ADHESIVE ANCHORS
PennDOT / APC Fall Seminar
November 21, 2019

Tim Carre P.E. C.W.I.
Bridge Design & Technology Division
Bureau of Project Delivery
History

• FHWA
  – First technical advisory T 5140.26 on 10/17/2007
  – Second technical advisory T 5140.30 issued on 03/21/2008
    • Both technical advisories strongly discourage use of fast set epoxy for adhesive anchors applications
  – Technical advisory T 5140.34 issued on 01/16/2018
    • allowed the use of adhesive anchors with caveats

• PennDOT
  – Issues SOL 483-19-02 on March 28, 2019
PennDOT SOL 483-19-02

- SOL issued on March 28, 2019 in accordance with FHWA Technical Advisory T5140.334
- SOL prohibited the use of adhesive anchors
- Revised DM-4 PP1.7.13 Additional Notes for Contract Drawings
- Revised DM4 PP3.6.8 Adhesive Anchors
  - Do not use for sustained tension applications
Sustained Tension Applications
Sustained Tension Applications

- Catenary Scaffold – Suspended Platforms
Sustained Tension Applications

- Not permitted since 2007
“Adhesive Anchor Installer” certification program by ACI and CRSI
  - More to come by Jim Casilio

Installation of adhesive anchors horizontally or upwardly inclined to support sustained tension shall be performed by personnel certified by ACI/CRSI certification program

Continuous inspection of adhesive anchors installed in horizontal or upwardly inclined orientations to resist sustained tension loads

Use only adhesive anchor systems designed using ACI 318-14 & qualified per ACI 355.4-11 or later editions for vertical, horizontal or overhead loading conditions for new federal-aid projects

For existing projects, that uses adhesive anchor systems not qualified under loading per ACI 355.4-11 or later editions for permanent sustained tension, institute a rigorous and regular inspection program or retrofit and/or replace existing adhesive anchors with a mechanical or adhesive anchor that meets requirements of ACI 318-14 / ACI 355.4 or later editions
Criteria for adhesive anchors

• Design:
  – AASHTO LRFD Bridge Design Specifications, 8th Edition, Sec. 5.13
  – ACI 318-14, Chapter 17

• Testing & Installation:
  – ACI 355.4-11

• Manufacture:
  – Manufacturers are to hold ICC-ES Reports published on or after Jan 15, 2015
DESIGN

- AASHTO LRFD Bridge Design Specifications 8th Edition, Sec. 5.13
- ACI 318-14 Chapter 17 Provides design provisions for:
  - Concrete cone breakout in tension – ACI 318 17.4.2
  - Concrete breakout in shear – ACI 318 17.5.2
DESIGN

- Calculation of Strength of Anchor in Shear as Governed by Steel – ACI 318 17.5.1

(i) Steel failure preceded by concrete spall

- Calculation of Concrete Pryout Strength in Shear - ACI 318 17.5.3

(ii) Concrete pryout for anchors far from a free edge
- Calculation of Strength of Anchor in Tension as Governed by Steel - ACI 318 17.4.1

![Diagram](image1)

(i) Steel failure

- Calculation of Pullout Strength of Anchor in Tension - ACI 318 17.4.3

![Diagram](image2)

(ii) Pullout
• All acceptable adhesive anchors shall have an Evaluation Service Reports (ESR)

• ESR will indicate Compliance with the following codes:
  – 2015 and earlier International Building Code
    ▪ IBC 1901.3 Anchoring to Concrete: anchoring to concrete shall be in accordance with ACI 318
    ▪ ACI 318 references ACI 355.4 for testing, assessment, installation and inspection of adhesive anchors

• ESR will indicate under Evidence Submitted:
  – ICC-ES Acceptance Criteria for Post-installed Adhesive Anchors in Concrete (AC308) incorporates requirements in ACI 355.4
Testing Standards


- **ASTM E1512 (2007)** - Standard Test Methods for Testing Bond Performance of Bonded Anchors: Assesses effects of bond strength under factors such as elevated temperatures, fire, moisture and free/thaw cycles. *Also includes long-term creep testing.*

- **ACI 355.4-11** – Qualification of Post-Installed Adhesive Anchors in Concrete: Uses Stress vs Time-to-Failure (SvTTF) graph to predict life of an adhesive anchoring system under a specific long-term tension load.

- **ICC ES- AC308** - Acceptance Criteria For Post-installed Adhesive Anchors In Concrete Elements (Latest June 2019): Supplements ACI 355.4 to allow a product to be issued as a third-party evaluation report from ICC-ES or IAPMO-ES. Based on LRFD.
ACI 355.4 (2011)

- Most current test methods
- Includes methodology of long-term tests
- Long-term testing to be performed at a stress level of 55% of material’s Mean Static Load (MSL) – SvTTF approach (Stress vs. Time to Failure Approach)
- Test for 42 days at both ambient and elevated room temperature
- Acceptance criteria applied on the displacement of anchor at the end of testing period as:
  - projected displacement at 10 years < mean displacement at failure of reference elevated temperature tests
  - projected displacement at 50 years < mean displacement of reference standard temperature tests
  - residual capacity from the static test > 90% of the MSL
Types of Anchor Adhesives

- **Pure Epoxy Adhesives**
  - High resistance to thermal variation (freeze/thaw cycles)
  - Higher bond strength and good resistance to sub-freezing temperatures
  - Minimal shrinkage

- **Polyester Adhesives**
  - Shorter curing time than epoxy adhesives
  - Weaker strength than epoxy adhesive
  - Delaminates when subjected to quick temperature change as they are a very rigid system

- **Vinylester Adhesives (Epoxy Acrylate)**
  - Curing time falls in between pure epoxy & polymer adhesives
  - Worst creep performance compared to other adhesives
Types of Anchor Adhesives

- **Pure Epoxy Adhesives**
  - High resistance to thermal variation (freeze/thaw cycles)
  - Higher bond strength and good resistance to sub-freezing temperatures
  - Minimal shrinkage

- **Polyester Adhesives**
  - Shorter curing time than epoxy adhesives
  - Weaker strength than epoxy glue
  - Delaminates when subjected to quick temperature change as they are a very rigid system

- **Vinylester Adhesives (Epoxy Acrylate)**
  - Curing time falls in between pure epoxy & polymer adhesives
  - Worst creep performance compared to other adhesives
Key Factors Affecting Adhesive Bond Strength

- High temperatures of base material
  - Bond strength reduces with high base material temperature
  - ACI 355.4 requires minimum base material temperature for long-term temperature testing & design to be 110 °F (43 °C)
  - Creep capacity of adhesive anchors are greatly reduced by elevated temperatures
  - Fast-cure products have better high-temperature resistance

- Low temperatures & Freeze-Thaw of base material
  - Bond strength at room temperature & minimum base material temperature are essentially the same
  - AC308 permits installation of adhesive systems at a base material temperature less than 40 °F. After curing, concrete temperature is raised to more than 80 °F in a 12-hour period while sustained load is applied
Creep Behavior of Adhesive Anchor Systems

- Creep displacement is increased with high temperature, high sustained loads or long loading durations.
- Creep displacement rate significantly decreases over time for an anchor that is properly designed and installed.
- Creep resistance is significantly reduced when the anchors are loaded before the manufacturer’s minimum cure times.
- Creep performance can be determined by testing & evaluation in accordance with ICC-ES AC308.
- As per AC308, creep test is mandatory and the product technical data published depends on creep test results.
- AC308 also identifies creep-resistance properties of adhesive anchors for specific temperature conditions & applications.
NCHRP Research

• NCHRP 639 – Adhesive Anchors in Concrete Under Sustained Loading Conditions (2009)
  – Determines creep resistance of adhesive anchors
  – Developed a standard test procedure for AASHTO

  – Investigates influence of parameters such as type of adhesive, installation conditions, in-service conditions on sustained-load performance of adhesive anchors
  – Shows sensitivity of adhesive anchor’s creep capacity to a specified parameter
  – Long-term loading capacity is adversely affected when in-service temperatures >120 °F & when loaded before completion of manufacturer’s required cure time of 24 hours minimum
On Site Testing

Confined Pull out Test – Tensile test on anchors and adhesive

- Qualified personnel must perform tests & provide test reports
- Tested on site in presence of customer
- Determine failure load of anchor or verification of supporting resistance of anchorage – stress

Reasons for On-Site Testing

- Determine Resistance
  - Destructive: Pull-out test for statistical evaluation
  - Non-destructive: Proof-load test for simplified evaluation
- Verify Installation Quality
  - Non-destructive: Test-load for field assessment
Going Forward

• Add new Section to PUB 408 – Materials Section 739 for Adhesive Anchors as a single source location for all adhesive anchors
  – Classify anchors based on application: Only Tension applications (Sustained Tension Load); Non-Tension applications; Dowel bars
  – Specify limitations of each anchor applications
  – Mandate Evaluation Service Report (ESR) by ICC-ES for product review submittals

• Reorganize Bulletin 15 items
  – Remove unqualified products from Bulletin 15 items
  – Remove Section MISC: Miscellaneous (Anchoring Devices for Use in Vertical Positions Only)
  – Link every product’s ICC-ES Reports through Bulletin 15
Going Forward

- Training & Inspection
  - Implement “Adhesive Anchor Installation Certification (AAIC)” program by ACI/CRSI as requirement for adhesive anchor systems installed horizontally or upward inclined & supporting tension loads
  - Special inspection required during adhesive anchor installation
  - Generate an inspection protocol to monitor in-service concrete adhesive anchor systems

- Update/new SOL once certified installers are trained

- Continue restriction of adhesive anchors in permanent tension applications
Thank you!

TIM CARRE

tcarre@pa.gov