete Nozzleman Certification* is valid for a period of five (5) years. Thereafter the nozzleman has to successfully complete a recertification program to maintain ACI Certification. To avoid duplicating the expense of the initial shotcrete nozzleman certification, ACI established the following criteria for recertification:

- a.) Candidates may recertify by successfully completing:
 - A structured oral interview with the Examiner. The interview is in lieu of the formal written examination required for initial certification. The interview is designed to ascertain that the candidates have retained their knowledge of the safe and competent application of shotcrete.
 - A performance examination the same as is required for initial certification.
- b.) Candidates must possess at least 1000 hours of work experience as a shotcrete nozzleman within the two years immediately prior to seeking recertification, or possess an average of 500 hours per year of shotcrete nozzleman experience within the 5 years immediately prior to seeking recertification

The costs of recertification have been able to be kept to a minimum by the ACI Examiner travelling to a job site where the nozzleman seeking recertification is working. The nozzleman shoots the test panel(s) and undergoes the oral examination on the work site. No special mobilization (other than fabrication of the test panel(s)) is required. Many shotcrete nozzlemen have now been recertified by ACI for a further five (5) years using this process.

6.0 QUALIFICATION FOR SPECIFIC PROJECTS

In addition to shotcrete nozzlemen certification, many projects with structural shotcrete now also require prequalification of the entire shotcrete crew for the specified project, by shooting and evaluation of a preconstruction mock-up. The mock-up should incorporate the most complex reinforcing steel details and any embedments in the structural shotcrete. Mock-ups should be shot by each nozzleman proposed for the project, using the same shotcrete mixture design, supply methods and equipment proposed for use on the project.

After shooting the mock-ups are evaluated by coring or diamond saw cutting to expose intersecting reinforcing steel, so that the quality of the workmanship can be assessed. Figure 3 shows an example of a mock-up constructed for a complex seismic retrofit project. Cores can also be taken from locations without reinforcing steel, or separate plain shotcrete test panels, to prequalify the shotcrete mixture design supplied. Parameters evaluated can include compressive strength, boiled absorption and volume of permeable voids (ASTM C642).

The mock-up can also serve to establish the line and grade and type and quality of finish for the project. Details such as tooled control joints and construction joints can also be constructed in the mock-up. Once approved, the mock-up is then usually left on site and forms a basis for acceptance of subsequent shotcrete work.

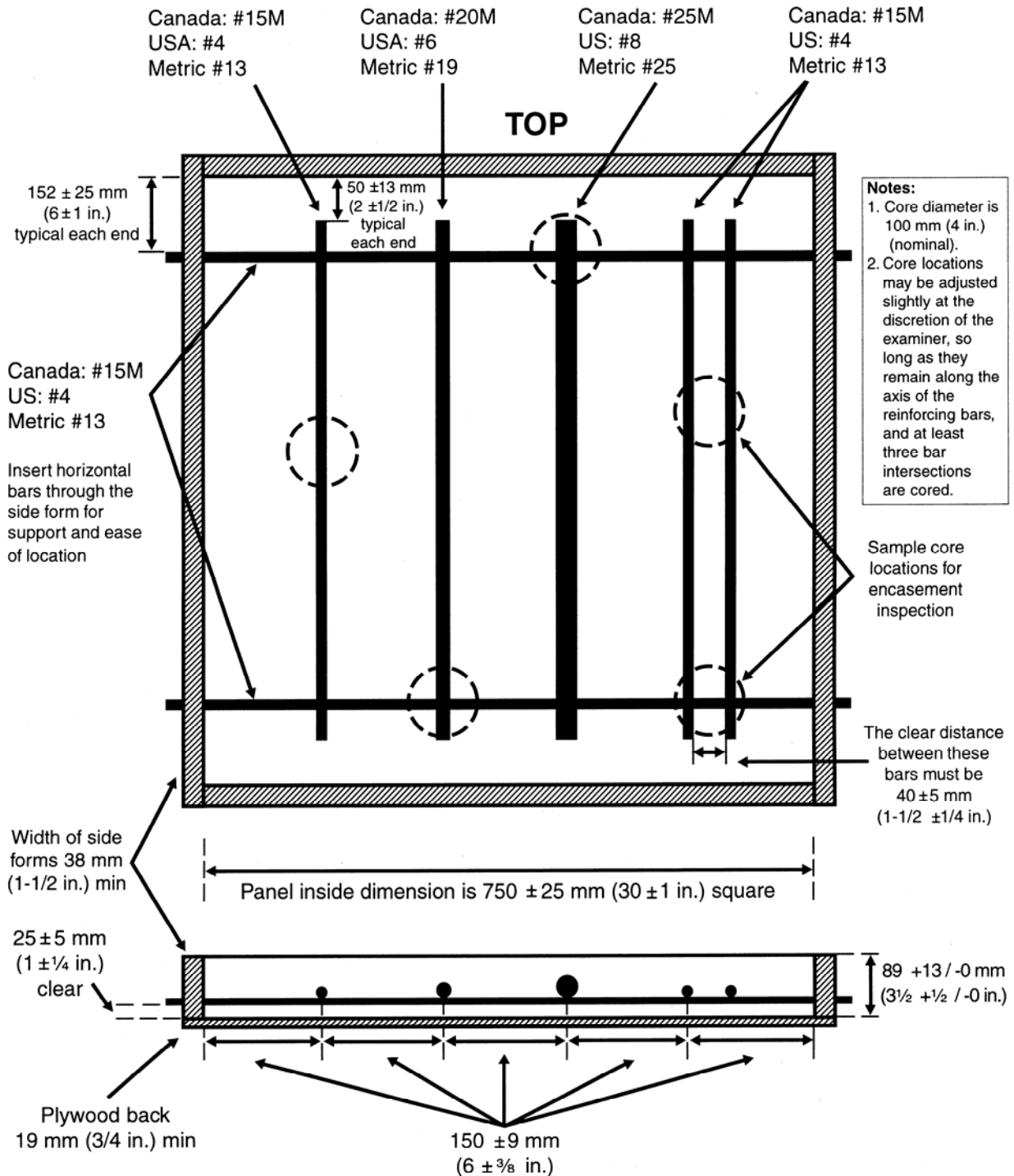
Finally, nozzleman are not permitted to apply shotcrete on the project unless they have shot an accepted mock-up. This requirement is sometimes waived when nozzleman can provide proof that they have previously successfully applied shotcrete on another project with the same shotcrete mixture design, equipment and reinforcing/section details.

7.0 SUMMARY

In summary, the combination of ASA Shotcrete Nozzleman Training, ACI Shotcrete Nozzleman Certification and the use of preconstruction mock-ups to prequalify shotcrete nozzlemen/entire shotcrete crew to shoot on specific projects is having a major beneficial impact on the quality of structural shotcrete work in North America. This has given many owners, engineers, architects and other specifying authorities a level of comfort regarding the use of structural shotcrete on their projects. More and more contractors are spending the time and money required to get their nozzlemen trained and ACI certified for shotcrete's ever increasing share of the construction market.

Certain parts of North America, particularly the West Coast, are seeing an increasing share of structures which would previously have been constructed by the conventional concrete form-and-pour method, now being constructed with shotcrete using either no formwork (for foundation walls) or single sided formwork (for internal walls or above grade walls). In underground support there is increasing use of final shotcrete linings, in lieu of formed cast-in-place conventional concrete linings. This trend is expected to continue as long as the shotcrete industry can consistently produce high quality, durable structures, meeting the owner's expectations in a timely and cost effective manner. Shotcrete nozzleman certification and qualification plays a critical role in this process.

APPENDIX I



Sketch A: Reinforced test panel layout with core sampling locations -- Includes proposed construction method.

Figure 1: Standard ACI Shotcrete Nozzleman Certification Panel
(Figure from ACI CP60 (02))

ACI SHOTCRETE NOZZLEMAN CERTIFICATION - OVERHEAD STANDARD SET-UP -

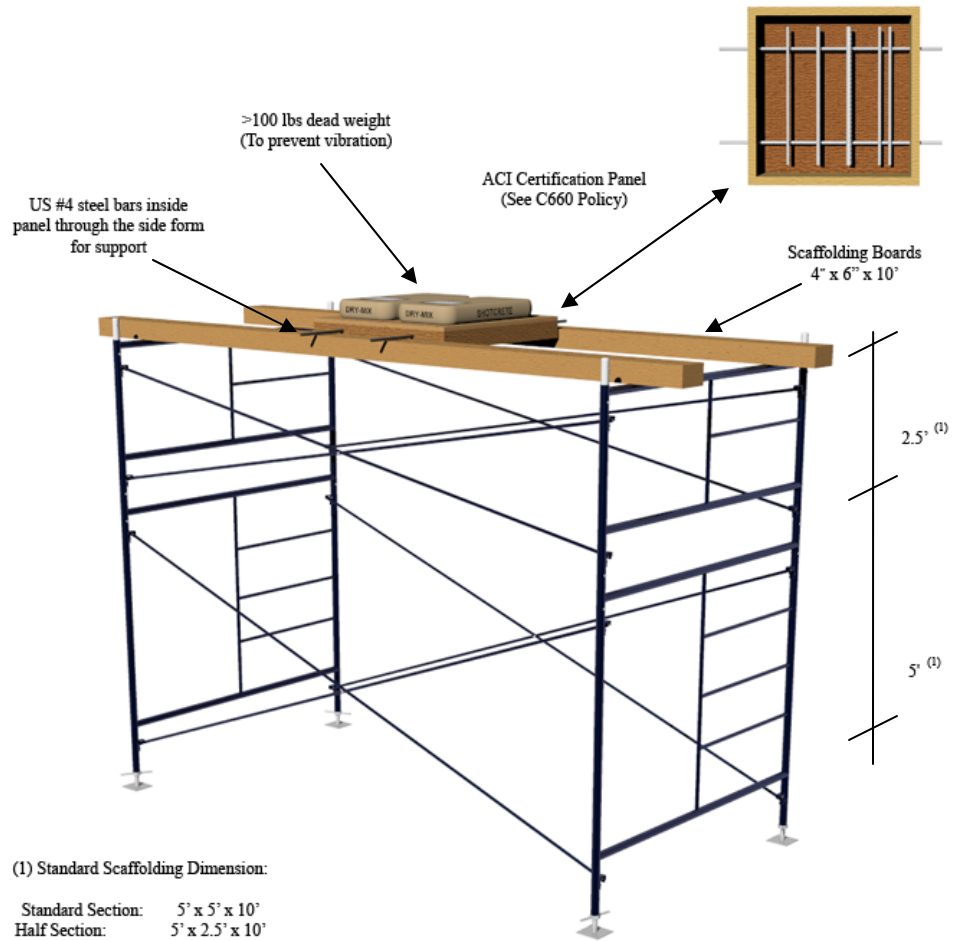


Figure 2: ACI Shotcrete Nozzleman Certification Overhead Standard Set-up
(Figure courtesy Marc Jolin, Laval University)



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