InSights

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Post-Installed Anchors

The Present State of the Industry

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Formal concrete anchorage design provisions first appeared in ACI 318-02 as Appendix D, with applications limited to cast-in-place anchors and post-installed mechanical expansion anchors. The codified design provisions represented a generic approach to anchorage design, which diverged from past design practice of using manufacturers design tables; these tables may or may not have represented all characteristics associated with an anchor's design capacity.

In 12 years, we have codified anchorage design procedures and developed anchor qualification standards that have greatly raised the reliability bar for anchors used in practical design conditions. So, what is the state of the anchoring industry and where do the codes go from here?

ACI 318-14

The new structural building code (ACI 2014) will be re-organized based on member type. Appendix D will now formally be placed in the body of the Code as Chapter 17. But unlike other chapters in the re-organized Code, Chapter 17 essentially remained an untouched clone of Appendix D. This was a conscientious decision by the 318 Code Committee at the beginning of the reorganization work, because: (1) the Appendix D anchor design provisions are still "relatively new" and (2) there was a desire to keep things the same, as the design profession and university classrooms are just getting familiar with the provisions. The next code cycle will contemplate further additions and layout reorganization.

Adhesive Anchors

This anchor type was accepted by ACI 318-11 in a three-part acceptance format:

Design Provisions

Adhesive anchors were incorporated into ACI 318 under the premise that the existing design models would be minimally affected. Adhesive anchor design provisions for tension were the only provisions supplemented, necessitating new checks for concrete bond stress. Adhesive anchors loaded in shear behave similar to other post-installed and cast-in-place anchors, and, hence, existing design models and procedures could be used.

Qualification

For post-installed mechanical anchors, anchors must be qualified to the criterion in the ACI 355.2 standard (ACI 355 2007). Similarly, adhesives used in ACI 318-11 (2011) anchor designs must be qualified in accordance with the ACI 355.4-11 standard (ACI 355 2011). ACI 355.4 is a comprehensive product standard for structural adhesives used for anchoring, modelled after the ICC/ES Acceptance Criteria (AC) 308 (2013). Due to improvements in the ACI qualification document, AC308 was recently revised to conform to ACI 355.4-11, to avoid having the anchoring industry work to two different standards for acceptance.

Figure 1. Undercutting of screw threads in concrete (from Olsen, et. al., 2012).

Certification

Based partially on the Boston Big Dig tunnel accident, the adhesive anchor installer must be certified to install anchors in certain orientations and under certain load conditions. This requirement is recognition by the ACI 318 Code committee that adhesive anchor installation needed some oversight qualifications to achieve satisfactory installations, consistent with the written design requirements and anchor manufacturer installation instructions. The success, or failures, of adhesive anchors are highly dependent on the installer and the procedures employed to install the anchor. Certification was deemed an important component of adhesive anchor usage, on par with certified welders for welding key structural steel connections. In addition to installer certification, inspection is an important requirement required in ACI 318-11.

The ACI Code provisions are not mandatory unless adopted by the local building code for the given jurisdiction. For states and municipalities using the 2012 *International Building Code* (IBC 2012), IBC 2012 has adopted ACI 318-11 and ACI 355.4-11. However, the U.S. is under a stepped phase-in period for adoption of the design and qualification of adhesive anchors.

As of 15 January 2014, the following actions were taken:

- All adhesive anchor Evaluation Service Reports (ESR) will reference ACI 318-11, Appendix D. This includes the design provisions for bond strength and concrete breakout.

- ESR's also carry forth several of the code provisions for qualified installation personnel and inspection.

As of 15 January 2015, the following will be required:

- Testing referenced in the ESR's by the manufacturers will conform to the revised AC308, which is essentially ACI 355.4-11.

There are many more nuances to the IBC 2012 and ACI codes referenced and the phase-in situation. Reference should be made to a paper by Hoermann-Gast (2013) for additional information.

Screw Anchors

There are a wide variety of post-installed concrete anchors, and the newest post-installed anchor is the screw anchor. In reality, screw anchors have been around since the early 1990s. They are intended to carry direct tension, direct shear, or combinations of tension and shear loadings. Although the design procedure for screw anchors has not been codified, they are gaining acceptance in building practice as a reliable fastening element (Olsen, et. al., 2012).

To provide the mechanical interlock to the concrete, the screw anchor cuts a thread into the concrete during the installation process. This makes the use of screw anchors a single-use item; removing and reusing the screw anchor in the drilled hole is not advised because the cutting threads on the screw are worn and getting the screw threads into the original cut threads in the concrete is difficult. In *Figure 1*, the undercutting of the threads in the concrete is illustrated. The creation of the threads in the concrete gives the screw anchor some advantage in cracked concrete where a small-narrow crack intersecting the threads has only a minor reduction on tension capacity.

Currently, screw anchors fall outside the scope of ACI 318-11 Appendix D and Chapter 17 of ACI 318-14, *Anchoring to Concrete.* In the next Code cycle, screw anchors will be studied for inclusion. Research testing of screw anchors has shown that failure can occur in tension via three modes: steel failure, concrete breakout failure, and pullout failure. Pullout failures look very much like bond failures for adhesively bonded anchors. Pullout failures also occur for screw anchors only when they are deeply embedded. Deep embedments are often difficult to achieve because the friction of cutting a thread can exceed the torsional capacity of the screw shank and fail the steel in torsion. Consequently, it is recommended that screw anchors be used within a limited embedment depth, that is, 1⅝ inches < h_{ef} < 11 d_a.

A design procedure for screw anchors does exist; they can be safely designed using a procedure found in ICC/ES AC193 (2012). The AC193 design procedure follows closely the European design procedures in ETAG 001 (2013). AC193 also outlines the qualification tests required for screw anchors. The ACI qualification standard, ACI 355.2, is being updated to include screw anchor qualification testing.▪

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