Overview

- What is an Adhesive Anchoring “System”? 
- Reinforced Concrete Member Design 
- Anchor Theory & Code Requirements 
- Alternative Methods of Design 
- Design Concept of Post-Installed Reinforcing 
- Applications
What is an Adhesive Anchoring “System”?
Adhesive Anchoring Systems

Adhesive “System” Has Two Components:

- Adhesive
- Threaded Rod
- Torque-Controlled Bonded Anchor
- Reinforcing Bar
Adhesive Anchoring Systems

Adhesive “System” Has Two Components:

Adhesive + Reinforcing Bar
Reinforced Concrete Member Design
Reinforced Concrete Member Design

Uses Reinforcing Bar to:
• Increase bending strength
• Increase tensile strength
• Increase compressive strength (confinement)

Traditionally Cast-in-Place
Adhesive Anchoring Systems as Recognized by IBC
D.2.2 — This appendix applies to cast-in anchors and to post-installed expansion (torque-controlled and displacement-controlled), undercut, and adhesive anchors. Adhesive anchors shall be installed in concrete having a minimum age of 21 days at time of anchor installation. Specialty inserts, through-bolts, multiple anchors connected to a single steel plate at the embedded end of the anchors, grouted anchors, and direct anchors such as powder or pneumatic actuated nails or bolts are not included in the provisions of Appendix D. Reinforcement used as part of the embedment shall be designed in accordance with other parts of this Code.
ACI 318-11 Scope

D.2.3 — Design provisions are included for the following types of anchors:

(a) Headed studs and headed bolts having a geometry that has been demonstrated to result in a pullout strength in uncracked concrete equal to or exceeding $1.4N_p$, where $N_p$ is given in Eq. (D-14);

(b) Hooked bolts having a geometry that has been demonstrated to result in a pullout strength without the benefit of friction in uncracked concrete equal to or exceeding $1.4N_p$, where $N_p$ is given in Eq. (D-15);

(c) Post-installed expansion and undercut anchors that meet the assessment criteria of ACI 355.2; and

(d) Adhesive anchors that meet the assessment criteria of ACI 355.4.
ACI 355.4

- Establishes Requirements for Code Recognition
- Addresses Conditions Using “Anchor Theory” Only
- Post-Installed Reinforcing Applying Concepts of Development & Lap Splices is Excluded
Principles of Anchor Theory
Basic Principles of “Anchor Theory”

- ACI 318 Appendix D uses “Anchor Theory” as a Calculation Model
- Reinforcing Dowels Are Designed As Anchor Bolts
- Principle stresses transferred from the rods to the surrounding concrete
- Three failure modes considered for both tension and shear
Basic Principles of “Anchor Theory”

Tension Failure Modes:

- Steel
- Concrete Breakout
- Bond Stress
Basic Principles of “Anchor Theory”

Shear Failure Modes:

- Steel
- Concrete Breakout
- Concrete Pryout
Basic Principles of “Anchor Theory”

• Embedment Depth: 4d to 20d
  #8 Rebar Max. Embedment Depth = 20”

• Concrete Splitting Failure Precluded
  By Increasing Edge Distance

• Steel Strength Defined by Ultimate Tensile Strength, $f_{ut,a}$
Basic Principles of “Anchor Theory”

• Does Not Explicitly Consider the Influence of Reinforcement in the Member

• “Supplementary Reinforcement” Used to Control Splitting or Increase

• “Anchor Reinforcement” Increase Concrete Breakout Capacity
R1.2.6 This standard is intended to provide parameters for the design of adhesive anchors in conjunction with the provisions of ACI 318, Appendix D. Those provisions are derived from the principles of anchor theory, whereby anchor forces are transferred to the concrete in a manner that generally precludes splitting of the concrete and where spacing, edge distance, and member thickness are explicitly considered in the evaluation of the concrete breakout capacity (Fig. R1.1(a)). It is not intended to address the assessment or design of post-installed reinforcing bars proportioned according to the concepts of development and splicing of reinforcement (Fig. R1.1(b)). While the provisions of Chapter 12 of ACI 318 may be used to establish embedment lengths for post-installed reinforcing bars in such cases, the ability of an adhesive anchor system to transfer loads to adjacent embedded bars, particularly where longer splice lengths are required, should be verified by appropriate testing. Testing for the splice length is outside the scope of this standard.
Alternative Methods of Design
[A] 104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, not less than the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety. Where the alternative material, design or method of construction is not approved, the building official shall respond in writing, stating the reasons why the alternative was not approved.

[A] 104.11.1 Research reports. Supporting data, where necessary to assist in the approval of materials or assemblies not specifically provided for in this code, shall consist of valid research reports from approved sources.
ICC-ES AC308

ACCEPTANCE CRITERIA FOR POST-INSTALLED ADHESIVE ANCHORS IN CONCRETE ELEMENTS

AC308

Approved May 2014
Compliance date January 15, 2015

• Addresses Post-Installed Reinforcing Using Development & Lap Splices
• New Design Tool
• Significant Benefits To This Design Approach
AC308 Test Program

Total of 17 Tests:

- 4 Bond strength
- 1 Bond/Splitting
- 6 Reliability
- 2 Installation Procedure
- 3 Durability
- 1 Seismic

Table 3.8 – Test program for evaluating deformed reinforcing bars for use in post-installed reinforcing bar connections

<table>
<thead>
<tr>
<th>Test no.</th>
<th>Test ref.</th>
<th>Purpose</th>
<th>Test parameters</th>
<th>US/M</th>
<th>Assessment</th>
<th>Load &amp; dupl.</th>
<th>f'</th>
<th>Bar embedment</th>
<th>Minimum sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>9.4.3.1</td>
<td>Bond resistance</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td>#4/12</td>
<td>10.25.2</td>
<td>low</td>
<td>7d₀</td>
<td>Five</td>
<td></td>
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<tr>
<td>1b</td>
<td>9.4.3.1</td>
<td>Bond resistance</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td>#8/25</td>
<td>10.25.2</td>
<td>low</td>
<td>7d₀</td>
<td>Five</td>
<td></td>
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<tr>
<td>1c</td>
<td>9.4.3.1</td>
<td>Bond resistance</td>
<td>Tension, confined, single reinforcing bar⁴</td>
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<td>10.25.2</td>
<td>low</td>
<td>7d₀</td>
<td>Five</td>
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<tr>
<td>1d</td>
<td>9.4.3.1</td>
<td>Bond resistance</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td></td>
<td>10.25.2</td>
<td>high</td>
<td>7d₀</td>
<td>Five</td>
<td></td>
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<tr>
<td>2</td>
<td>9.4.3.2</td>
<td>Bond splitting behavior</td>
<td>Tension, confined, reinforcing bars in corner condition</td>
<td>#8/25</td>
<td>10.25.6</td>
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<td>Six</td>
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<tr>
<td>3</td>
<td>9.4.4.1</td>
<td>Sensitivity to hole cleaning, dry substrate⁷</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td>dₘₐₓ</td>
<td>≥ 0.8</td>
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<td>7d₀</td>
<td>Five</td>
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<td>4</td>
<td>9.4.4.2</td>
<td>Sensitivity to installation in saturated concrete⁷</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td>dₘₐₓ</td>
<td>≥ 0.8</td>
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<td>5</td>
<td>9.4.4.3</td>
<td>Sensitivity to freezing/thawing conditions⁷</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td>#4/12</td>
<td>10.25.7</td>
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<td>9.4.4.4</td>
<td>Sensitivity to sustained load at elevated temperature⁷</td>
<td>Tension, confined, single reinforcing bar⁴</td>
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<td>7</td>
<td>9.4.4.5</td>
<td>Decreased installation temperature⁷</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td>#4/12</td>
<td>10.25.7</td>
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<td>7d₀</td>
<td>Five</td>
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<td>8</td>
<td>9.4.4.6</td>
<td>Sensitivity to installation direction⁷</td>
<td>Tension, confined, single reinforcing bar⁴</td>
<td>dₘₐₓ</td>
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<td>10.25.7</td>
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<td>7d₀</td>
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<td>9</td>
<td>9.4.5.1</td>
<td>Installation at deep embedment</td>
<td>Bar installation in injected hole, horizontal</td>
<td>dₘₐₓ</td>
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<td>9.4.5.2</td>
<td>Injection verification</td>
<td>Injection in clear tube</td>
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<td>11a</td>
<td>9.4.6.1.1</td>
<td>Resistance to alkalinity³</td>
<td>Slice test</td>
<td>#4/12</td>
<td>10.25.10</td>
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<td>-</td>
<td>Ten</td>
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<tr>
<td>11b</td>
<td>9.4.6.1.2</td>
<td>Resistance to sulfur³</td>
<td>Slice test</td>
<td>#4/12</td>
<td>10.25.10</td>
<td>low</td>
<td>-</td>
<td>Ten</td>
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<tr>
<td>12</td>
<td>9.4.7</td>
<td>Corrosion resistance</td>
<td>Current and potential test</td>
<td>#4/12</td>
<td>10.25.9</td>
<td>low</td>
<td>2²₀</td>
<td>Three</td>
<td></td>
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</tbody>
</table>

Table 3.8 – Test program for evaluating deformed reinforcing bars for use in post-installed reinforcing bar connections

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<th>Bar embedment</th>
<th>Minimum sample size</th>
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</thead>
<tbody>
<tr>
<td>13</td>
<td>9.4.8</td>
<td>Seismic qualification for reinforcing bar connections⁸</td>
<td>Cyclic tension, confined, single reinforcing bar</td>
<td></td>
<td>10.25.11</td>
<td>low</td>
<td>7d₀</td>
<td>Five</td>
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</tbody>
</table>
Qualified Adhesive Anchor Systems
Qualified Adhesive Anchoring System:

2.0 USES

The Hilti HIT-RE 500-SD Adhesive Anchoring System and Post-Installed Reinforcing Bar System are used to resist static, wind and earthquake (Seismic Design Categories A through F) tension and shear loads in cracked and uncracked normal-weight concrete having a specified compressive strength, $f'_c$, of 2,500 psi to 8,500 psi (17.2 MPa to 58.6 MPa).

The anchor system complies with anchors as described in Section 1909 of the 2012 IBC and is an alternative to cast-in-place and post-installed anchors described in Section 1908 of the 2012 IBC, and Sections 1911 and 1912 of the 2009 and 2006 IBC. The anchor systems may also be used where an engineered design is submitted in accordance with Section R301.1.3 of the IRC.

The post-installed reinforcing bar system is an alternative to cast-in-place reinforcing bars governed by ACI 318 and IBC Chapter 19.
Qualified Adhesive Anchoring System:

3.2.5 Steel Reinforcing Bars for Use in Post-Installed Reinforcing Bar Connections: Steel reinforcing bars used in post-installed reinforcing bar connections are deformed bars (rebar). Tables 35, 36, 37, and Figure 8 summarize reinforcing bar size ranges. The embedded portions of reinforcing bars must be straight, and free of mill scale, rust and other coatings that may impair the bond with the adhesive. Reinforcing bars must not be bent after installation, except as set forth in Section 7.3.2 of ACI 318 with the additional condition that the bars must be bent cold, and heating of reinforcing bars to facilitate field bending is not permitted.
## Evaluation Report

<table>
<thead>
<tr>
<th>DESIGN INFORMATION</th>
<th>Symbol</th>
<th>Criteria Section of Reference Standard</th>
<th>Units</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>#8</th>
<th>#9</th>
<th>#10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal reinforcing bar diameter</td>
<td>$d_b$</td>
<td>ASTM A615/A706</td>
<td>in. (mm)</td>
<td>0.375 (9.5)</td>
<td>0.500 (12.7)</td>
<td>0.625 (15.9)</td>
<td>0.750 (19.1)</td>
<td>0.875 (22.2)</td>
<td>1.000 (25.4)</td>
<td>1.125 (28.6)</td>
<td>1.250 (31.8)</td>
</tr>
<tr>
<td>Nominal bar area</td>
<td>$A_b$</td>
<td>ASTM A615/A706</td>
<td>in$^2$ (mm$^2$)</td>
<td>0.11 (71.3)</td>
<td>0.20 (126.7)</td>
<td>0.31 (197.9)</td>
<td>0.44 (285.0)</td>
<td>0.60 (387.9)</td>
<td>0.79 (506.7)</td>
<td>1.00 (644.7)</td>
<td>1.27 (817.3)</td>
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<tr>
<td>Development length for $f_y = 60$ ksi and $f_c = 2,500$ psi (normal weight concrete)</td>
<td>$l_d$</td>
<td>ACI 318 12.2.3</td>
<td>in. (mm)</td>
<td>12.0 (304.8)</td>
<td>14.4 (365.8)</td>
<td>18.0 (457.2)</td>
<td>21.6 (548.6)</td>
<td>31.5 (800.1)</td>
<td>36.0 (914.4)</td>
<td>40.5 (1028.7)</td>
<td>45.0 (1143)</td>
</tr>
<tr>
<td>Development length for $f_y = 60$ ksi and $f_c = 4,000$ psi (normal weight concrete)</td>
<td>$l_d$</td>
<td>ACI 318 12.2.3</td>
<td>in. (mm)</td>
<td>12.0 (304.8)</td>
<td>12.0 (304.8)</td>
<td>14.2 (361.4)</td>
<td>17.1 (433.7)</td>
<td>24.9 (632.5)</td>
<td>28.5 (722.9)</td>
<td>32.0 (812.8)</td>
<td>35.6 (904.2)</td>
</tr>
</tbody>
</table>
Development & Lap Splices for Post-Installed Reinforcing
Concept of Development & Lap Splices

• Max. Embedment Depth: 60d
  #8 Rebar = 60”

• Assumes:
  1. Reinforcing Bar Reach
     Minimum Yield Strength
  2. Reinforcing Bar is Controlled by
     Yield Strength
  3. Embedment is Sufficient to Preclude
     Splitting
Concept of Development & Lap Splices

- Post-Installed Reinforcing is Limited to Straight Reinforcing Bars
- ACI 318 Chapter 12 is Used to Determine Development Length
- ACI 318 Chapter 7 is Used to Determine Spacing and Cover Requirements
- ACI 318 Chapter 21 is Used for Earthquake-Resistant Structures Steel Steel Detailing
Powerful Design Tool

• Bypasses “Anchor Theory” Design Considerations:
  1. Concrete breakout
  2. Splitting reduction factor
  3. Ultimate tensile strength
  4. Embedment Depth Limit = 20d

• “Post-Installed Reinforcement” Concept:
  1. Develops bar sufficiently to preclude splitting
  2. Develops bar sufficiently to yield reinforcing
  3. Embedment Depth Limit = 60d
Applications

The Possibilities Are Endless!

• Slab Extension

• Stacked Wall Panels

• Moment Frame Extension

• Column Extensions
Questions?

Jeff Stoneman, P.E.
Field Engineer
Simpson Strong-Tie Co. Inc.
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