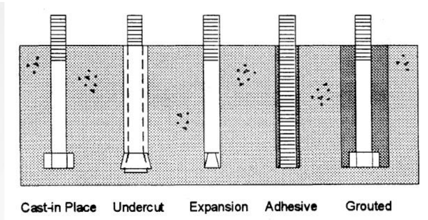
October 28-29, 2025
Orlando, FL



TRANSPORTATION SYMPOSIUM

Post-Installed Anchors for Connection to Concrete Elements

Christina Freeman, P.E. & Yukai Yang
FDOT Structures Research Lab

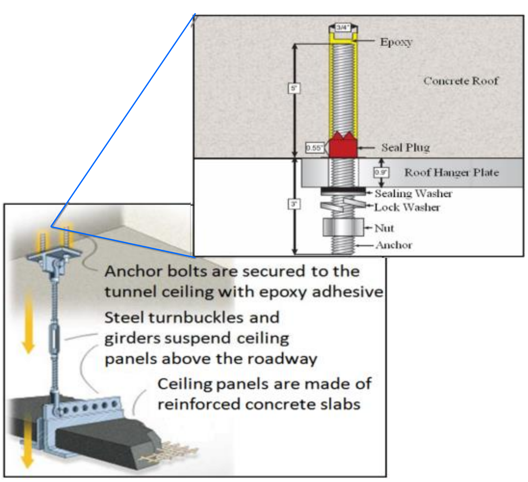
Transportation Symposium Website

SCAN ME

9:35am-10:30am October 29, 2025

1

Introduction & Motivation



Collapse of Big Dig Ceiling in Boston Is Tied to Glue

Share full article

A year ago Wednesday, a woman died in the collapse of the ceiling of a Big Dig tunnel in Boston. A report on the collapse was released Tuesday.
Michael Dwyer/Associated Press

By Matthew L. Wald
July 11, 2007

TRANSPORTATION SYMPOSIUM

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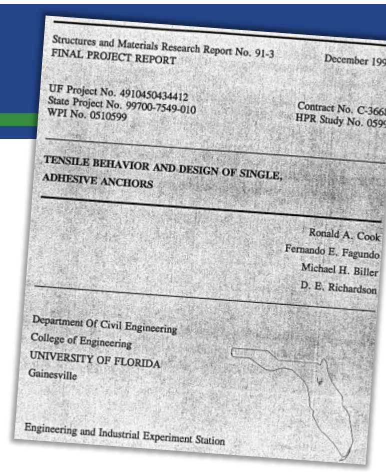
In the early years…

- 1990's FDOT began sponsoring formal research on Adhesive Bonded & Grouted Anchors for Concrete Fastening.
- 1991 Dr. Ron Cook published ***Tensile Behavior and Design of Single Adhesive Anchors***, FDOT WPI 0510599.
- 1991 **ACI 355** committee Task Group began developing a "Design Guide" to provide design examples for comparison of the Concrete Capacity Design (CCD) method to the **ACI 349 Appendix B** 45-degree cone method.



Structures and Materials Research Report No. 91-3
FINAL PROJECT REPORT
December 1991

UF Project No. 4910450434412
State Project No. 99700-7549-010
WPI No. 0510599
Contract No. C-3668
HPR Study No. 0599

TENSILE BEHAVIOR AND DESIGN OF SINGLE, ADHESIVE ANCHORS

Ronald A. Cook
Fernando E. Fagundo
Michael H. Biller
D. E. Richardson

Department Of Civil Engineering
College of Engineering
UNIVERSITY OF FLORIDA
Gainesville

Engineering and Industrial Experiment Station

<u>ACI 355 Task Group for CCD Method Guide</u>
Rich Klingner, ACI 355 Task Group Chair
Pete Carrato
Ron Cook
Rolf Eligehausen
Harry Wiewel
Dick Wollmershauser

TRANSPORTATION SYMPOSIUM

In the early years…

- 1996 Dr. Ron Cook published Specifications for Adhesive-Bonded Anchors and Dowels, FDOT WPI 0510662.
- 1999 **Structures Design Guidelines** updated *(Section 7.15)*
- 1999 FDOT Specifications 416 & 937 introduced and Type "J" epoxy removed.
- 2000 FDOT FM 5-568 Test Method published

Structures and Materials Research Report No. 96-3
FINAL PROJECT REPORT
September 1996

UF Project No. 4910 45 04 498 12
HPR Study No. 0662
State Job No. 99700-3507-119
Contract No. B-9195
WPI No. 0510662

SPECIFICATIONS FOR ADHESIVE-BONDED ANCHORS AND DOWELS

Ronald A. Cook
Robert C. Konz
Daniel S. Richardson

Department of Civil Engineering
College of Engineering
UNIVERSITY OF FLORIDA
Gainesville

FDOT FLORIDA DEPARTMENT OF TRANSPORTATION
State Materials Office
5007 NE 39th Avenue
Gainesville, Florida 32609
September 1, 2000

Florida Method of Test
for
ANCHOR SYSTEM TESTS FOR ADHESIVE-BONDED ANCHORS AND DOWELS

Designation: FM 5-568

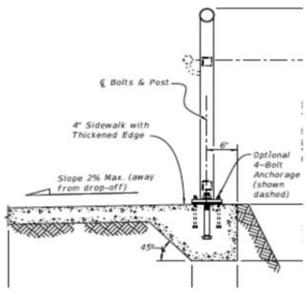
1. SCOPE

This document describes the test methods for determining the bond strength and performance characteristics of adhesive-bonded anchors and dowels in structural applications of connections to uncracked concrete. This method is applicable to products specified under FDOT Standard Specifications Section 937 and installed under Section 416.

TRANSPORTATION SYMPOSIUM

BDV28 TWO 977-06

- Confinement Effect of Metal Railing Narrow Baseplates on Adhesive Anchor Breakout Resistance



- Principal Investigator: Nakin Suksawang, PhD, PE
- Project Manager: Steven Nolan, PE
- Completed: 2019

TRANSPORTATION SYMPOSIUM

Project Objectives

- To optimize the adhesive anchor bolt edge distances and embedment depths for the installation of steel pedestrian/bicycle railings.
- Review and identify the effect of confinement (e.g., Ψm) of metal railing narrow baseplates on adhesive anchors breakout resistance.
- Develop designs for standard metal railings with reduced edge distances and embedment for sidewalks and retaining walls.
- Develop recommendation for general design procedure modifications to be expanded for other structural applications.

TRANSPORTATION SYMPOSIUM

Experimental Modeling, Casting, and Field Preparation

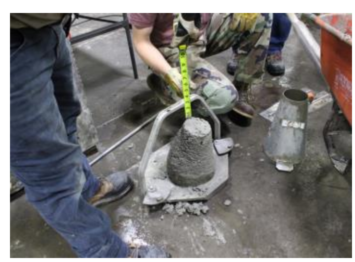
A total of 33 specimens were tested: 27 block specimens in Schemes 1 and 3, and 6 gravity-wall specimens in Scheme 2, covering embedments of 4, 6, 9, and 12 inches with edge distances ranging from 3 to 15 inches.

Class NS Concrete
7/8” anchor bolt
1/8” bearing pad
Pedestrian post was fabricated in accordance with Index 852 (now 515-052)

TRANSPORTATION SYMPOSIUM

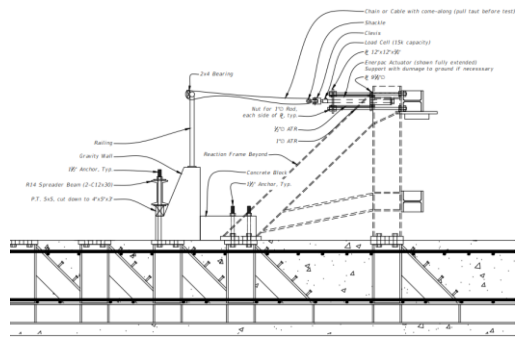
Experimental Modeling, Casting, and Field Preparation

- Concrete placement for the specimens was performed in accordance with ASTM C31/C31M, with sampling in accordance with ASTM C172
- Compressive strength: 2500psi



TRANSPORTATION SYMPOSIUM

Experimental Modeling, Casting, and Field Preparation



TRANSPORTATION SYMPOSIUM

Test Matrix

- Scheme 1 — Concrete Blocks (large edge distance; focus on confinement + embedment)

Sample	Embedment (in)	Edge distance (in)	Loading point (in)	Repeats
S9	9.0	15.0	37.5	3
S6	6.0	10.5	37.5	3
S4	4.0	7.5	37.5	3

- Scheme 2 — 3-ft Gravity Walls (confinement + embedment + reinforcement layout)

Sample	Description	Embedment (in)	Edge distance (in)	Loading point (in)	Repeats
W12	Standard reinforcement	12.0	4.0	32.5	2
W9	Standard reinforcement	9.0	4.0	32.5	2
W9-X	Tighter vertical bars (1′ c/c vs 1′-6″)	9.0	4.0	32.5	2

TRANSPORTATION SYMPOSIUM

Test Matrix

- Scheme 3 — Concrete Blocks with **Reduced Edge Distance**

Sample	Embedment (in)	Edge distance (in)	Loading Point (in)	Repeats
S9-6	9.00	6.00	37.50	3
S9-4.5	9.00	4.50	37.50	3
S9-3	9.00	3.00	37.50	3
S6-6	6.00	6.00	37.50	3
S6-4.5	6.00	4.50	37.50	3
S6-3	6.00	3.00	37.50	3

Result

- Scheme 1 – Confinement effect without edge distance

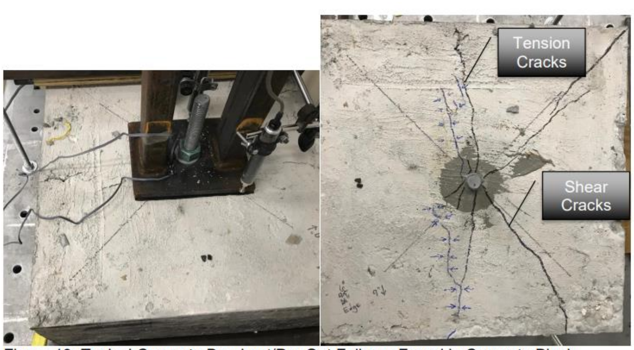


Figure 19: Typical Concrete Breakout/Pry-Out Failures Found in Concrete Block Specimens

Result

- Scheme 2 — Gravity walls (reinforced tops)

TRANSPORTATION SYMPOSIUM

Result

- Scheme 3 — Reduced edge distance (6 in → 4.5 in → 3 in)

	Scheme 3					
Sample	S9-6	S9-4.5	S9-3	S6-6	S6-4.5	S6-3
Embedment, h_{ef} (in)	9.00	9.00	9.00	6.00	6.00	6.00
Edge Distance, C_{a1} (in)	6.00	4.50	3.00	6.00	4.50	3.00
Loading Point, L (in)	37.50	37.50	37.50	37.50	37.50	37.50
Concrete Strength (psi)	3258					
Experimental Test Results (lbs)	29579	24032	21740	21879	20949	13500
	27705	26431	25320	18155	21870	14580
	26895	24756	19760	24867	18450	12750
Average	**28060**	**25073**	**22273**	**21634**	**20423**	**13610**
SDG Procedure						
Tensile Strength, N_s	27059	27059	27059	27059	27059	27059
Adhesive Bond, N_o	20669	17056	13764	13779	11371	9176
ACI Procedure						
Tensile Strength, N_{sa}	34630	34630	34630	34630	34630	34630
Adhesive Bond, N_a	9680	9096	8513	10231	9614	8997
Concrete Breakout, N_{cb}	16764	14855	13050	12018	10216	8546

TRANSPORTATION SYMPOSIUM

BDV28 TWO 977-09 Screw Anchors

- Confinement Effect of Narrow Baseplates or Reaction Area on Anchor Breakout, Part 2

- Principal Investigator: Nakin Suksawang, PhD, PE
- Project Manager: Steven Nolan, PE
- Completed: 2023

TRANSPORTATION SYMPOSIUM

Project Objectives

- Review and identify the effect of confinement of narrow baseplates or reaction area on screw anchors breakout resistance.
- Determine the effect of anchor groups and configurations on the anchor breakout resistance.
- Determine the failure mechanism and appropriate confinement modification factor of screw anchors used in various applications.
- Determine the screw anchors' performance under cyclic loads.
- Develop new FDOT Structures Design Guidelines criteria for screw anchors with confinement effects.
- Develop modified FDOT Structures Design Guidelines criteria for adhesive anchors with confinement effects if necessary.

TRANSPORTATION SYMPOSIUM

Experimental Modeling, Casting, and Field Preparation

- **45 specimens** in total: **Scheme 1 (Pedestrian)** had **14** (sidewalk 5—three later cycled, gravity wall 5, parapet 4); **Scheme 2 (Guiderail)** had **14** (sidewalk 5—four later cycled, gravity wall 6, parapet 3); **Scheme 3 (Bullet Railing)** had **6** parapet specimens (three with 8-in anchors and three with 6-in anchors); and **Scheme 4 (Modified Pedestrian/Picket)** had **11** (sidewalk 7, gravity wall 2, parapet 2). Aggregated by foundation, that's **17 sidewalks**, **13 gravity walls**, and **15 parapets**.

Class NS Concrete-Pedestrian & Guiderail
Class II Concrete- Parapet
3/4" screw anchor
5/8" screw anchor

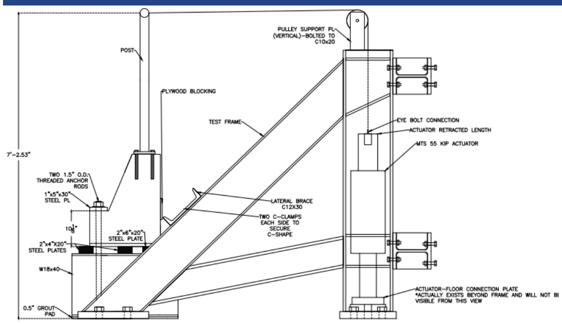
TRANSPORTATION SYMPOSIUM

Experimental Modeling, Casting, and Field Preparation

- Concrete placement for the specimens was performed in accordance with ASTM C31/C31M, with sampling in accordance with ASTM C172
- Compressive strength: 3500psi

TRANSPORTATION SYMPOSIUM

Experimental Modeling, Casting, and Field Preparation



- **Monotonic loading**—ramped to failure in roughly 5–10 minutes
- **Cyclic loading** at 0.25 Hz for at least 1,000 cycles

TRANSPORTATION SYMPOSIUM

Test Matrix

- Scheme 1 — Pedestrian / Picket Railing

Foundation	Anchors	Anchor size × length	Edge to baseplate CL	Notes
Sidewalk (1-bolt)	1	¾″ × 8.5″	6.0″	Monotonic + cyclic
Gravity Wall (1-bolt)	1	¾″ × 8.5″	4.5″	Monotonic only
Parapet (1-bolt)	1	¾″ × 8.5″	4.0″	Monotonic only

- Scheme 2 — Guiderail

Foundation	Anchors	Anchor size × length	Anchor spacing	Edge to baseplate CL	Notes
Sidewalk (2-bolt)	2	¾″ × 6″	5″	6.0″	Monotonic + cyclic
Gravity Wall (2-bolt)	2	¾″ × 6″	5″	4.5″	Monotonic
Parapet (2-bolt)	2	¾″ × 6″	5″	4.0″	Monotonic

TRANSPORTATION SYMPOSIUM

Test Matrix

- Scheme 3 — Parapet Railing

Foundation	Anchors	Anchor size × length	Anchor spacing	Edge to baseplate CL	Notes
Parapet (2-bolt)	2	⅝″ × 6″ and 8″	3″	4.0″	Monotonic only

- Scheme 4 — Modified Pedestrian/Picket

Foundation	Anchors	Anchor size × length	Edge to baseplate CL	Notes
Sidewalk (3-bolt)	3	⅜″ × 6″	3.0″	monotonic only
Gravity Wall (3-bolt)	3	⅜″ × 6″	3.0″	Two specimens
Parapet (3-bolt)	3	⅜″ × 6″	3.0″	Two specimens

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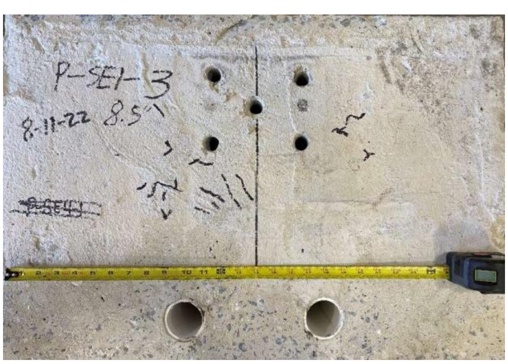
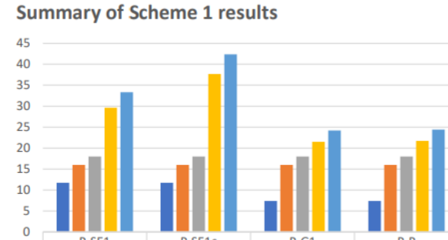
Result

- Scheme 1 — Pedestrian/picket rail on sidewalk, gravity wall, and parapet



Summary of Scheme 1 results



	P-SE1	P-SE1c	P-G1	P-P
Nominal Strength (ACI) (Kip)	11.74	11.74	7.38	7.38
Design Load Method 1 (Kip)	15.99	15.99	15.99	15.99
Design Load Method 2 (Kip)	17.98	17.98	17.98	17.98
Avg. Actual Load Method 1 (Kip)	29.62	37.67	21.5	21.72
Avg. Actual Load Method 2 (Kip)	33.33	42.38	24.18	24.43

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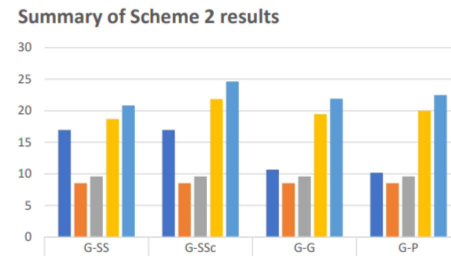
Result

- Scheme 2 — Guiderail behavior and why some multipliers look smaller



	G-SS	G-SSc	G-G	G-P
Nominal Strength (ACI) (Kip)	16.95	16.95	10.66	10.18
Design Load Method 1 (Kip)	8.53	8.53	8.53	8.53
Design Load Method 2 (Kip)	9.59	9.59	9.59	9.59
Avg. Actual Load Method 1 (Kip)	18.69	21.86	19.47	19.99
Avg. Actual Load Method 2 (Kip)	20.83	24.62	21.91	22.49

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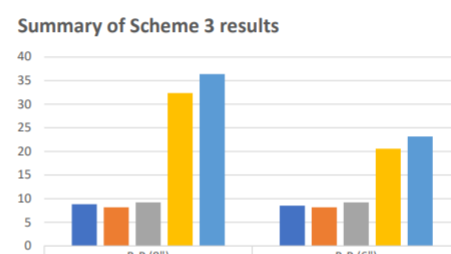
Result

- Scheme 3 — Bullet rail on parapet; anchor length sensitivity



	B-P (8")	B-P (6")
Nominal Strength (ACI) (Kip)	8.84	8.53
Design Load Method 1 (Kip)	8.19	8.19
Design Load Method 2 (Kip)	9.21	9.21
Avg. Actual Load Method 1 (Kip)	32.35	20.58
Avg. Actual Load Method 2 (Kip)	36.39	23.15

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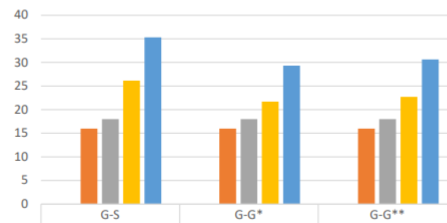
Result

- Scheme 4 — Modified pedestrian/picket (3-bolt) and what it implies for SDG

Summary of Scheme 4 results



	G-S	G-G*	G-G**
Nominal Strength (ACI) (Kip)	0	0	0
Design Load Method 1 (Kip)	15.99	15.99	15.99
Design Load Method 2 (Kip)	17.98	17.98	17.98
Avg. Actual Load Method 1 (Kip)	26.13	21.7	22.69
Avg. Actual Load Method 2 (Kip)	35.28	29.3	30.64

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Result

- **Capacities exceeded ACI 318-19 nominal strengths** across configurations; sidewalk multipliers were lower **only** because the guiderail/baseplate yielded first (test stopped before concrete anchorage failure).
- **Cyclic loading showed no degradation**; anchors performed the same after cycling (seismic qualification per ACI 355.2 still required).
- **Design resistance factor**: using **ϕ = 0.75** generally makes factored resistance ≥ design load; **ϕ = 0.65** (ACI) fails several cases. **Adopt ϕ = 0.75** for design and for evaluating future tests.
- **Fractile approach**: 5% fractile and ϕ = 0.75 is **over-conservative**; recommend using **average test results** instead (pullout/pry-out were not abrupt like cone breakout).

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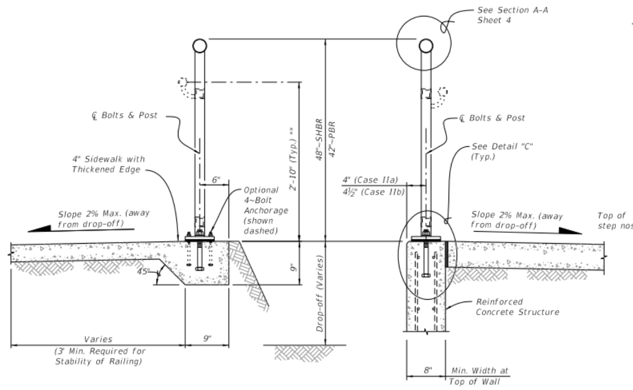
Implementation

- FDOT Standard Plan 515-062

ANCHOR BOLT TABLE							
CASE	STRUCTURE TYPE	DIMENSIONS			ANCHOR LENGTH		ANCHOR SIZE
		"A" Edge Dist.	"B" Edge Dist.	"C" Embedment	C.I.P Hex Head Bolt	Adhesive Anchor	
I	Unreinforced Concrete	6"	1'-2"	6"	7½"	8"	⅞" Ø
IIa	Reinforced Concrete	4"	4"	9"	10½"	11"	⅞" Ø
IIb	Gravity Wall Index 400-011	4½"	3½" @ top	9"	10½"	11"	⅞" Ø
III	Step Cheekwall	4½"	4½"	9"	10½"	11"	⅞" Ø
IV	Varies	5"	5"	5"	6½"	7"	7/16" Ø



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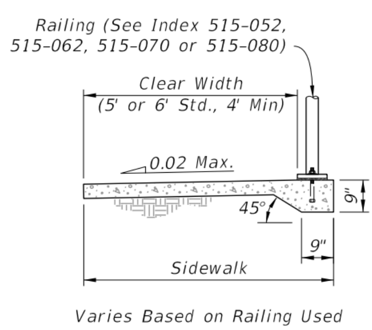
Implementation

- FDOT Standard Plan 522-001



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Implementation

- Structures Design Guidelines

  - **Adhesive anchors:** use only when installation & creep are controlled; not allowed if sustained tension > 30% of φN_t.
  - **Design basis:** target ductile, steel-governed failure → embed to reach 125% Fy (or 100% Fu); in shear, use 70% of the embedment length.
  - **Undercut & screw anchors:** align with ACI 318 Ch. 17 / ACI 355.2; assume cracked concrete; φ = 0.75 for breakout.
  - **Durability & process:** stainless steel required outdoors; galvanized allowed only outside splash zones; selection/install per APL & Dev 416/937 specs.

1.6 POST-INSTALLED ANCHOR SYSTEMS

1.6.1 General

A. Post-Installed Anchor Systems are used to attach new construction to structurally sound concrete. Post-Installed Anchor Systems shall be limited to:

1. Adhesive Bonded Anchor Systems with adhesive bonding material listed on the Department's ***Approved Products List*** (***APL***).
2. Undercut Anchor and Screw Anchor Systems as approved on a project-by-project basis by the DSDE and the SSDE.

Delete ***LRFD*** 5.13. Design criteria and specific usage limitations for these anchor systems are provided in the following sections.

B. Specify an Adhesive Bonded, Undercut, or Screw Anchor System based on the specific usage limitations contained herein, product availability, installation and testing requirements, construction sequence and potential associated traffic control requirements, and all associated costs.

Commentary: Consider the adhesive bonding material cure time required between installation and field testing of adhesive bonded anchors when developing construction sequence and/or traffic control plans.

TRANSPORTATION SYMPOSIUM

Implementation

- Developmental Specifications Dev416PIAS and Dev937PIAS

INSTALLATION OF POST-INSTALLED ANCHOR SYSTEMS AND DOWELS FOR STRUCTURAL APPLICATIONS IN CONCRETE ELEMENTS.
(REV 8-20-24)

SECTION 416 is deleted and the following substituted:

SECTION 416
INSTALLATION OF POST-INSTALLED ANCHOR SYSTEMS AND DOWELS FOR STRUCTURAL APPLICATIONS IN CONCRETE ELEMENTS

416-1 Description.

Prepare and install post-installed anchor systems and dowels in hardened concrete as indicated in the Plans, as directed by the Engineer, and in accordance with the manufacturer's instructions and this Section.

Post-installed anchors and dowels in this Section are intended for use in structural applications where designated in the Plans. Requirements provided in this Section are not applicable for anchoring conduit(s) unless specifically called for in the Plans.

416-2 Materials.

Meet the following requirements:

Adhesive Bonding Material Systems* .... Section 937
Undercut Anchor Systems* .... Section 937
Screw Anchors* .... Section 937
*Use products listed on the Department's Approved Product List (APL).

416-2.1 Adhesive Bonded Anchors and Dowels: Use anchors and dowels installed in positions ranging from vertically downward to horizontal. Do not use material from containers which are damaged or have been previously opened. Use only full packages of components. Combining of adhesive bonding components from bulk supplies is not permitted.

416-2.1.1 Type HV Adhesives: Use Type HV adhesive bonding materials for all installations other than constructing doweled pile splices. Do not use Type HV adhesives as a substitute for Type HSHV adhesives.

416-2.1.2 Type HSHV Adhesives: Use higher strength Type HSHV adhesive bonding materials for installation of traffic railing reinforcement and anchor bolts into existing concrete bridge decks and approach slabs. Type HSHV adhesives may be used as a substitute for Type HV adhesives provided the length and diameter of the anchor bolt and drilled hole remain as designed for the Type HV adhesive.

416-2.1.3 Storage of Materials: The adhesive bonding material system shall be delivered to the project site in original unopened containers with the manufacturer's label identifying the product. Store materials delivered to the job site within an appropriate facility capable of maintaining storage conditions consistent with the manufacturer's recommendations.

416-2.2 Screw Anchors and Undercut Anchor Systems: Obtain all screw anchors or undercut anchor systems from the same manufacturer per anchor type. Submit proposed anchor systems meeting the loads shown in the plans to the Engineer for capacity verification and approval.

Install anchors in concrete members having a minimum compressive strength of

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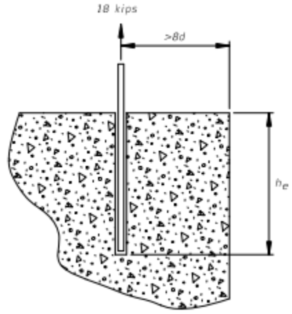
Design Example

Design Example 1 - Single Anchor Away from Edges and Other Anchors

Design an adhesive anchor using threaded rod (ASTM A193, Grade B7) for a factored tension load of 18 kips. The anchor is located more than 8 anchor diameters from edges and is isolated from other anchors. The anchor embedment length is to be sufficient to ensure steel failure.



Section View

Given:
N_u = 18.0 kips
f_y = 100.0 ksi
f_u = 125.0 ksi
T' = 1.08 ksi

Adhesive Bonded Anchor Design Examples

Design Procedure Example 1 See Figure 1	Calculation
Step 1 - Determine required rod diameter	
Determine the required diameter of the threaded rod by setting the factored tension load equal to the design steel strength.	$N_u = N_s$
The effective area for the threaded rod may be taken as 75% of the gross area. As with reinforcing bars, the minimum specified yield strength of the rod is used to determine the required diameter.	$N_s = \phi_s A_e f_y$ Where: $\phi_s = 0.9$; $A_e = 0.75(\pi d^2/4)$; and $f_y = 100$ ksi
Substituting and solving for **d**:	$18 = (0.9)[(\pi d^2/4)](100)$ $d = 0.583$ in. therefore, use 5/8" threaded rod.
Step 2 - Determine required embedment length to ensure steel failure	
Basic equation for embedment length calculation. Since there are no edge or spacing concerns, Ψ_e and Ψ_{gn} may be taken as unity.	$N_c = \phi_c \Psi_e \Psi_{gn} N_o$ (for embedment) Where: $\phi_c = 0.85$; $\Psi_e, \Psi_{gn} = 1.0$ (no edge/spacing concern); and $N_o = T' \pi d h_e$
For ductile behavior it is necessary to embed the anchor sufficiently to develop 125% of the yield strength or 100% of the ultimate strength, whichever is less.	$N_c(req'd) = 1.25 A_e f_y \le A_e f_u$
Determine the effective area for a 5/8" threaded rod:	$A_e = 0.75(\pi 0.625^2/4)$ $A_e = 0.23\ in^2$
Determine the required tension force, $N_c(req'd)$, to ensure ductile behavior.	$N_c(req'd) = 1.25 A_e f_y \le A_e f_u$ $N_c(req'd) = 1.25(0.23)(100) \le (0.23)(125)$ $N_c(req'd) = 28.75$ kips $= 28.75$ kips therefore, use $N_c(req'd) = 28.75$ kips
Substituting and solving for h_e:	$28.75 = 0.85\ (1.0)\ (1.0)\ (1.08)\ \pi\ (.625) h_e$ $h_e = 16$ in

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Safety Message

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Contact Us

Christina Freeman

- (850) 921-7111
- Christina.Freeman@dot.state.fl.us

Yukai Yang

- (850) 921-7106
- Yukai.Yang@dot.state.fl.us

TRANSPORTATION SYMPOSIUM

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October 28-29, 2025
Orlando, FL

TRANSPORTATION SYMPOSIUM

DEADLINE

Please be sure to **certify your attendance** before leaving this event or no later than **November 30th**, in order to receive PDH/CEC. Detailed instructions are available on the Transportation Symposium website.

Transportation Symposium Website

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