





American Concrete Institute®
Advancing concrete knowledge

Introduction of Revised Specification for Shotcrete and Other Shotcrete Development

**ACI Spring 2012 Convention
 March 18 – 21, Dallas, TX**

ACI
 WEB SESSIONS

Principal Ragland, Aderman & Associates, Inc., Consulting Engineers in Baton Rouge LA. Mr. Ragland has 40 years of experience working on complex structural projects. Licensed Professional Engineer in eight states. Expertize is specialized in design of repair of structures undergoing the effects of chemical attack and harsh environments in Industrial Plants. Member of ACI Technical Committees 506, Shotcrete and 563, Specification of Repair of Structural Concrete for Buildings. Member of NACE Technical Committee Corrosion Associated with Concrete. Mr. Ragland has presented at ACI, ASCE, NACE, and SSPC meetings. Presented "Repair of Columns, Beams and Slab Soffits in Difficult Industrial Plant Environments Using Shotcrete," at the ACI Fall Convention, Chicago, Illinois, October 1985.

ACI
 WEB SESSIONS

Quality Assurance Guidance For Encapsulation of Reinforcing Steel

ACI 506.2 - Specifications for Shotcrete

Dallas, March 2012

James A. Ragland, PE
 Ragland, Aderman & Associates,
 Structural Engineers

Member, Subcommittee 506.2

Encapsulation from Structural Engineer's Perspective - Challenging

Preparation of Contract Documents and Specification of Quality Assurance

IBC 2009 - The International Building Code
 Maximum size reinforcement shall be # 5 bars unless demonstrated adequate.

506.2 Prior to 1995 – Simple Specification
 Certification performed by engineers and contractors
 Engineers had to learn the basics or depend on contractors

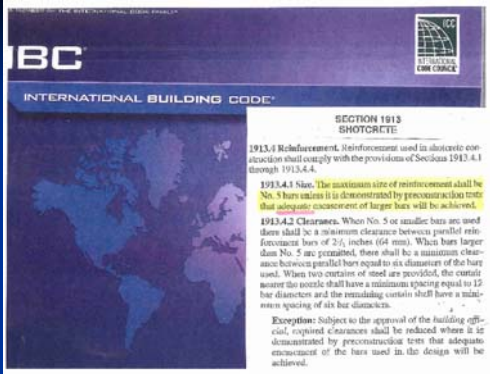
506.2-95 Currently in effect
 Core grading introduced for purpose of nozzleman testing on panels.
 Encapsulation acceptance problems:

- Specifiers selected highest quality regardless of project
- Core grading incorrectly applied for acceptance criteria
- Core grading method of void calculations flawed.

ACI C660 – ACI Nozzleman Certification - 2001

506.2-XX-Pending – Defers Acceptance Criteria to Engineer

506 Shotcrete Documents - Future Direction



IBC
 INTERNATIONAL BUILDING CODE®

**SECTION 1913
 SHOTCRETE**

1913.1 Reinforcement. Reinforcement used in shotcrete construction shall comply with the provisions of Sections 1913.4.1 through 1913.4.4.

1913.4.1 Size. The maximum size of reinforcement shall be No. 5 bars unless it is demonstrated by preconstruction tests that adequate encasement of larger bars will be achieved.

1913.4.2 Clearances. When No. 5 or smaller bars are used there shall be a minimum clearance between parallel reinforcement bars of 2½ inches (64 mm). When bars larger than No. 5 are permitted, there shall be a minimum clearance between parallel bars equal to six diameters of the bars used. When two courses of steel are provided, the center-to-center of the nozzles shall have a minimum spacing equal to 12 bar diameters and the remaining surface shall have a minimum spacing of six bar diameters.

Exception: Subject to the approval of the building official, exposed clearances shall be reduced where it is demonstrated by preconstruction tests that adequate encasement of the bars used in the design will be achieved.

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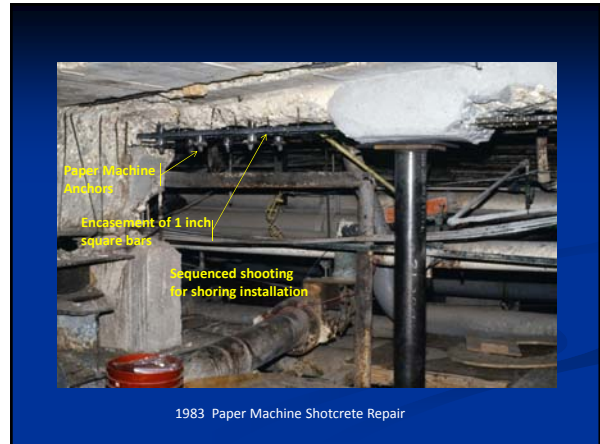
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1983 Paper Machine Project – Nozzleman Certification per ACI 506.2-77



1983 Paper Machine Shotcrete Repair

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ACI 506.2-95 Core Grading

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506 Shotcrete Documents - Future Direction





Dock Girders Overhead – ACI Certified Nozzleman – Not Approved



Sulfur Pit Walls – #8 with Stainless Fibers Certified Nozzleman



Sulfur Pit - #8 with Stainless Fibers Certified Nozzleman Not Approved



Owner Selected Shotcrete Contractor

Encapsulation from Structural Engineer's Perspective - Challenging Preparation of Contract Documents and Specification of Quality Assurance

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[506 Shotcrete Documents - Future Direction](#)

FUTURE GUIDE DOCUMENT - PRELIMINARY

TABLE XXX- QUALITY ASSURANCE FOR SHOTCRETE

SHOTCRETE APPLICATION DIFFICULTY	SCOPE OF PROJECT SPECIFICATION	PRE-CONSTRUCTION TESTING	CONSTRUCTION TESTING
DIFFICULTY LEVEL 1			
Performance by an <u>unapproved</u> nozzleman certified for the type and shooting position of the project will be needed to meet project acceptance criteria. Standard preconstruction and construction phase Q.A. testing recommended to confirm the shotcrete quality. Examples are: thick sections requiring multiple passes, sections with large reinforcing steel, closely spaced steel, steel face.	Reference ACI 506.2. Specify the mandatory requirements. Submit of Nozzleman ACI C660 certification. Submit of crew and nozzleman experience on similar projects. Specify pre-construction testing. Allow waiver based on evaluation of experience.	Pre-construction testing is optional.	Periodic field inspection and testing (recommended as needed) to document overall construction quality.
DIFFICULTY LEVEL 2			
Performance by an <u>approved</u> nozzleman certified for the type and shooting position of the project may not be sufficient to assure the owner of a successful shotcrete application. Preconstruction and construction testing is required to verify that nozzleman and crew are qualified shot project. Examples are structurally critical reinforcement or large diameter bars, projects of extremely difficult access conditions such as industrial plant environments.	Specify Acceptance Criteria for defects and steel encapsulation, refer to ACI 506.2B-XX. Specify pre-construction testing of mock up or demonstration segment relevant to the special features and difficulty of the project. Specify Acceptance Criteria for defects and steel encapsulation for the specific project. Specify Owner's representative or party responsible for evaluation of testing.	Plan preconstruction test panels for the project shooting position. Panels to contain the largest diameter steel for the project. Evaluation of the nozzleman & crew during shooting preconstruction test panels by a qualified shotcrete evaluator is optional, dependent on the difficulty and importance of the project. Test specimens for compliance with specified physical properties. Evaluate acceptance of core or saw-cut samples for presence of voids, sand holes and steel encapsulation to the level specified.	Plan frequency of inspection by qualified shotcrete inspector based on project difficulty, level of contractor experience and compliance on similar projects. Inspect surface preparation and steel placement prior to shotcrete application. For repairs and overlays, test surface preparation of bond surface. For multi-pass layers, check condition of hardened surface. Inspect completed surfaces, sound for delaminations. Proceed to further testing in suspect areas. Evaluate strength of construction phase test panels.
DIFFICULTY LEVEL 3			
Performance by an <u>approved</u> nozzleman certified for the type and shooting position of the project may not be sufficient to assure the owner of a successful shotcrete application. Preconstruction and construction testing is required to verify that nozzleman and crew are qualified shot project. Examples are structurally critical reinforcement or large diameter bars, projects of extremely difficult access conditions such as industrial plant environments.	To Level 1 and 2 above, add project specific requirements, include the following: Specify pre-construction testing of mock up or demonstration segment relevant to the special features and difficulty of the project. Specify Acceptance Criteria for defects and steel encapsulation for the specific project. Specify Owner's representative or party responsible for evaluation of testing.	Prepare mock up or demonstration segment of structure for preconstruction testing. Incorporate project specific difficulties including complicated reinforcing to be embedded. Evaluate the nozzleman & crew during shooting of preconstruction test panels by a qualified shotcrete evaluator. Evaluate acceptance of core or saw-cut samples for presence of voids, sand holes and steel encapsulation.	Plan full time construction phase inspection by qualified shotcrete inspector. Evaluate strength of construction phase test panels. Core pre-selected non-structurally critical locations. Evaluate core acceptance of presence of voids, sand holes and steel encapsulation. Recommend acceptance based on specified acceptance criteria.

SHOTCRETE APPLICATION DIFFICULTY

DIFFICULTY LEVEL 1
An ACI certified nozzleman should assure acceptable quality.

- Periodic quality assurance inspection and testing recommended. Examples:
 - Lightly reinforced sections,
 - Thin sections
 - Non-critical applications.
- A Nozzleman in Training may be allowed provided the NIT works under the direct supervision of a experienced certified nozzleman of the same discipline.

DIFFICULTY LEVEL 2
Performance by an experienced nozzleman certified for the type and shooting position of the project will be needed to meet project acceptance criteria.

- Standard preconstruction and construction phase Q.A. testing is recommended to confirm the shotcrete quality. Examples are:
 - Thick sections requiring multiple passes;
 - Sections with large reinforcing steel;
 - Closely spaced steel and bar laps;
 - Overhead
 - Bond critical

SHOTCRETE APPLICATION DIFFICULTY

DIFFICULTY LEVEL 3
Performance by an experienced nozzleman certified for the type and shooting position of the project may not be sufficient to assure the owner of a successful shotcrete application.

- Preconstruction and construction testing is required to verify that nozzleman and crew are qualified to shoot project.
- Examples are:
 - Structurally critical embedment of large diameter bars;
 - Projects of extremely difficult access conditions such as industrial plant environments;
 - Seismic structural conditions;
 - Timing and placement, difficult ground conditions;
 - Pre-contract qualification of shotcrete method for unusually complex projects;

SCOPE OF PROJECT SPECIFICATION

DIFFICULTY LEVEL 1
Reference ACI 506.2. Specify the mandatory requirements.

DIFFICULTY LEVEL 2
Reference ACI 506.2. Specify the mandatory requirements. Add project specific requirements, include the following:

- Submittal of Nozzleman ACI C660 certification;
- Submittal of contractor, foreman and nozzleman experience on similar projects
- Specify pre-construction testing; allow waiver based on evaluation of experience;
- Specify surface preparation and bond testing where applicable;
- Specify Acceptance Criteria for defects and steel encasement
 - Refer to upcoming revision ACI 506.4-XX Evaluation of Shotcrete
 - Refer to Tech Note - Method for Evaluation of Encapsulation
 - Refer to Tech Note – Visual/Picture Guide of Core Evaluation

DIFFICULTY LEVEL 3
To Level 1 and 2 above, add project specific requirements, include the following:

- Specify pre-construction testing of mock up or demonstration segment relevant to the special features and difficulty of the project.
- Refer to ACI 506.X-XX, Qualifications for Specific Shotcrete Projects.
- Specify Acceptance Criteria for defects and steel encasement adjusted for the specific project difficulties.
 - Refer to upcoming revision ACI 506.4-XX Evaluation of Shotcrete
 - Refer to Tech Note - Method for Evaluation of Encapsulation
 - Refer to Tech Note – Picture Guide of Core Evaluation

FUTURE TECH NOTE - PRELIMINARY
TECHNICAL NOTE – EVALUATION OF CORES

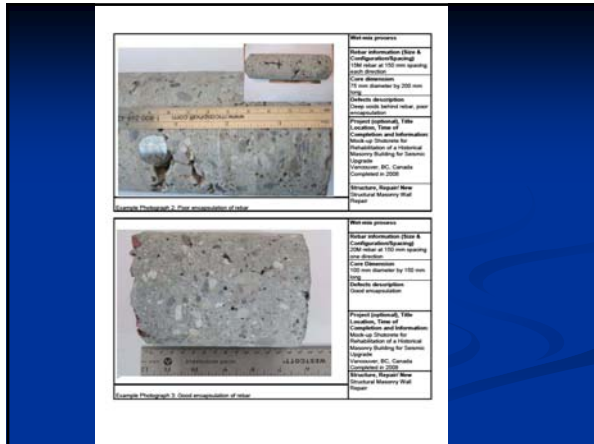
Evaluation is based on degree of encapsulation of steel and the size and location of voids.

- Cores are graded in broad categories for each criteria.
- The contract documents should specify a minimum grade category for acceptance.
- For a specific core grade, all 3 criteria (a, b, and c) should be satisfied.
- Based on project conditions, the specifier may chose additional latitude.

CRITERIA	Excellent Very good	Good to very good	Fair	Poor
a Encapsulation of reinforcing steel as a % of the circumference of the bar (any individual bar cross-section or total of all bars in the core);*	90	85 to 90	75 to 80	<75
b Maximum size ** of any void touching the reinforcing bar, as a percentage of the cross-section of that bar; and	25%	30%	35%	>35%
c Maximum total area*** of other voids, as a percentage of the total cylindrical surface area of the core****.	10%	15%	20%	>20%

FUTURE TECH NOTE

Cores will be grouped according to difficulty level and rating.



The Challenges of Core Grading

PRE-CONSTRUCTION TESTING

DIFFICULTY LEVEL 1

- No preconstruction testing required.

DIFFICULTY LEVEL 2

- Document contractor experience is appropriate for plan preconstruction test panels for the project shooting position.
- When preconstruction tests are needed,
 - Design panels to contain the largest diameter steel for the project.
 - Observe the nozzleman & crew during shooting of preconstruction test.
 - Test specimens for compliance with specified physical properties
 - Evaluate acceptance of cored or saw-cut samples for presence of voids, sand lenses and rebar encapsulation to the level specified

DIFFICULTY LEVEL 3

- Document contractor experience is appropriate.
- Prepare mock up or demonstration segment of structure for preconstruction testing. Incorporate project specific difficulties including complicated reinforcing to be embedded.
- Evaluate the nozzleman & crew during shooting of preconstruction test panels.
- Evaluate acceptance of cored or saw-cut samples for presence of voids, sand lenses, poorly consolidated material and rebar encapsulation.

CONSTRUCTION TESTING

DIFFICULTY LEVEL 1

- Periodic field inspection and testing recommended as needed to document overall construction quality.

DIFFICULTY LEVEL 2

- Plan frequency of inspection by qualified inspector based on project difficulty, level of contractor experience and competence on similar projects.
- Inspect surface preparation and steel placement prior to shotcrete application.
- In bond critical areas such as repairs and overlays, test surface preparation of bond surface.
- For multi-pass layers, check condition of hardened surface.
- Inspect completed surfaces, sound for delaminations. Proceed to further testing in suspect areas.
- Evaluate strength of construction phase test panels.

DIFFICULTY LEVEL 3

- Plan full time construction phase inspection by qualified shotcrete inspector.
- Evaluate strength of construction phase test panels.
- Core pre-selected non-structurally critical locations. Evaluate core acceptance of presence of voids, sand lenses and rebar encapsulation. Recommend acceptance based on job specific acceptance criteria.

California Memorial Stadium
Berkeley, CA




Preconstruction Test Panel

Test Panel Cores

California Memorial Stadium
Berkeley, CA



Scaffold Setup of Historic Wall

California Memorial Stadium Berkeley, CA



Shotcrete Operation on Historic Wall

California Memorial Stadium Berkeley, CA



Finished Shotcrete Historic Wall

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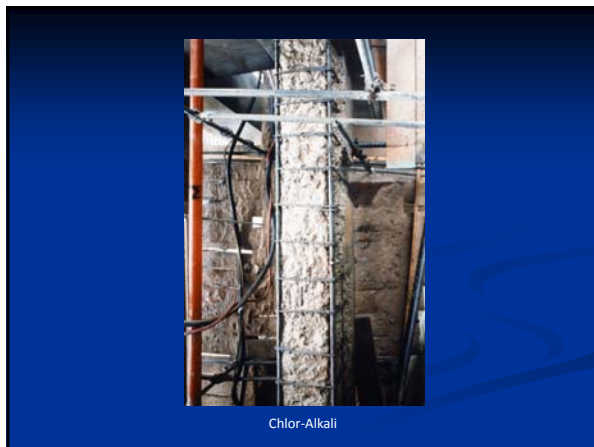
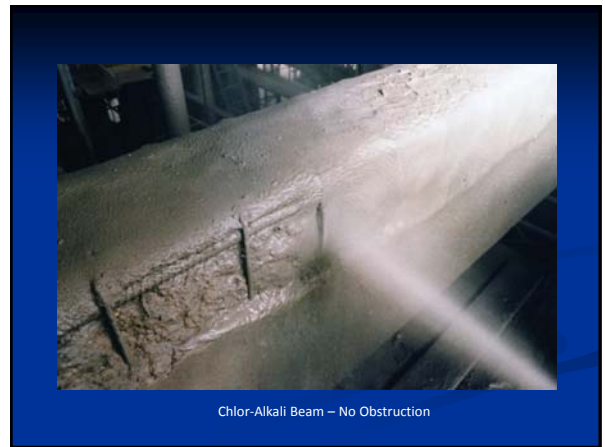
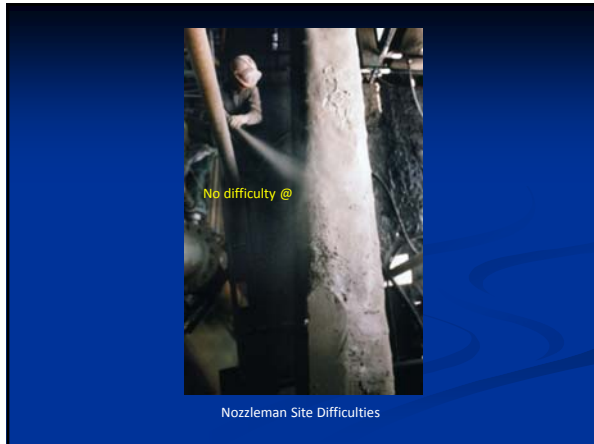
506 Shotcrete Documents - Future Direction

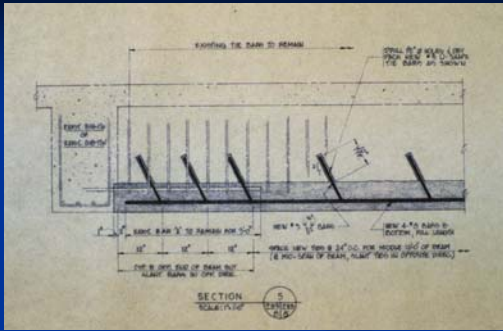


1983 - Experienced ACI 506 Member Certifier & Inspector
Difficult Paper Machine Project



Nozzleman Site Difficulties





Paper Machine – Design Change



Shot Below & Above White Water Pit

