

2015

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Recommended Citation

Marc Jolin, J. Nehasil, and C. Hanskat, "SHOTCRETE EDUCATION AND NOZZLEMEN CERTIFICATION IN NORTH AMERICA" in "Shotcrete for Underground Support XII", Professor Ming Lu, Nanyang Technological University Dr. Oskar Sigl, Geoconsult Asia Singapore PTE Ltd. Dr. GuoJun Li, Singapore Metro Consulting Eds, ECI Symposium Series, (2015). http://dc.engconfintl.org/shotcrete_xii/15

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SHOTCRETE EDUCATION AND NOZZLEMEN CERTIFICATION IN NORTH AMERICA

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This paper provides an overview of the *American Shotcrete Association* (ASA) shotcrete education programs in parallel with the *American Concrete Institute* (ACI) shotcrete nozzle-men certification program. The complete test procedure of the certification program is described in details, particularly with regards to the standardized test panel that contains reinforcing steel bars with diameters ranging from 15 mm to 25 mm. Recognizing the importance of training and education, the paper also describes the effort put forth by the *ASA* in their training material; some of the significant changes made to the most recent educational documents recently published are also highlighted.

1. Introduction

The American Shotcrete Association (ASA) was founded in 1998 to promote shotcrete. The Association's Vision Statement: "Structures built or repaired with the shotcrete process are accepted as equal or superior to cast concrete", and the Mission Statement: "ASA provides training, qualification, certification, education, networks, and leadership to increase the acceptance, quality, and safe practices of the shotcrete process.". In the same period, the American Concrete Institute (ACI) was in the initial steps in developing a Shotcrete Nozzleman Certification Program through its certification committee C660.

At that time, the discussion over the importance of shotcrete nozzleman certification in the industry, and the vehicle by which a certification program could be delivered, was debated everywhere. After considerable efforts through 1999 and 2000 by both ASA and ACI members to fast track the launch of the nozzleman certification, the result was a fully tested and proven program first offered in January 2001 (Isaak 2002, Dufour 2008, Morgan and Dufour 2008).

Since then, the ASA has recognized the need for a comprehensive education program for nozzle-men who plan to take the ACI certification examination. Thus, an early priority of the ASA Education Committee was the development of a Shotcrete Nozzleman Education program. This program was based on development of PowerPoint modules for presentation by an instructor with long shotcrete experience in a classroom setting. As a result, the ASA became an ACI-sanctioned Sponsoring Group to administer the ACI Nozzleman Certification Program. The ASA provides the Shotcrete Education for nozzle-men taking the ACI Certification Examination or for those simply interested in learning shotcrete's material and equipment needs as well as correct nozzleman techniques. To put it simply, ASA educates, and ACI certifies.

Note that the program requires a certain amount of experience of shotcrete-nozzle-handling to qualify for shotcrete nozzleman certification. This is described in detail as well in the paper.

2. Education and Certification

The Education and Underground Committees of the American Shotcrete Association have developed a series of Shotcrete Education Modules tailored to best suit the type of application the nozzleman routinely places shotcrete. This ASA Education program consists of concrete/shotcrete related technical modules such as: introduction to shotcrete, history and uses of shotcrete, shotcrete materials and properties, shotcrete mix designs, quality control/quality assurance, shotcrete equipment, preparation for shotcreting, shotcrete nozzling and application techniques, shotcrete finishing and curing procedures, and safety. Modules for shotcrete for swimming pools and spas are also available.

2.1 The Educators & Examiners

Shotcrete education would not be possible without an adequate number of ASA-approved Examiners qualified to conduct the ASA education program. Examiners for the ACI Certification sessions are also approved by ACI. The detailed requirements to become an ASA or ACI Examiner (and maintain these statuses) can be found on the respective web sites of the associations (www.concrete.org, www.shotcrete.org); however, the main requirements are quite similar and can be summarized as follows.

In order to be considered for approval as an ACI examiner, one must document and demonstrate that he or she:

- a. Is knowledgeable about shotcrete and thoroughly familiar with the current applicable reference documents.
- b. Has a total of at least 5 years documented experience in at least two of the following four categories: 1) Testing, inspection, and quality control of shotcrete, 2) Supervision of shotcrete construction work, 3) Design of shotcrete structures 4) Shotcrete-nozzle-operation.
- c. Has sufficient experience to evaluate and judge the qualifications of shotcrete nozzleman applicants and conduct written and performance examinations. For each process, this experience must be, but is not limited to:
 - Knowledge of both vertical and overhead spraying
 - Knowledge and experience on more than one type of equipment (gun, pump, nozzle)
- d. Has, to the satisfaction of the examiners of record, participated in all phases of at least two (2) ACI-sanctioned Nozzleman Certification programs for each process for which approval is sought, with different examiners of record for each session. For the first session, the applicant must serve as a proctor and supplemental examiner. For the second session, the applicant shall serve as a proctor and supplemental examiner and personally conduct all phases of the session including written examination, performance examination, and core grading, under direct supervision of the examiner of record for both vertical and overhead orientations.
- e. Has attained a passing grade on the written exam for each process sought.

2.2 Education session

Unlike the ACI nozzleman certification, attending an ASA Education session does not require any pre-requisites of the attendees, such as 500 hours of nozzling experience, for the education session to take place. Attending an ASA shotcrete nozzleman education session is a valuable tool for nozzlelemen wishing to improve their knowledge and placement skills, and for others who may not be nozzlelemen, but want to learn more about the latest in shotcrete technology and equipment. This program is a great overview session for those interested in becoming involved in the shotcrete industry.

The goal of the ASA is to promote and gain acceptance of shotcrete. Companies wanting their nozzleman to have the certified nozzleman credential host the large majority of ASA-sponsored sessions. However, many sessions have been held at a central location and open to participation by any nozzleman interested in achieving certification. ASA has sponsored or overseen over 650 shotcrete educational sessions to this day. The ASA Education Committee is currently finalizing a Shotcrete Inspector's Education Program for Inspectors involved in the shotcrete industry.

3. ACI Shotcrete Nozzleman Certification Program

In addition to the ASA shotcrete education program, the ACI Shotcrete Nozzleman Certification program provides stringent standards when it comes to shotcrete quality. In addition to good quality, well-proportioned shotcrete mixes and suitable well-maintained equipment, qualified and certified shotcrete nozzlemen are a key element to the success of this process. The ACI, through its C660 Committee, is delivering a credible and thorough program with strict policies, guidelines and procedures that respond to the demands of the construction industry (Morgan and Dufour 2008).

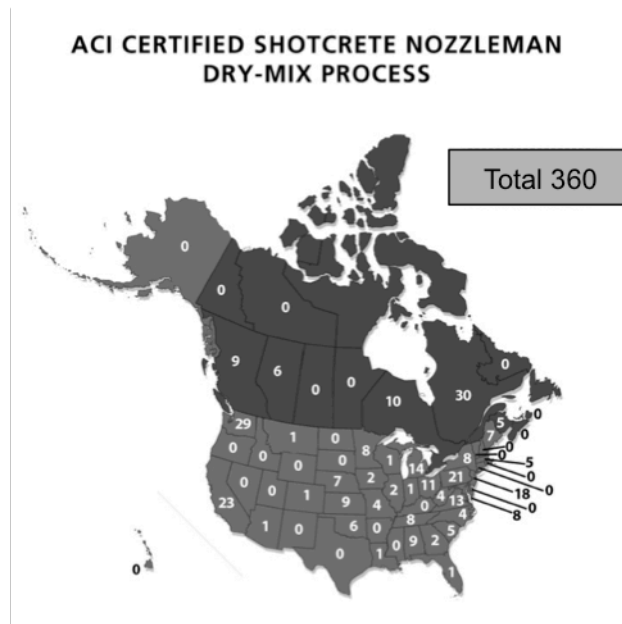


Figure 1: ACI Certified Dry-Mix Shotcrete Nozzlemen in North America

The program is continually improving over time, as many active ACI shotcrete examiners are also members of the C660 Committee. Since nozzleman certifications may take place in a more hazardous work environments than any other ACI certification program, one of the documents the Committee has developed is a performance specification document. This document assists hosts in setting up certification sessions in a safe manner, including guidelines for overhead panel affixation. ACI also has a setup guide for hosts detailing their specific responsibilities, and a checklist for items needed for a successful certification session.

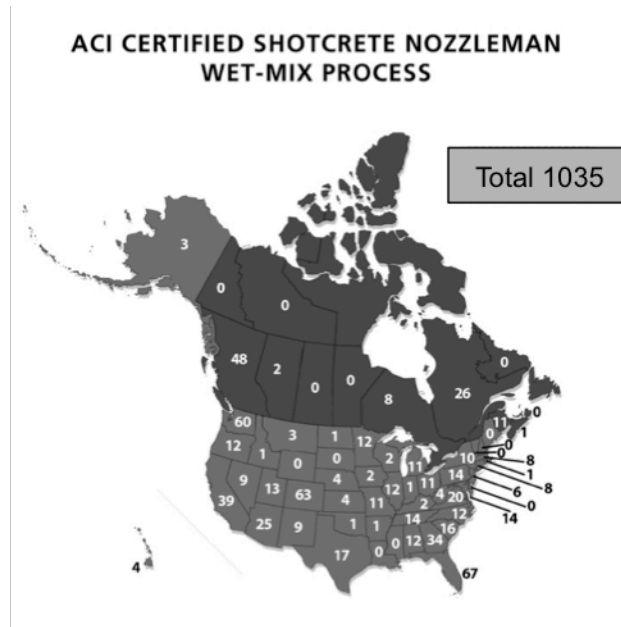


Figure 2: ACI Certified Wet-Mix Shotcrete Nozzlemen in North America

Overall, the number and location of ACI shotcrete nozzlemen certified throughout North America for both the dry and wet-mix processes since the start of the program until now is illustrated in Figure 1 and 2. Since 1904, ACI has been a leader in producing consensus committee documents for the concrete industry: codes, specifications, reports, and education materials. Since the shotcrete nozzleman certification program started, the ACI C660 Committee with the assistance of ASA members who routinely implement the ACI policy has continued to improve the scope of the program, refined the operational aspects of the exams and the increased the quality of the study documents, making it more nozzleman user friendly.

A nozzleman will become certified once successfully passing both the written exam and the performance exam in the process (dry- or wet-) and orientation for which he is applying. The written exam consists in 60 multiple choices questions. The performance exam consists in shooting a vertical test panel (described below) and, optionally, an overhead test panel, all under the direct observation of the ACI Examiner. Both the nozzleman's technique and the resulting test panel are evaluated during the performance exam portion (see section 5 below).

4. Craftsman Workbook for ACI Certification of Shotcrete Nozzleman; CP-60 (15)

One of the education documents also used by nozzlemen for the certification program, CP-60 Craftsman Workbook for ACI Certification of Shotcrete Nozzleman (ACI 2015) (fig.3), has been revised and includes an easy-to-read section on concrete technology. This section has been adopted to introduce the shotcrete process as a method of placing concrete. It was agreed by committee members that shotcrete craftsman should understand the basics of concrete production and behavior. Shotcrete workers should also understand safety procedures, including the use of personal protective equipment when they are placing and finishing concrete. A series of detailed illustrations were added to the 2009 version of CP-60.

Examples are presented in the following figures of illustrations incorporated into the new Workbook (ACI 2008):



Figure 3: Cover of the CP-60 (15) Craftsman Workbook for ACI Certification of Shotcrete Nozzleman

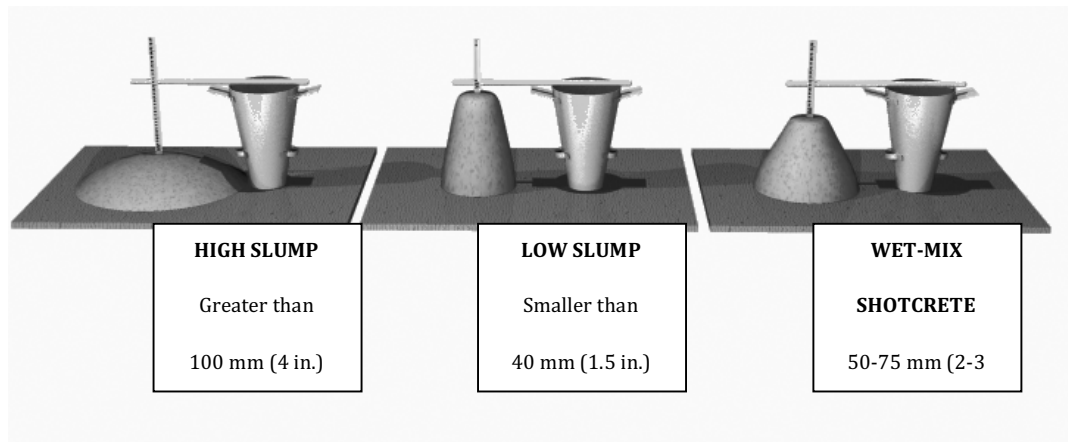


Figure 4: Measure of Workability of Wet-Mix Shotcrete.

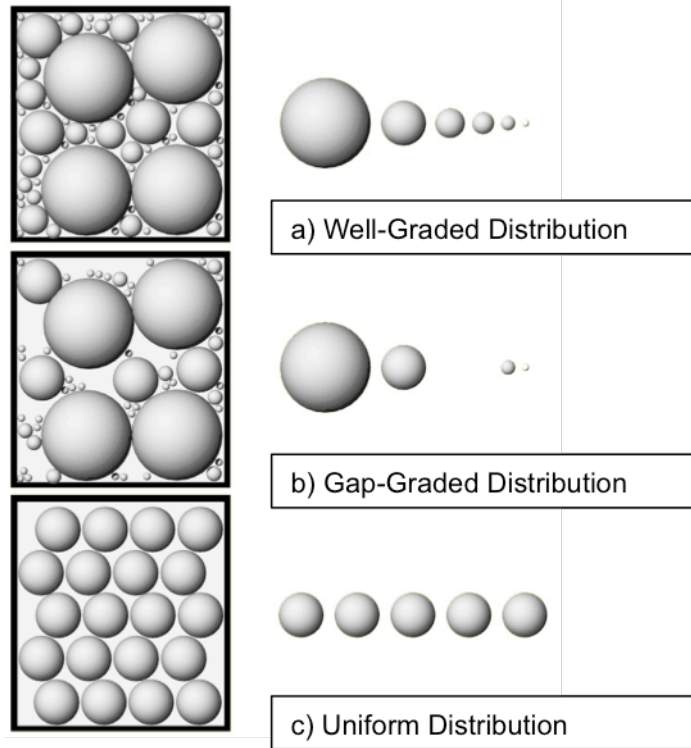


Figure 5: Illustration of different aggregate size distributions: a) well-graded distribution, b) gap-graded distribution, and c) uniform distribution

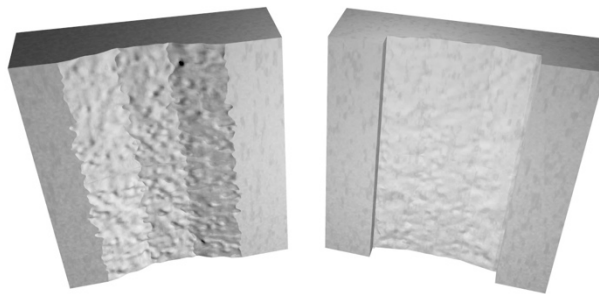


Figure 6: Concrete Surface Preparation - Feathered vs. Sawcut Edges

This recent workbook document, CP-60 (15) Craftsman Workbook for ACI Shotcrete Nozzleman Certification, is the official document that is handed to the nozzleman before an education/certification session. It is comprised of the following:

- Program Information,
- Education modules,

- Appendices.

The ACI Committee C660 has also recently reviewed the written examination questions based on the new literature. This international certification program and its supporting literature (Workbooks, written examination, etc.) are also available in three languages: English, Spanish and French.

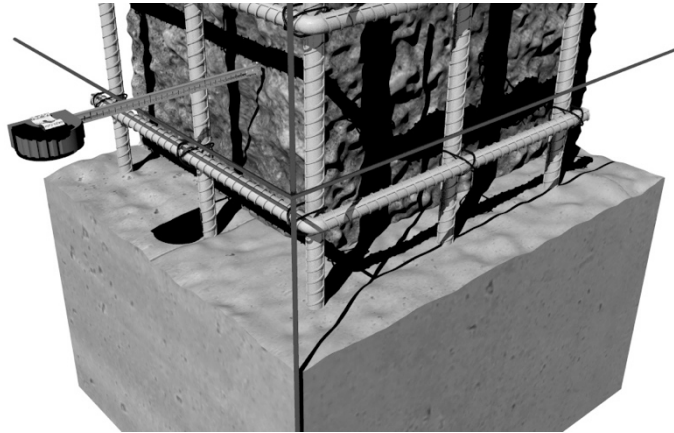


Figure 7: Guide wires installed vertically and horizontally. Wires strung along to the finished grade line provide a visual guide for the nozzleman and finishers.

5. Test Panel and Performance Exam

The use of shotcrete core grading to quantify the quality of shotcrete cores has been overused for years and, in the past, was included in many ACI shotcrete-related documents. With the exception of the nozzleman certification program, core grading has been discontinued. Industry experts felt that it was risky to propose such a subjective tool to members of the engineering and construction industries with very little experience in the field of shotcrete (problem related to its misuse). The core grades example displayed in the CP-60 appendix do not represent nor attempt to cover all the structural configurations where shotcrete is applied, and therefore, made it irrelevant.

Core grading however is an appropriate means to evaluate the skills of nozzle men with respect to shotcrete consolidation and reinforcing bar encapsulation in the standardized test panel. Although it is still a subjective method, it allows consistent grading among ACI Examiners with proven experience in the shotcrete field. Therefore, each of the test panels shot by the nozzleman examinee is cored and inspected for quality of reinforcement encapsulation and rebound control. The size (length and diameter) of the cores, the five (5) core locations in the panel, the size and configuration of the reinforcing steel and the size of the panels are consistent parameters important for a standardized certification program (Fig. 8).

It should be noted that a total of five cores are graded using these criteria at specific locations in each test panel. A test panel with any single core grade with a grade of No. 4 or No. 5, or with more than two of the five cores having a core grade No. 3 is declared a failure. Averaging of core grades is not permitted. Definitions of core grades No. 1 to 5 are provided in the Program Policy (ACI 2015).

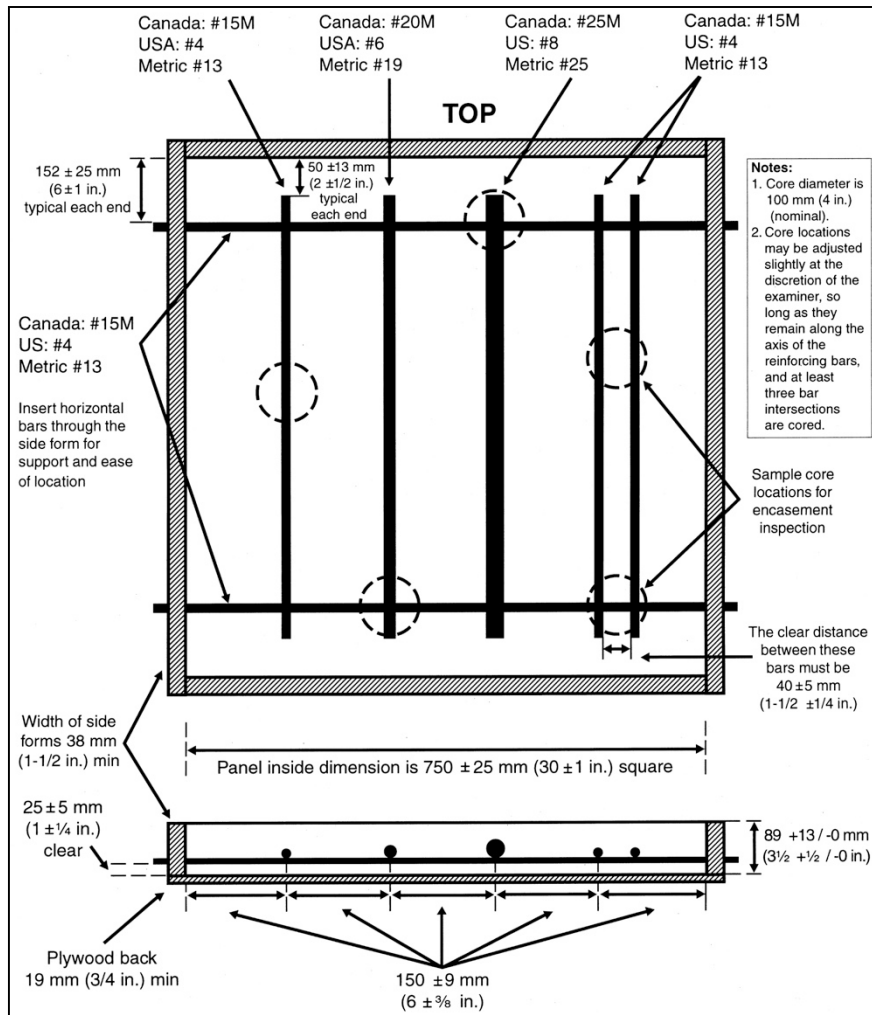


Figure 8: Standard ACI Shotcrete Nozzleman Certification Panel (2015).

A recent update to the policies also include an improved *core grading* appendix. While the current system only addresses rebar encapsulation, it often does not address properly other defects within the cores. The objective is to offer numerous visual support examples including evidence and size of sand lenses, pockets and voids in order to provide better analysis in the examiner's reports to ACI.

As an example, a core grade No. 3 can be hard to evaluate and may display different defect patterns (Fig.9). This new document will be used as guidance to improve accuracy and consistency during the visual examination, and to help all ACI examiners coming from different locations throughout North America. This document is now an appendix to the current policies.

CORE GRADE 3



Dry-mix shotcrete, #4 bar, sand lenses.



Dry-mix shotcrete, #8 bar, one important void directly behind rebar, smaller than 1/4 dept and 3/4 in long.



Dry-mix shotcrete, intersection #4 bars, mid size void too large to be a Core Grade #2.



Dry-mix shotcrete, intersection #4 bars, linear defect from bar extending to back of panel. No interconnection detected or void against panel.

Core Grade 3: Shotcrete specimens shall have no more than two laminations or sandy areas with dimensions exceeding 3/16 in. thick by 1 1/4 in. long, or one major void, sand pocket, or lamination containing loosely bonded sand not to exceed 5/8 in. thick and 1 1/4 in. in width. The surface against the form or bond plane may be sandy with voids containing overspray to a depth of 1/16 in.

Figure 9: Example of visual support in Core Grade appendix of Policies– ACI Shotcrete Nozzleman Certification (#4 bars are 13 mm in diameter, #8 bars are 25 mm in diameter; 1 in. is equal to 25.4 mm)

6. Nozzleman experience requirements

In order to attempt the certification program, a nozzleman must document 500 hours of work experience as a nozzleman, with with at least 100 hours in the process (wet- or dry-) and orientation (vertical & overhead) for which certification. This work experience is then reviewed and verified by the examiner of records.

A recent addition to the program is the *Nozzleman-in-Training* category. This new category allows the starting nozzleman who can show at least 25 hours of work experience to participate in the full certification program. They must take the full day ASA classroom education, and ACI written exam and performance exam(s) in the shotcrete processes and orientations they are pursuing certification in. Upon successful completion, they receive a Nozzleman-In-Training (NIT) card issued by ACI. Completion of the remaining field experience hours to reach the minimum of 500 required for full nozzleman certification

should be under the supervision of an ACI-certified nozzleman, essentially as an apprentice. The NIT is required to maintain a detailed log to record hours placed until they accumulate the required minimum of 500 hours for full certification. They have 5 years to accumulate and document the additional hours of field shooting experience. Upon completion of the minimum of 500 hours, within 5 years, they must obtain their employer's sign off and submit the entire log to their sponsoring group for verification by the examiner-of-record. Upon verification, they may be upgraded to a certified ACI Shotcrete Nozzleman in the process(es) and orientation(s) reflected in the verified work experience for the remainder of the original NIT certification term. After the original 5-year certification these individuals would then qualify for recertification and follow the procedures for ACI certified nozzlemen. If they are not able to submit the remaining 500 hours prior to their 5 year anniversary, they will no longer be searchable in the ACI verification site and can either wait until 500 hours are met to test for full nozzleman certification or retake the exams for another five years to complete the hours within the NIT designation.

A key element of this is the *Nozzleman-In-Training Log* which is a project-based record of placement hours. Each project requires a project page followed by the Nozzleman-In-Training Project Shooting Log which details their shotcrete placement experience. Each entry should give details such as project name and location, type of work, process used, description of equipment (hose diameter and length, pump/gun type, nozzle, air compressor), hours of nozzling, etc. Each NIT card holder must maintain this log to document their experience until they reach the requisite 500 hours to upgrade to full nozzleman certification.

7. Shotcrete Nozzleman Education and Certification around the World

A series of articles illustrating available nozzleman education and certification programs in Europe, South Africa, South America, and Australia have been published and presented at previous conferences (Boniface 2008, Larive 2009, Teofilusson 2011). Recently, computer based virtual environment have even been developed to further improve the training and understanding of underground shotcrete nozzlemen (Teofilusson 2011).

The quality of shotcrete is highly dependent on the skill of the Nozzleman. Excellent education and certification programs around the world are available to continually improve the quality of shotcrete placement leading to better quality work. Regardless of the industry type (civil, repair, structural work, tunneling, mining, pool and spa construction, etc.), we shall all use these available tools to improve knowledge and awareness of the shotcrete process. As an industry, we have set the bar high, but collectively, we can raise it even higher!

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