

GUIDE TO CERTIFICATION OF SHOTCRETE NOZZLEMEN

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This is a guide for a means of certifying wet mix and dry mix shotcrete nozzlelemen for application of several but not all types of shotcrete. Certification procedure includes a learning and training period, a written/oral examination, and a workmanship demonstration.

Keywords: certification; evaluation; examinations; placing; refractory shotcrete; shotcrete; structural shotcrete; tanks (containers); training courses; underground shotcrete.

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ACI Committee Reports, Guides, Standard Practices, and Commentaries are intended for guidance in designing, planning, executing, or inspecting construction and in preparing specifications. Reference to these documents shall not be made in the Project Documents. If items found in these documents are desired to be part of the Project Documents, they should be phrased in mandatory language and incorporated into the Project Documents.

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This report supersedes ACI 506.3R-82, effective Nov. 1, 1991. A number of minor revisions have been made to the report. Several key references have been added and existing references have been updated. The document has been reformatted and reorganized for enhanced clarity.

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CHAPTER 1 -- INTRODUCTION

1.1 -- Purpose of nozzleman certification

This guide has been prepared to assist those specifiers, public agencies, shotcrete applicators, shotcrete users, testing laboratories, and others who may find it desirable to broaden their own knowledge and/or to establish a procedure for training and certification of shotcrete nozzlemen. Since at this time, no official certification programs based on this guide are recognized, modifications in procedure and questionnaires to suit local requirements are encouraged. Nothing included herein is mandatory, this being only a guide with the goal of eventual establishment of a uniform national certification program for shotcrete nozzlemen.

Training and examining personnel will find the bibliography and certification procedure in the guide to be helpful tools in any educational program to: (1) train new nozzlemen and other members of the shotcrete crew; or (2) increase the knowledge and broaden the capabilities of their trained personnel to possibly include additional types of shotcrete applications. This guide does not imply that an individual nozzleman is required to prepare himself unaided for certification, although that possibility is not precluded. It is the intent that qualified personnel, with the aid of this guide, references included herein, and other experience, will train and prepare candidates for certification.

1.2 - Available procedure for testing nozzlemen

ACI 506R, Chapter 3 -- Preconstruction testing, or

paragraph 1.6.4.2 of ACI 506.2, provides testing procedures to be conducted prior to the start of shotcrete construction, to check the operation of the equipment and the workmanship of the application crew, particularly the shotcrete nozzleman. Preconstruction testing may be required for any type of shotcrete construction. It should verify the ability of the nozzleman to apply the quality of shotcrete specified for the particular job.

Although the procedure is available to pretest the ability of a nozzleman on a shotcrete project, it may also be desirable to require that the nozzleman be certified to be knowledgeable and to have previously demonstrated his ability to apply a specific type of shotcrete. The presence of a certified nozzleman should not preclude a degree of preconstruction testing, but should provide increased assurance that the shotcrete applicator will be able to apply the specified quality of shotcrete. Furthermore, having a certified nozzleman available for small projects may justify the elimination of all or part of the somewhat costly and time-consuming preconstruction testing.

Until a reasonable number of nozzlemen have been certified, the owner and specifier should carefully weigh the cost and time required to certify a nozzleman against the size and cost of a shotcrete project, before specifying that a certified nozzleman be used on the project.

CHAPTER 2 -- CERTIFICATION PROCEDURE

2.1 -- General

The certification procedure should be divided into two parts: (1) a training and study period; and (2) the certification examination, which consists of a written (or oral) examination and a field demonstration test.

2.2 -- Training and study period

The applicable publications listed in the bibliography found in Appendix A should be available to certification examiners and examinees prior to the certification examination. Answers to most of the questions asked in the certification examination written test are in the bibliography publications.

2.3 -- Certification examination

The certification examination should be conducted by qualified personnel of an independent testing laboratory, materials bureau, local ACI Chapter, or the testing laboratory of a public agency. The testing laboratory or materials bureau should issue the actual certification, which should be valid for a stated period of two or three years. The nozzleman may renew his certification by repeating the entire examination or, at the option of the certification examiner, by repeating the workmanship demonstration only.

The examination may be adapted to certify dry mix or wet mix shotcrete nozzlemen in the following types of shotcrete applications:

- a) Structural
- b) Refractory
- c) Underground
- d) Prestressed Tanks
- e) Special Products -- Fiber-reinforced shotcrete, latex modified shotcrete, and others as the need develops.

It is recommended the examination consist of two parts, a written (or oral) test, and a field workmanship demonstration.

2.4 -- Written test

The written test offered herein is divided into three sections. The questions in the first section are based on general shotcrete practice. The second section of the test presents specific questions on the particular types of shotcrete for which the examinee may be certified. The third section of the test presents specific questions on the particular types of shotcrete application for which the examinee may be certified.

1. General Questions: Ten questions may be selected in part or entirely from the questions listed in Appendix B.
2. Specific Type Shotcrete Questions: Fifteen or more questions may be selected in part or entirely from the questions listed in Appendixes C (Dry Mix), or D (Wet Mix).
3. Specific Type Application Questions: Fifteen or more questions may be selected in part or entirely from the questions listed in Appendixes E, F, G, and H.

The certification examiner may give this test either orally or written.

2.5 -- Workmanship demonstration

2.5.1 General -- The examinee should be required to demonstrate his ability to correctly and successfully apply the type of shotcrete for which he will be certified. Effective nozzling is a skill learned from experience and is physically demanding. Only persons who are physically able and experienced should be allowed to take the exam.

A test panel or test area, simulating a surface suitable for the type of shotcrete for which the examinee is to be certified, should be shot by the examinee using the equipment, materials, mix proportions, and reinforcement normally used for the particular type of shotcrete. The test panel or area should be a minimum of 4 ft. (1.2 m) square to allow the examinee to adequately demonstrate his ability. Provision may be made to accumulate and measure rebound from the panel or test area.

Certification requirements may vary from different types of shotcrete, and the certification examiner should consult with the shotcrete applicator to establish the

proper type of shooting surface for the test panel or area, the proper thickness of the shotcrete application to correlate with acceptable core or cube dimensions, mix proportions for dry mix or concrete proportion mix for wet mix, and normal reinforcement requirements.

The test panel or area should be checked by the certification examiner to verify that the forms are adequately braced, reinforcing steel bar laps are spaced $2\frac{1}{2}$ bar diameters apart, mesh is lapped $1\frac{1}{2}$ squares, reinforcement is properly spaced and rigidly tied and secured to avoid movement during the shotcrete operation, and shooting surfaces and reinforcement are clean and properly prepared to receive shotcrete application.

2.5.2 Test panel requirements -- The surface to be shot against, anchorages, reinforcement, panel orientation (vertical, horizontal, or overhead), total sample thickness, material, and mix shall duplicated job requirements as nearly as practical.

2.5.3 Materials for the demonstration test -- The certification examiner may refer to ACI 506R-90, Chapter 2 -- Materials, as a guide for quality requirements for shotcrete materials. The certification examiner should consult with the shotcrete applicator to establish the materials and mix proportions for the test.

2.5.3.1 Mixture proportions -- If sufficient data are available from previous tests of the materials, shotcrete mixture proportions may be selected from such data to produce a given compressive strength.

If insufficient or no previous data are available, at least three shotcrete control test panels with a minimum thickness of 3 in. (75 mm) should be shot by an experienced nozzleman using different proportions. Cores or cubes taken from the test control panels shall be removed and tested in accordance with ASTM C 42. See paragraph **2.5.8** for additional requirements.

Based on the compressive strength achieved by the cores or cubes taken from the test control panels, a mixture proportion should be selected for the test which should produce shotcrete with a 28-day compressive strength of at least 4000 psi (27.5 MPa). Core strengths should be corrected to an L/D of 2 in accordance with ASTM C 42 and cube strengths should be reduced by 15 percent in accordance with ACI 506.2. Compressive strength and setting time requirements for refractory test panels differ from other mixes. Where quick-setting additives or comments are used, compressive strength and setting time may be adjusted to test for initial set time and initial strength in addition to ultimate compressive strength.

2.5.4 Equipment for the demonstration test -- The test should be conducted using equipment of a design and size normally used for the specified type of shotcrete. The certification examiner may refer to ACI 506R, Chapter 4 -- Equipment Requirements, as a guide for recommended equipment requirements for either the dry mix process or the wet mix process.

2.5.5 Shotcrete crew -- A competent crew, including an experienced gunman or pump operator, nozzle helper,

and possibly a finisher, should be provided to assist the nozzleman examinee in his demonstration.

2.5.6 Shooting the test panel or area -- The certification examiner should carefully observe shooting of the test panel or area, and note if the nozzleman examinee:

1. Cleans shooting surface with air and water prior to shooting.
2. Applies bonding coat on shooting surface ahead of heavier shotcrete applications.
3. Directs shotcrete application around reinforcement in a manner which prevents buildup on face of reinforcement and allows shotcrete to flow and compact tightly around back and remainder of reinforcement.
4. If applicable, directs finisher or nozzle helper to cut out any sags or sand pockets.
5. If applicable, and where necessary, directed finisher or nozzle helper to broom shotcrete surface prior to application of additional layer of shotcrete. Notes, photographs, or other documentation made by the certification examiner during gunning of the test panel or area will be helpful later in testing and analyzing the test panel or area.

2.5.7 Curing -- The test panel or area should be properly cured in accordance with ACI 506R, Chapter 6-- paragraph 6.4 -- Curing and Cold Weather Protection, and ACI 506.2, paragraph 3.7.

Curing requirements for refractory shotcrete panels should be in accordance with ACI 547R.

2.5.8 Testing and analysis of test panel or area -- Tests and observations of the test panel or area will be used to evaluate the workmanship demonstration.

A minimum of six cores or cubes should be cut from the panel or test area. Three cores or cubes cut through unreinforced sections of the test panel or area should be subjected to compressive strength tests. Test results will be compared with the compressive strength requirement established for the test. At least three cores or cubes should be cut through the reinforcement for analysis of quality and extent of shotcrete encasement. All cores or cubes should be examined for evidence of sand pockets, voids, and sags.

Where applicable, the stripped side of the panel should also be examined for evidence of sags, sand pockets, and lack of bonding coat. Corners and other sections of the panels or areas should be cut or broken open for observation of laminations, sand lenses, or other defects.

The certification examinee should be allowed to examine the cores or cubes and cut or broken sections of the test panel or area.

CHAPTER 3 -- EVALUATION OF THE CERTIFICATION EXAMINATION

The value of the three segments of the examination may be weighted as follows:

Written or Oral Examination

- | | |
|------------------------------|--------------|
| 1. General Questions | - 10 percent |
| 2. Specific Type Questions | - 15 percent |
| 3. Specific Use Questions | - 15 percent |
| 4. Workmanship Demonstration | - 60 percent |

The examinee should attain an overall 70 percent grade to pass, with not less than a 60 percent grade in any single segment of the examination.

Allow 100 points for both the general and each of the specific question segments, making the value of each question correspond with the total number of questions used to achieve 100 points.

The examinee shall achieve a passing grade in the written or oral examination before he is allowed to proceed with the workmanship demonstration.

Allow 100 points for the workmanship demonstration test. Deduct points for unsatisfactory parts of shotcrete application as noted below. All items should be evaluated and graded.

1. Compressive strength tests -- Average strength of three cores or modified cube results below strength established for test -- deduct SO points
2. Encasement of reinforcement -- Sandy pockets or voids around or behind reinforcement or sags under horizontal reinforcement -- deduct 15 points
3. Sand pockets or voids in corners of panels -- deduct 1-7 points
4. Sags or sandy pockets apparent on stripped sides or backs of panels -- deduct 1-7 points
5. Sand lenses within the destroyed panel -- deduct 1-7 points
6. Failure of nozzleman to clean shooting surface with air and water prior to shotcrete application -- deduct 1-7 points
7. Excessive rebound -- Local shotcrete testing requirements may make it necessary to include measurement of rebound from a test panel or area as part of the test. Any deductions of points for excessive rebound should be made in accordance with value established locally for allowable amount of rebound -- deduct 1-7 points