### Attendance Sheet

<table>
<thead>
<tr>
<th>Name</th>
<th>Employer</th>
<th>Email Address</th>
<th>Phone Number</th>
<th>Committee Member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Vinik</td>
<td>FL DOT</td>
<td><a href="mailto:gsmith@aashto.org">gsmith@aashto.org</a></td>
<td>512-606-5821</td>
<td>X</td>
</tr>
<tr>
<td>Greta Smith</td>
<td>AASHTO</td>
<td><a href="mailto:jerry.petersen@txdot.gov">jerry.petersen@txdot.gov</a></td>
<td>512-606-5821</td>
<td></td>
</tr>
<tr>
<td>Jerry Peterson</td>
<td>TXDOT</td>
<td><a href="mailto:edward.hughes@illinois.gov">edward.hughes@illinois.gov</a></td>
<td>217-782-4689</td>
<td>X</td>
</tr>
<tr>
<td>Ed Hughes</td>
<td>IL DOT</td>
<td><a href="mailto:dave.meggers@kdot.org">dave.meggers@kdot.org</a></td>
<td>785-291-3840</td>
<td></td>
</tr>
<tr>
<td>Dave Meggers</td>
<td>KS DOT</td>
<td><a href="mailto:kenneth.spadar@tn.gov">kenneth.spadar@tn.gov</a></td>
<td>615-820-4175</td>
<td>X</td>
</tr>
<tr>
<td>Kenny Spadar</td>
<td>OK DOT</td>
<td><a href="mailto:kenneth.spadar@tn.gov">kenneth.spadar@tn.gov</a></td>
<td>615-820-4175</td>
<td></td>
</tr>
<tr>
<td>Danby Lane</td>
<td>Tenn DOT</td>
<td><a href="mailto:david.lane@tn.gov">david.lane@tn.gov</a></td>
<td>615-820-4175</td>
<td>X</td>
</tr>
<tr>
<td>celery Sturgill</td>
<td>MS DOT</td>
<td><a href="mailto:david.lane@tn.gov">david.lane@tn.gov</a></td>
<td>615-820-4175</td>
<td></td>
</tr>
<tr>
<td>David Ketzer</td>
<td>S DOT</td>
<td><a href="mailto:david.ketzer@dot.state.co.uk">david.ketzer@dot.state.co.uk</a></td>
<td>703-332-6506</td>
<td>X</td>
</tr>
<tr>
<td>Dave Kuniega</td>
<td>DENN DOT</td>
<td><a href="mailto:rick.davis@ag.gov">rick.davis@ag.gov</a></td>
<td>717-787-3966</td>
<td></td>
</tr>
<tr>
<td>Rick Davis</td>
<td>GA DOT</td>
<td><a href="mailto:peter.kemp@dot.state.co.uk">peter.kemp@dot.state.co.uk</a></td>
<td>608-246-7957</td>
<td>X</td>
</tr>
<tr>
<td>Peter Kemp</td>
<td>Wis DOT</td>
<td><a href="mailto:david.gagne@maine.gov">david.gagne@maine.gov</a></td>
<td>207-624-3205</td>
<td></td>
</tr>
<tr>
<td>Doug Gagne</td>
<td>ME DOT</td>
<td><a href="mailto:dan.segerman@azdot.gov">dan.segerman@azdot.gov</a></td>
<td>602-712-8577</td>
<td>X</td>
</tr>
<tr>
<td>Dan Seagerman</td>
<td>AZ DOT</td>
<td><a href="mailto:stephanie.huang@azdot.gov">stephanie.huang@azdot.gov</a></td>
<td>602-712-6634</td>
<td></td>
</tr>
<tr>
<td>Stephanie Huang</td>
<td>Arizona DOT</td>
<td><a href="mailto:jay@azdot.gov">jay@azdot.gov</a></td>
<td>602-712-1466</td>
<td></td>
</tr>
<tr>
<td>Richelle Crenshaw</td>
<td>Louisiana DOT</td>
<td><a href="mailto:richelle.crenshaw@la.gov">richelle.crenshaw@la.gov</a></td>
<td>225-248-9217</td>
<td>V</td>
</tr>
<tr>
<td>David Goode</td>
<td>KYKE</td>
<td><a href="mailto:david.cole@kysenate.gov">david.cole@kysenate.gov</a></td>
<td>859-560-3160</td>
<td></td>
</tr>
<tr>
<td>Bob Lutz</td>
<td>AASHTO</td>
<td><a href="mailto:flutz@amrl.net">flutz@amrl.net</a></td>
<td>210-436-4801</td>
<td></td>
</tr>
<tr>
<td>Mike Rafauskas</td>
<td>FMU</td>
<td>michael.rafauskas@t稂.gov</td>
<td>207-366-15-71</td>
<td>V</td>
</tr>
<tr>
<td>Jim McGinnis</td>
<td>MD DOT</td>
<td><a href="mailto:jim.mcginnis@state.mt.us">jim.mcginnis@state.mt.us</a></td>
<td>406-394-5548</td>
<td></td>
</tr>
<tr>
<td>Heather Hall</td>
<td>TN DOT</td>
<td><a href="mailto:heather.purdy@tn.gov">heather.purdy@tn.gov</a></td>
<td>615-358-4104</td>
<td></td>
</tr>
<tr>
<td>Neal Anderson</td>
<td>CRSE</td>
<td><a href="mailto:andersen@crse.org">andersen@crse.org</a></td>
<td>847-517-1200</td>
<td>V</td>
</tr>
<tr>
<td>Andrew Mrozakowski</td>
<td>Connecticut DOT</td>
<td><a href="mailto:andrew.mrozakowski@ct.gov">andrew.mrozakowski@ct.gov</a></td>
<td>860-594-3296</td>
<td></td>
</tr>
</tbody>
</table>

### National Transportation Product Evaluation Program 2012

Sheraton Indianapolis City Center
Indianapolis, Indiana
Appendix D - Adhesive Anchors & Installer Certification

A New ACI 318-11 Requirement

Neal S. Anderson, PE, SE, FACI, FPCI
Vice President of Engineering

Learning Objectives

- How we got to ACI 318-11 provisions
  - Review of the Big Dig Accident
- ACI’s Code response (318, 355.4, etc.)
- ACI / CRSI Adhesive Anchor Installer
  - Certification program elements
  - Written & Performance examinations
- Specifying adhesive anchors
  - Review of CRSI Technical Note

How Did We Get Here (Part 1)?

- Adhesive anchors
  - Versatile connection in the engineer’s toolbox
  - Manufacturer’s instructions
- Design parameters not codified
  - Structural design
  - Material performance

But unfortunately we had a big catalyst to push us....

BOSTON I-90 TUNNEL

Central Artery / Tunnel (CA/T)
10 July 2006
Ceiling Panel Collapse
Adhesive Anchor Failure

How Did We Get Here (Part 2)?

- Boston revealed many issues . . .
  - Manufacturer’s instructions vary
  - Structural design needed
  - Material performance consistency
  - Installation is not easy
- NTSB Reality Check . . .

How Did We Get Here (Part 3)?

- To get approved by ACI Committee 318 certification was imperative . . .
  - Critical connections
  - They are not idiot-proof
  - On par with structural welding
- Design provisions + product qualifications + installer certification =

ACI’s Response

- Partnered with CRSI to identify criteria for an Adhesive Anchor Installer and develop a certification program
- Fast Track of a new document for Adhesive Anchors 355.4 “Acceptance Criteria for Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary (Provisional Standard)”
- Change in 318-11 Building Code, addressing Adhesive Anchors
ACI 318-11 Code Requirements

- Design guidelines
- Certified Installers
  - Horizontal to upwardly inclined
  - Sustained tension
- Reference to ACI 355.4 document

Appendix D Additions (Highlights)

THE CODE SIDE

D.2.2 – Scope

- Adhesive anchors: Concrete minimum age of 21 days at time of anchor installation
  - Not a strength issue
  - A moisture issue

D.2.3 – Scope

- Post-Installed Adhesive Anchors Do Not Have Predictable Pullout Capacities
- Post-Installed Adhesive Anchors Must Meet:
  - ACI 355.4 Qualification Tests
Influence of Cracked Concrete

Appendix D, Section D.9.2.2

**D.9.2.2** — Installation of adhesive anchors horizontally or upwardly inclined to support sustained tension loads shall be performed by personnel certified by an applicable certification program. Certification shall include written and performance tests in accordance with the ACI / CRSI Adhesive Anchor installer Certification program, or equivalent.
Façade Attachment
(*sustained tension in downhand application*)

Hinge or hard welded connection

Appendix D, Section D.9.2.3

**D.9.2.3** — The acceptability of certification other than the ACI / CRSI Adhesive Anchor Installer Certification shall be the responsibility of the licensed design professional.

Appendix D, Section D.9.2.4

**D.9.2.4** - Adhesive anchors installed in horizontal or upwardly inclined orientations to resist sustained tension loads shall be continuously inspected during installation by an inspector specially approved for that purpose by the building official.
And you ask, “Why do we need Certification?”

Actual hidden camera on a jobsite

Typical Applications

Adhesive Systems

- **Nozzle mixing**
  - Zigzag type of nozzle tube

- **Capsule**
  - Insert in hole, break packaging, and mix

- **Bulk mixed**
  - Component A
  - Component B

Bonded Anchors
Factors Influencing Bond Strength

- Drilling method
- Hole cleaning
- Mixing
- Installation
  - Wet concrete
  - Submerged
- Shelf life
- Hole Diameter
- Embedment depth
- Temperature
- Freezing and thawing
- Chemicals
  - Alkalinity
  - Sulfur
  - Ozone
- Sustained loading
- Fatigue / seismic
- Fire
- Cracked concrete
- Curing

Factors are product dependent – Prequalification necessary

Certification Program

- ACI Committee 355 / C601-A
  - Experts on anchorage to concrete
  - Body of knowledge in this field
  - Major manufacturer’s represented
- Developed thru ANSI guidelines

But you may be faced with determining what is an equal program

AAI Certification

- Written Examination
- Performance Examination
  - ACI Certification Dept.
  - Professional Testing (PT)
    - Test development consultant
    - ANSI requirements

Quickly, Program Consists of:

- 75 question written examination
  - Closed book, 90 minutes
- A performance examination for
  - Vertical Down
  - Vertical Overhead - Piston Plug
  - Vertical Overhead - Retaining Cap
Adhesive Anchor Installer Criteria

- Ability to read, comprehend, & execute anchor installation instructions
- Assess ambient conditions, condition of concrete, materials, equipment, & tools
- Determine when to proceed with installation or get additional guidance from supervisor
- Pass written & practical exams

Written Examination

- Subject Matter Experts (SMEs)
- Chicago area meeting – June 2010
- SME complexion
  - Engineers, specifiers
  - Contractors
  - DOT representative
  - Manufacturers – field engineers
  - ACI

Performance Examination

- 2-part examination
- ACI Local Sponsoring Groups (LSGs) to administer
  - Apparatus & manpower
  - Examiners to be trained
- MPIIs are very important

Manufacturers Printed Installation Instructions (MPII)

- What is an MPII?
- Where do I find the MPII?
- Are they all the same?

- For this Program – A “Generic” (MPII) was developed.
Performance Specifics

- **Downhand vertical position (1)**
  - Concrete cylinder (block)
  - Hole clean-out procedures
  - Random choice of product
- **Overhead vertical position (2)**
  - Acrylic tube
  - Hole filling imperative
  - Cap & piston plug systems

Vertical Down or Downhand

- Hole depth
- Perpendicularity of hole
- Hole cleaning technique
- Initial discharge of adhesive product
- Adhesive dispensing
- Rod / bar installation
Hole Drilling

- Hole normal to surface
- Correct depth
- Removal of concrete dust spoil

Downhand – Depth Verification

Hole Cleaning

- Brush for each hole diameter
- Brush sized for multiple hole diameter range
- Nylon or steel
- Mechanical means
- Hand tool means

Hole Cleaning

Wire Brush

SDS Chuck
Poor hole cleaning was the culprit for this failure. At a minimum – (Blow – Brush – Blow)
Hole Cleaning

Photos courtesy of Mr. Don Meinheirt, WJE

Downhand – Injection Prep

Nozzle Mixed System

Mixing & Express Material
Overhead Vertical

- Tube of finite length & diameter
- Blind installation
- Adhesive dispensing
  - Straight or flexible dispensing tube
  - Proprietary systems

Overhead Test – Simulation Tube

1 in. x 8 in. long simulated hole

- Pumping action of hand
- Withdrawal of insertion tube
  - User speed
  - Proprietary gizmo

Testing Set-Up

Blind Insertion & Injection - 1

- Piston plug system
Blind Insertion & Injection - 2

- Bottom cap system

Overhead – Retaining Cap

Adhesive installation technique is important!

Testing Set-Up

Overhead – Retaining Cap
Evaluation of Overhead Tests

- Cutting of Hardened Test Specimens
- Initial Pilot – all were sectioned
- Second Pilot all were cut longitudinally
- Size and location of voids are key
- Grading rubric

Next Steps in Program

- Study guide(s) / education
- Translation to Spanish
- Inspector certification
- Computer Based Testing (CBT)
  - Use of photos & drawings
  - Security
  - Minimum of 250 test centers

2011 - 2012 Phase-In Period

- Training by manufacturers in interim
  - CAMA developing training course?
- Lag in Code editions
- What about new products?
  - Manufacturers train on new
  - List as additional training on submittal form
Specifying Adhesive Anchors

- Strongly suggest presentation on record drawings
- Drawings & specs get separated after the job
- Can incorporate info into specs

Summary

- Central Artery / Tunnel (CA/T) – Big Dig
- ACI 318-11 Code requirements
- Certification Program
  - Development mechanics
  - Installation / examination
- How to specify adhesive anchors

Questions?

Thank you
Suggested General Drawing Notes for Adhesive Anchors

Introduction

Adhesive anchor design provisions and installation requirements for certain orientations and loading conditions were incorporated into the Appendix D provisions of ACI 318-11, *Building Code Requirements for Structural Concrete* [2011]. These provisions were in response to the issues associated with the Big Dig Tunnel accident in Boston and the subsequent recommendations of the National Transportation Safety Board [2007]. The adhesive anchor design provisions in the Building Code have been harmonized into the Appendix D CCD model, whereas in the past the design was under the purview of the individual anchorage manufacturers.

To assist the design Engineer in coordinating the adhesive anchor design into cohesive construction and installation requirements for the design drawings, CRSI has prepared this Technical Note presenting recommended General Notes for Adhesive Anchor Installation. As appropriate, the individual notes have been augmented with commentary for the Engineer / Specifier. Many of the notes are consistent with the requirements in ACI 318, and the adhesive material qualification requirements stipulated in ACI 355.4 [2011]. Other notes outline proper installation techniques, and the necessary qualifications of the anchor installer. The certification requirements of ACI 318 are highlighted in the notes, and recommended inspection and proof-load testing requirements are presented. The latter requirements represent recommendations from, the Concrete Anchor Manufacturer’s Association (CAMA) [2011].

Suggested Drawing Notes

Materials

1. The adhesive anchor system used for post-installed anchorage to concrete shall conform to the requirements of the most recently published ACI 355.4, *Acceptance Criteria for Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary*. The anchor system shall be one of the following:

   a. [Comment: Provide a list of products]
   b. An approved equal meeting ACI 355.4 and the minimum bond stress values below. Bulk-mixed adhesives are not permitted.

2. The adhesive anchors selected from paragraph 1, above, shall be supplied as an entire system. The system shall include, but is not limited to, the new adhesive cartridge, a clean mixing nozzle, extension tube, a dispensing gun, and all manufacturer recommended supplies for properly cleaning the drilled hole.

3. Anchorage design is in accordance with Appendix D of ACI 318-11. For adhesive anchors, the following minimum values for bond stress were assumed for the design using the above adhesive anchor assemblies:

   a. Cracked concrete bond stress:  \( \tau_{cr} = \text{_____ psi} \)
   b. Uncracked concrete bond stress:  \( \tau_{uncr} = \text{_____ psi} \)

   [Comment: Table D.5.5.2 of ACI 318-11 lists minimum characteristic bond stress values for outdoor and indoor applications. Manufacturers also have these values available for their specific products.]

4. All-threaded rod (eyebolts, threaded studs, internal threaded parts) to be used in adhesive anchor assemblies shall conform to ASTM A36, A193 (Grade B7), A307, B348.
**General Installation Guidelines**

7. Concrete shall have a minimum compressive strength \( f'_c \) of 2,500 psi \( (17.2 \text{ MPa}) \) at the time of adhesive anchor installation.

8. Concrete at time of adhesive anchor installation shall have a minimum age of 21 days.

[Comment: As stated in ACI 318-11, Section RD2.2, bond strength is in general not highly sensitive to concrete compressive strength. The design performance of adhesive anchors cannot be ensured by establishing a minimum concrete compressive strength at the time of installation in early-age concrete. Therefore, a minimum concrete age of 21 days at the time of adhesive anchor installation was adopted in the ACI 318-11 Code, as there is a possible effect due to concrete moisture content and the tensile properties of early-age concrete.]

9. Concrete temperature at the time of adhesive anchor installation shall be at least 50°F \( (10^\circ\text{C}) \).

10. Embedment depth and anchor projection (stick-out) from the concrete surface shall be as shown on the drawing or detail for the particular anchor or group of anchors being installed. Absent any information, the minimum embedment depth shall be ___ in. and minimum stick-out shall be ___ in.

[Comment: One rule-of-thumb for a minimum embedment depth might be 10\( \phi_r \) however this is dependent on the adhesive used. The manufacturer’s engineering literature might have some requirements for a minimum embedment depth for their product.]

11. Adhesives shall be stored and installed at the service temperature ranges recommended by the manufacturer.

**Installation Techniques**

12. Adhesive anchors shall be installed by qualified personnel trained to install adhesive anchors in accordance with the Specifications (Alt: contract documents). Post-installed adhesive anchors shall be installed in accordance with the Manufacturer’s Printed Installation Instructions (MPII).

13. Installation of adhesive anchors horizontally or upwardly inclined to support sustained tension loads shall be performed by personnel certified by the ACI/CRSI Adhesive Anchor Installer Certification program. These anchors are designated with a (CERT) after the anchor call-out. Note: Some downhill installations shown on these drawings support sustained tension loads and are so designated with a (CERT) after the anchor call-out.

[Comment: A suggested anchor callout may be: (4) \( \frac{1}{2} \) in. \( \phi \) x 6 in. adhesive anchors embedded 4 in. (CERT). Certified personnel are required to install anchors in this range of directional orientations, that is, horizontal to upwardly inclined (overhead), that carry sustained tension loads. This is an ACI 318-11 Code requirement. Downhand to horizontal installations may also be subjected to sustained tension loads and must be installed by certified personnel. Note that the ACI/CRSI Adhesive Anchor Installer Certification program includes both written and performance tests in accordance with the development guidelines established by ANSI.]
his certification as a Certified Installer. This form also provides the installer an opportunity to further document his installation experience and training in a specific manufacturer’s adhesive anchor system that may be considered unique or new, and beyond the minimum requirements for which he/she was originally tested.

15. The Contractor shall provide all equipment required to install the adhesive anchor including, but not limited to, drills, setting tools, clean-out brushes, blow out bulbs, oil-free compressed air, shop vacuums, wrenches, etc.

16. Anchors shall be installed in holes drilled with a rotary impact hammer drill or rock drill.

17. Anchor holes shall be thoroughly cleaned prior to adhesive injection, as required by the MPII.

[Comment: At a minimum, this typically consists of cleaning with oil-free and moisture-free compressed air, using a nozzle extended to the bottom of the hole; supplemented with a brush or other tool cleaning to remove all concrete dust and loose material; and followed by a second compressed air cleaning. This is commonly known as Blow-Brush-Blow or BBB].

18. Drilled and cleaned anchor holes shall be protected from contamination until the adhesive is installed.

19. A drilled anchor hole shall be re-cleaned assuming the hole was just drilled, if in the opinion of the Engineer, Inspector, or Owner’s Representative that the hole has become contaminated after initial cleaning.

20. Unless otherwise indicated on the MPII, adhesive shall be dispensed through a tube or cartridge extension, beginning at the maximum depth of the hole and withdrawn as adhesive is injected, followed by insertion and rotating the anchor to the specified depth. Where necessary, spaces around anchors at the surface shall be sealed at horizontal to vertically overhead locations to prevent loss of the adhesive during curing.

21. Anchors to be installed in the adhesive shall be clean, oil-free, and free of loose rust, paint, or other coatings.

22. Installed adhesive anchors shall be securely fixed in-place to prevent displacement while the adhesive cures. Unless shown otherwise on the drawings, anchors shall be installed perpendicular to the concrete surface. Anchors displaced before full adhesive cure shall be considered damaged and replaced at the Contractor’s expense.

23. Reinforcing bars or all-threaded bars shall not be bent after being adhesively embedded in hardened, sound concrete, unless permitted by the licensed design professional (Alt: Engineer).

Field Quality Control

24. Adhesive anchors installed in horizontal or upwardly inclined orientations to resist sustained tension loads shall be continuously inspected during installation by an inspector specially approved for that purpose by the building official.

[Comment: ACI 318-11, Section RD.9.2.4 indicates that the IBC (ICC 2009) requires special inspection of all post-installed anchors; other local jurisdictions may have their own code inspection requirements or adopt a different code than the IBC document. The installation of adhesive anchors in horizontal or upwardly inclined orientations presents special challenges to the installer and requires particular attention to execution quality, as well as an enhanced level of oversight. It is expected that these anchor installations will be inspected by a certified special inspector, who is continuously present when and where the installations are being performed. As required by ACI 318-11, the special inspector is required to submit a report to the licensed design professional and building official describing the work covered by the report and stating the work has been performed, the materials and the installation procedures used conform to the approved contract documents, and the work was installed according to the MPII.]
25. Adhesive anchors shall be proof tested as required in the Specifications (Alt: contract documents). (5, 10, or 25) percent of each type and size of an adhesive anchor assembly shall be proof tested in tension by an independent testing laboratory.

a. Tension testing shall be performed in accordance with ASTM E488.

b. The independent testing laboratory shall submit an anchorage testing plan to the licensed design professional to ensure the testing requirements are fulfilled.

[Comment: For highly redundant applications, such as reinforcing bar doweling for a slab, proof loading a random sample of 5 percent of the anchors should be considered as a minimum. The Engineer or licensed design professional should consider higher sampling rates for installations with less redundancy or those installations considered more critical. In some instances, such as safety-related anchors, 100 percent testing may be justified, or owner required.]

26. The adhesive anchors shall be tension proof loaded to ___ kips. (Alt: Proof loads are indicated on the structural drawings for the specific anchor types.) Proof loading shall be performed after a minimum curing period specified by the manufacturer.

[Comment: Proof loading notes should be shown on the Drawings. If a single anchor diameter and embedment depth is used, the proof load can be stated in the note above. A proof load test table on the drawings may be appropriate for multiple anchors sizes and types. As recommended in a CAMA paper, tension proof loading should be the least of 50 percent of expected adhesive ultimate bond strength or 80 percent of steel yield strength of the anchor rod.]

27. Anchors shall have no visible indications of displacement or damage during or after proof load application. Concrete cracking in the vicinity of the anchor after loading shall be considered a failure.

28. If more than 10 (5, 25, or any) percent of the tested adhesive anchors fail to achieve the specified proof load within the limits defined on these Drawings, 100 (an additional 25 or 50) percent of the anchors of the same diameter and type as the failed anchor shall be proof tested, unless otherwise directed by the licensed design professional (Alt: Engineer).

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Contributors: The primary authors on this publication are Neal S. Anderson, P.E., S.E. and Donald F. Meinheit, PhD., P.E., S.E.

Keywords: General notes, adhesive anchor, Manufacturer’s Printed Installation Instructions, MPII, installer, certification, ACI 318-11, ACI 355.4


Historical: None. New Technical Note

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