ADHESIVE ANCHORS
PennDOT / APC Fall Seminar
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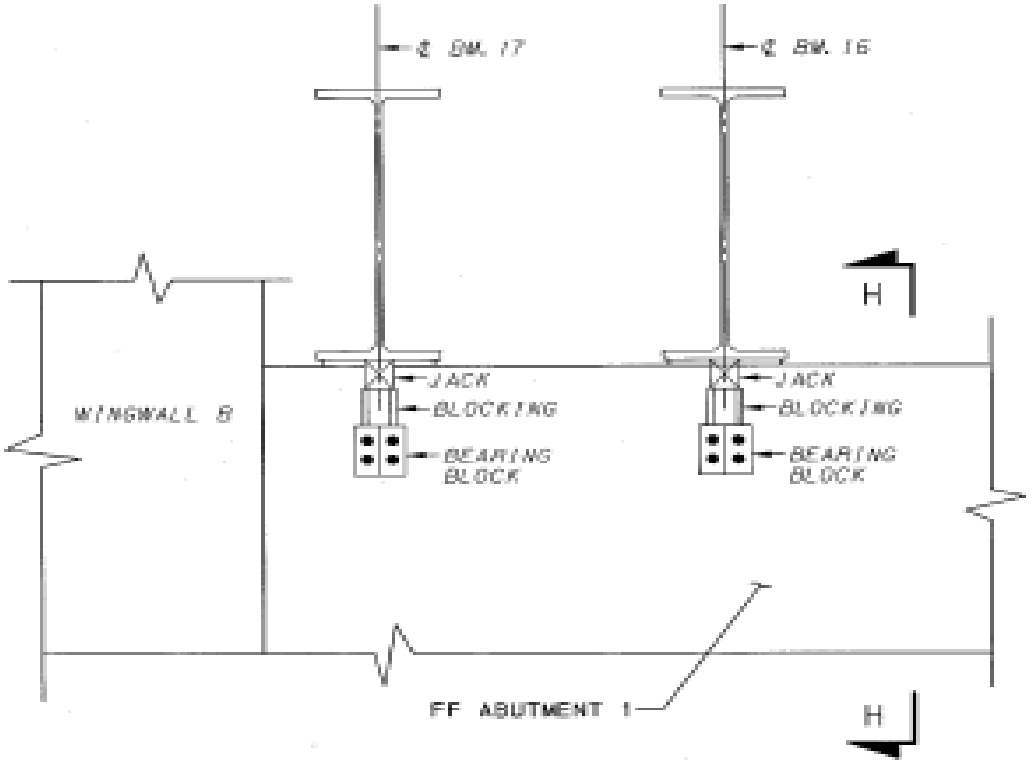
History

- 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 discourages 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



CONCEPTUAL JACKING AT ABUTMENT
(NOT TO SCALE)

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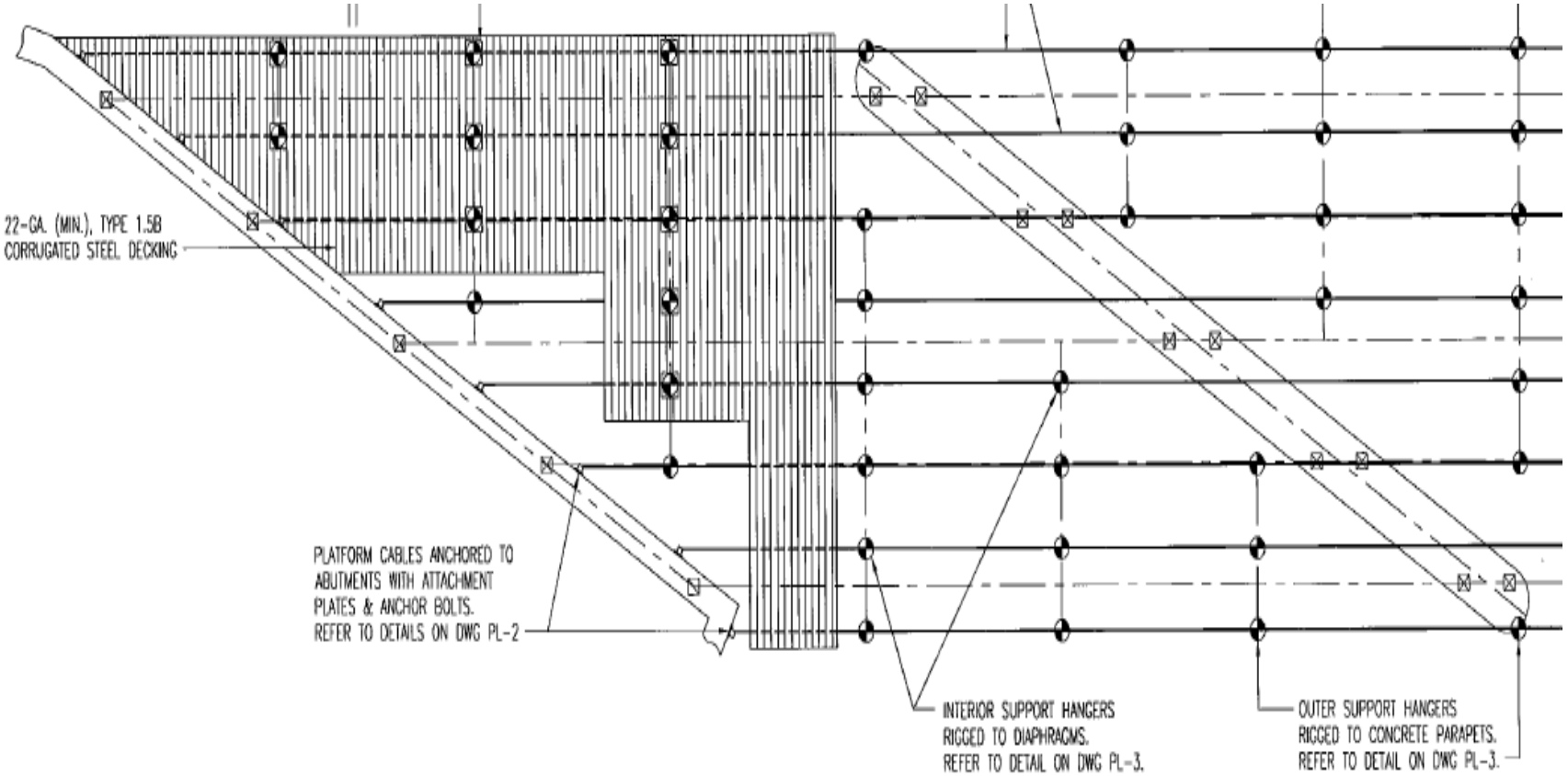
Sustained Tension Applications

- **Catenary Scaffold – Suspended Platforms**



Sustained Tension Applications

- **Not permitted since 2007**

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Current FHWA Technical Advisory T5140.34

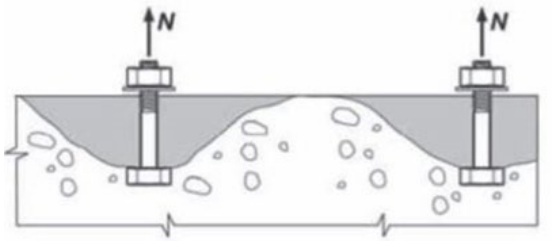
- "Adhesive Anchor Installer" certification program by ACI and CRSI
  - More to come by Jim Casilio
- Installation of adhesive anchors horizontally or upwardly inclined to support sustained tension shall be performed by personnel certified by ACI/CRSI certification program
- Continuous inspection of 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:
  - International Code Council Evaluation Service, Inc. (ICC-ES)
  - Manufacturers are to hold ICC-ES Reports published on or after Jan 15, 2015

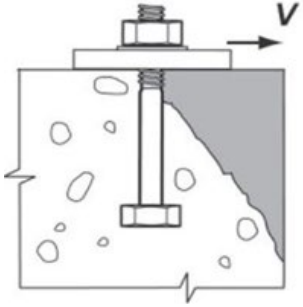
DESIGN

- 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



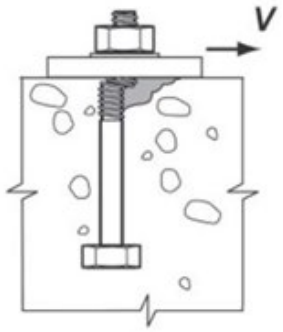
(iii) Concrete breakout

  - Concrete breakout in shear – ACI 318 17.5.2



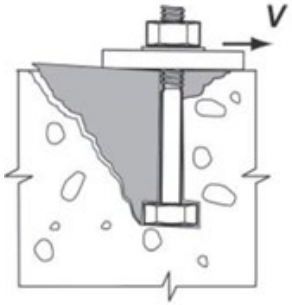
DESIGN

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



(i) Steel failure preceeded by concrete spall

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



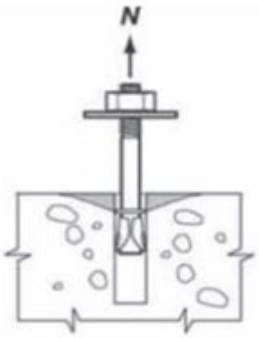
(ii) Concrete pryout for anchors far from a free edge

DESIGN

- Calculation of Strength of Anchor in Tension as Governed by Steel- ACI 318 17.4.1

(i) Steel failure

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



(ii) Pullout

MATERIALS

- 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 E488 (2010)- Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements : Determines short-term, seismic, fatigue & shock and shear strengths of anchorage systems
- 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 ⇦ Recommended
  - High resistance to thermal variation (freeze/thaw cycles)
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- Polyester Adhesives
  - Shorter curing time than epoxy adhesives
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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 ℉ (43 ℃)
  - 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 ℉. After curing, concrete temperature is raised to more than 80 ℉ 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
- NCHRP 757- Long-Term Performance of Epoxy Adhesive Anchor Systems (2013)
  - 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 ℉ & 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!

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