



Adhesive Anchor Systems

The Effects of Base Material Temperature during Installation and In-Service Use

By Christopher Gamache, P.E.

Post-installed adhesive anchor systems have been used for many years for the attachment of threaded rods and reinforcing bars to concrete and other masonry base materials. The code that governs the design of adhesive anchor systems is the American Concrete Institute's ACI 318-14, *Building Code Requirements for Structural Concrete*, Chapter 17 "Anchoring to Concrete." The test reference is ACI 355.4, *Qualification of Post-Installed Adhesive Anchors in Concrete*. In addition, the International Code Council's (ICC) Evaluation Services (ICC-ES) *Acceptance Criteria for Post-Installed Adhesive Anchors in Concrete Elements* (AC308) is a test criterion that supplements ACI 355.4, which then allows a product to be issued as a third party evaluation report from ICC-ES or other third party evaluation services, such as the International Association of Plumbing and Mechanical Officials (IAPMO) Evaluation Service.

In general, the design of post-installed adhesive anchor systems is very similar to the design of cast-in-place anchors and post-installed mechanical anchors. However, for the design engineer, there are additional bond strength considerations and additional temperature considerations for product testing. The base material temperature at the time of the installation of the adhesive anchor system, and during the in-service lifetime of the anchor, also must be considered. Additionally, there have been changes in ACI 318 and ACI 355.4 in recent years that affect the overall design bond strength.

High Temperatures

The most significant change in adhesive anchors has been in the adoption of the 2012 *International Building Code* (IBC), which references ACI 318-11. Appendix D, "Anchoring to Concrete," referenced adhesive anchors for the first time and appropriate bond strength failure modes were added. Appendix D referenced the test criterion ACI 355.4, which was also first published in 2011. ACI 355.4 followed the testing procedure and evaluation of adhesive anchor systems from AC308 very closely, but some changes were made. The most glaring difference was that ACI 355.4 required that the minimum base material temperature for long-term temperature testing and design was increased from room temperature to 110°F (43°C).

In general, a high base material temperature has a negative effect on the bond strength of an

adhesive anchor. Anchors that previously had testing in accordance with AC308 prior to the publication of ACI 355.4 would have published technical data typically showing a minimum long-term base material temperature of 70°F to 80°F (21°C to 27°C). After the publication of ACI 355.4 and with the increase in the minimum long-term base material temperature to 110°F (43°C), some adhesive anchor systems had reductions in the published bond strength. In general, slow-cure products, such as pure epoxies, were most affected, as higher temperatures can have significant effects on the bond strength. Fast-cure products were not as affected since their high-temperature resistance is better.

Cure Time and Installation Direction Temperature Tests

Also in ACI 355.4 and AC308, additional tests for the base material temperature at the time of installation have been updated, as well as the installation direction. Previously, testing for bond stress at cure time was not done or was considered optional. The manufacturer was responsible for providing the relevant working and cure time for the adhesive product at the minimum and maximum published base material temperatures during installation. ACI 355.4 and AC308 were modified in 2011 to include additional testing at the minimum and maximum installation base-material temperatures that the manufacturer recognizes for the specific product.

Similarly, AC308 had tests for installation direction that were used to show that anchors installed vertically downward had the same bond strength as for anchors installed overhead. This applied for anchors with the largest diameter threaded rod or reinforcing bar and at the maximum embedment depth. These tests were all performed at room temperature. ACI 355.4, when published, had the same tests but also required that the tests be performed at the revised minimum and maximum installation base material temperatures.

Low Temperature and Freeze-Thaw

Low-temperature in and of itself, is not typically a problem. Bond strength of adhesive anchor systems at room temperature and the minimum published base-material temperature are essentially the same. ACI 355.4 carried over the AC308 freeze-thaw tests which do test the ability of the adhesive anchor system

to maintain the published bond strengths over the lifetime of the anchorage when exposed to freeze-thaw cycles.

One additional optional test has been added in AC308 for adhesive systems that are permitted to be installed at a base material temperature less than 40°F (4°C). After installation and full curing of the adhesive at or below 40°F, the concrete temperature is raised to more than 80°F (27°C) in a 12-hour period while a sustained load is applied. This situation is unlikely in practice, as the concrete must be exposed to a large temperature fluctuation. An ambient temperature change from 40°F to 80°F, which is possible during the day, would not be able to increase the temperature over the full thickness of a concrete member at the same rate that same day. Thus, this situation would only be applicable where direct sun or heat exposure is concentrated on a thin concrete slab with a shallow adhesive anchor embedment, and the adhesive happened to be installed below 40°F.

Summary

Adhesive anchor systems used with threaded rod and rebar are covered under the current design codes of ACI 318-14 for use in concrete. It is known that unlike cast-in and post-installed mechanical anchors, the adhesive bond strength must be evaluated and the bond strength is affected by low and high temperatures of the base material. ACI 355.4 and AC308 test procedures are established to cover the effects of temperature on the adhesive not only during the installation process but also throughout the service life of the anchorage. Designers should be aware of the various in-service temperature considerations on the design of the anchorage by referring to the adhesive system's 3rd party evaluation report and applying the applicable bond stress to a proper anchor design in accordance with ACI 318-14 Chapter 17. ■

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