ACI WEB SESSIONS

Introduction of Revised Specification for Shotcrete and Other Shotcrete Development

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

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.

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
**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 experienced engineers and contractors
- Engineers had to learn the basics or depend on contractors

**506.2-95 Currently in effect - 2012**
- Core grading introduced for purpose of nozzleman testing on panels.
- Encapsulation acceptance problems:
  - Specifiers select highest quality regardless of project
  - Core grading incorrectly applied for acceptance criteria
  - Core grading method of void calculations flawed.

**ACI C660 – ACI Certified Nozzleman - 2001**

**506.2-XX-Pending – Defers Acceptance Criteria to Engineer**

**506 Shotcrete Documents – Future Direction**
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 Certified Nozzleman 2001

506.2-XX Pending – Defer Acceptance Criteria to Engineer

506. Shotcrete Documents - Future Direction

<table>
<thead>
<tr>
<th>SHOTCRETE APPLICATION DIFFICULTY</th>
<th>SCOPE OF PROJECT SPECIFICATION</th>
<th>PRE-CONSTRUCTION TESTING</th>
<th>CONSTRUCTION TESTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIFFICULTY LEVEL 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specified acceptance criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specify Acceptance Criteria for defects and steel reinforcing to be embedded.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIFFICULTY LEVEL 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specified acceptance criteria</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specify Acceptance Criteria for defects and steel reinforcing to be embedded.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE XXX - QUALITY ASSURANCE FOR SHOTCRETE

Dock Girders Overhead – ACI Certified Nozzleman – Not Approved

Sulfur Pit Walls – #8 with Stainless Fibers
Certified Nozzleman

Owner Selected Shotcrete Contractor

Sulfur Pit – #8 with Stainless Fibers
Certified Nozzleman Not Approved
**SHOTCRETE APPLICATION DIFFICULTY**

**DIFFICULTY LEVEL 2**
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 testing may be allowed provided the T/E works under the direct supervision of a experienced certified nozzleman of the same discipline.

**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 phase QA 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

---

**SCOPE OF PROJECT SPECIFICATION**
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 C060 certification.
- Submittal of contractor, foreman and nozzleman experience on similar projects.
- Specify preconstruction 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 – Methods for Evaluation of Encapsulation
- Refer to Tech Note – Visual/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.
- Core 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 choose additional latitude.

<table>
<thead>
<tr>
<th>CRITERIA</th>
<th>Excellent Very Good</th>
<th>Good to Very Good</th>
<th>Fail</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>90-85</td>
<td>75-70</td>
<td>60</td>
<td>&lt;55</td>
</tr>
<tr>
<td>2</td>
<td>25%</td>
<td>30%</td>
<td>35%</td>
<td>&gt;35%</td>
</tr>
<tr>
<td>3</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
<td>&gt;20%</td>
</tr>
</tbody>
</table>

---

**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 506.4-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**
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.
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 Certified Nozzleman
506.2-XX-Pending – Defers Acceptance Criteria to Engineer
506 Shotcrete Documents - Future Direction

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

Nozzleman Site Difficulties
Nozzleman Site Difficulties

Paper Machine Shotcrete In Progress

Chlor-Alkali Plant

Chlor-Alkali Beam – No Obstruction

Chlor-Alkali

Paper Machine Excessively Difficult
Paper Machine – Design Change

Shot Below & Above White Water Pit