

## Suggested General Drawing Notes for Post-installed Mechanical and Adhesive Anchors

### Introduction

ACI implemented design rules for post-installed mechanical anchors in ACI 318-02 Appendix D. Qualification and design provisions for adhesive anchors were added in ACI 318-11, partially in response to findings issued by the National Transportation Safety Board [2007] following the Big Dig Tunnel accident in Boston in 2006. Anchor design provisions and field quality control requirements associated with certain installation and loading conditions are now provided in Chapter 17 of ACI 318-19, Building Code Requirements for Structural Concrete [2019]. Anchor design provisions were substantially derived from procedures incorporated in acceptance criteria formulated by industry for the purposes of assessing anchor systems, which in turn were adapted from procedures developed and implemented in European design standards. They are incorporated in the deem-to-comply method (Concrete Capacity Design) adopted by ACI 318 in 2002.

To assist the design engineer in coordinating anchor design and installation requirements in construction documents, CRSI has prepared this *Technical Note* presenting recommended General Notes for Post-installed Mechanical and 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, the post-installed mechanical qualification, ACI 355.2 [2019] and the post-installed adhesive anchor qualification requirements in ACI 355.4 [2019]. The latest version of referenced ACI documents shall supersede previous versions. 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 rec-

ommendations from, the Concrete and Masonry Anchor Manufacturer's Association (CAMA) [2011].

### Suggested Drawing Notes

#### Materials

1. Mechanical anchors shall be tested and assessed in accordance with the most recent edition of ACI 355.2 *Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary*. Acceptable mechanical anchors are as follows:
  - a. *[Comment: Engineer to provide a list of approved products.]*
2. Adhesive anchor systems shall be tested and assessed in accordance with the most recent edition of ACI 355.4 *Qualification of Post-Installed Adhesive Anchors in Concrete (355.4) and Commentary*. Acceptable adhesive anchors are as follows.
  - a. *[Comment: Engineer to provide a list of approved products.]*
  - b. An approved equal tested and assessed in accordance with ACI 355.4 and providing the minimum bond stress values below for the specified conditions. Bulk-mixed (e.g., bucket-mixed) adhesives are not permitted.
3. Adhesive anchors selected from paragraph 2, above, shall be supplied as an entire system. The system shall include, but is not limited to, Manufacturers Printed Installation Instructions (MPII) as supplied with the adhesive, adhesive cartridge, mixing nozzle, extension tube, dispenser, and all required equipment for properly cleaning the drilled hole.

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4. Anchor design shall be in accordance with Chapter 17 of ACI 318-19. For adhesive anchors, the following minimum design values for bond stress were assumed for the design using the above adhesive anchor assemblies for impact- or rock-drilled holes:

- a. Cracked concrete bond stress:

$$\tau_{cr} = \underline{\hspace{2cm}} \text{ psi}$$

- b. Uncracked concrete bond stress:

$$\tau_{uncr} = \underline{\hspace{2cm}} \text{ psi}$$

*[Comment: Table 17.6.5.2.5 of ACI 318-19 lists minimum characteristic bond stress values for outdoor and indoor applications. Moreover, evaluation reports published by third-party agencies for the purposes of demonstrating code compliance provide product specific characteristic bond stress values. Bond stresses will be specific to defined in-service temperature ranges for threaded rods, reinforcing bars, and drilling method.]*

5. 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 (BD), F1554 or other approved anchor assembly types. (*Stainless steel anchor rods shall be AISI Type 304 or Type 316.*) Threads shall be UNC coarse threads, unless noted otherwise. Compatible nuts and washers shall be furnished with the all-thread rod and considered part of the assembly. The cost of the hardware shall be considered incidental to the installed adhesive anchor assembly.

*[Comment: Select one or more of the anchor rod materials. The last sentence may be more applicable to DOT type work. With hot-dipped galvanized rods, use oversized tapped, hot-dipped galvanized nuts.]*

6. Nuts, washers, and other hardware used with an all-threaded bar adhesive anchor system or with a mechanical expansion anchor shall have a material or an alloy designation that is compatible with the anchor rod/alloy. Galvanized assemblies shall be hot-dip galvanized in accordance with ASTM A153 Class C. Electroplate galvanizing is not acceptable. Dissimilar metal assemblies shall be separated by nylon, EPDM, or other approved non-metallic washers.

*[Comment: The engineer should consider clause if anchorage is exposed to an exterior environment and must mitigate corrosion.]*

7. Reinforcing bars to be used in adhesive anchor assemblies (e.g., as anchor reinforcement) or as

post-installed reinforcing shall conform to ASTM A615, A706, A995, or A1035.

### General Installation Guidelines

8. Concrete shall have a minimum compressive strength ( $f'_c$ ) of 2,500 psi (17.2 MPa) at the time of adhesive anchor installation.
9. Concrete at time of adhesive anchor installation shall have a minimum age of 21 days. For installation of adhesive anchors in concrete having an age less than 21 days, tests shall be conducted to verify the performance of the product in accordance with ACI 355.4.

*[Comment: 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 as there is a possible effect due to concrete moisture content and the tensile properties of early-age concrete.]*

10. The concrete temperature at the time of adhesive anchor installation shall be at least 50°F (10°C) unless testing has been conducted in accordance with recognized criteria to verify performance in concrete at lower temperatures.
11. Embedment depth and minimum anchor projection of the anchor element from the concrete surface shall be as shown on the drawing or detail for the particular anchor or group of anchors being installed.

*[Comment: The manufacturer's engineering literature or evaluation report specifies the minimum embedment depth.]*

12. Adhesive cartridges shall be stored under conditions in compliance with manufacturer recommendations regarding temperature, exposure to sunlight, etc. and evidence of compliance shall be made available upon request. The use of expired adhesive, as indicated by the expiration date on the cartridge, is prohibited.

### Installation

13. Adhesive anchors shall be installed by qualified personnel trained to install adhesive anchors in accordance with the Specifications (**Alt: contract documents**). Both post-installed expansion and adhesive anchors shall be installed in accordance with the Manufacturer's Printed Installation Instructions (MPII).

14. Adhesive anchors with diameter greater than 3/8-inch installed in orientations from horizontal to vertical shall employ a piston plug for the adhesive injection.

15. Installation of adhesive anchors in orientations from horizontal to vertical to support sustained tension loads shall be performed by personnel certified by the ACI Adhesive Anchor Installer Certification program or equivalent. These anchors are designated with a (CERT) after the anchor callout. Note: Some down-hole installations shown on drawings support sustained tension loads and are so designated with a (CERT) after the anchor callout.

*[Comment: A suggested anchor callout may be (4) ½ 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 318-19 Code requirement. Down to horizontal installations may also be subjected to sustained tension loads and must be installed by certified personnel. Note that the ACI Adhesive Anchor Installer Certification program includes both written and performance tests in accordance with the development guidelines established by ANSI]*

16. The installer's qualifications shall be submitted and approved in accordance with Section \_\_\_\_ of the Specifications (**Alt: contract documents**).

*[Comment: ACI has developed a submittal form for the installer to document 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.]*

17. The Contractor shall provide all equipment required to install the expansion and/or adhesive anchor including, but not limited to, drills, setting tools, clean-out brushes, blowout bulbs, oil-free compressed air, vacuums, wrenches, etc.

18. Unless otherwise specified, anchors shall be installed in holes drilled with a rotary impact hammer drill or, where not otherwise proscribed, a rock drill. Where specified and where permitted by the MPII, holes may be drilled with a diamond core drill. In all cases, the bit diameter shall be in accordance with the MPII.

*[Comment: Characteristic bond stresses for core-drilled holes may be substantially lower, hence,*

*the minimum characteristic bond stresses indicated in ACI 318-19 Table 17.6.5.2.5 are not applicable to core drilled holes.]*

19. Anchor holes shall be thoroughly cleaned in accordance with the procedures specified in the MPII prior to adhesive injection.

*[Comment: At a minimum this typically consists of cleaning with oil-free and moisture-free compressed air, using a nozzle extended to the bottom 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. Anchor manufacturers have developed vacuum systems that replace the traditional BBB approach.]*

20. Drilled and cleaned anchor holes shall be protected from contamination and water (e.g. rain) until the adhesive is installed.

21. A drilled anchor hole shall be re-cleaned just prior to adhesive injection if, in the opinion of the Engineer, Inspector, or Owner's Representative, the hole has become contaminated after initial cleaning.

22. Adhesive shall be injected in accordance with the MPII using equipment and procedures as specified therein for the specific conditions associated with the injection. This should be clearly specified in the MPII, if not, another product should be specified.

23. Anchor elements to be installed in the adhesive shall be clean, oil-free, and free of loose rust, paint, or other coatings. Threads on the projecting portion of the anchor element shall be protected from adhesive contamination.

24. 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.

25. Post-installed reinforcing bars or all-threaded bars shall not be bent after being installed unless permitted by the licensed design professional (**Alt: Engineer**).

#### **Field Quality Control**

26. The International Building Code (IBC 2018) requires special inspection of all post-installed anchors. ACI 318-19 sections 26.13.1.5 and 26.13.1.6 require

that all inspections of mechanical and adhesive anchors, respectively, are performed by a certified field inspector specifically approved for that purpose by the Licensed Design Professional and the building official. Certification is established through an independent assessment such as the ACI Post-Installed Concrete Anchor Installation Inspector Program or similar program with equivalent requirements. Adhesive anchors installed in horizontal or upwardly inclined orientations to resist sustained tension loads shall be continuously inspected during installation by a certified inspector.

*[Comment: 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. ACI 318-19 26.13.3.2(e) requires 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 318-19, 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.]*

27. Post-installed expansion and adhesive anchors shall be proof-loaded as required in the Specifications (**Alt: contract documents**). (5, 10, or 25) {**engineer to change percentage**} percent of each type and size of each type of size of anchor assembly shall be proof loaded in tension by an independent testing laboratory unless otherwise shown on the Contract Documents.
- Proof loading shall be conducted as confined tension testing for adhesive anchors using a center-hole cylinder.
  - 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 in the case of adhesively anchored reinforcing bar doweling for a slab, proof loading a minimum random sampling 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.]*

28. Post-installed expansion and adhesive anchors shall be proof-loaded to load levels as shown on the Contract Documents. (**Alt: Proof loads are indicated on the structural drawings for the specific anchor types.**) Proof loading of adhesive anchors 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. Adhesive anchor proof loads are typically set at 50 percent of expected adhesive ultimate bond strength or 80 percent of steel yield strength of the anchor rod, whichever is less. {See Mattis [2011]}]*

29. 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.
30. If more than 10 (5, 25, or any) percent of the tested 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**).

## References

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