APPENDIX D – ANCHORING TO CONCRETE

IMCYC

Mexico City

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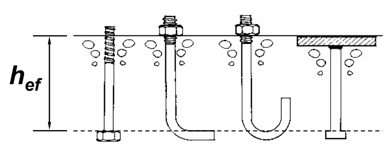
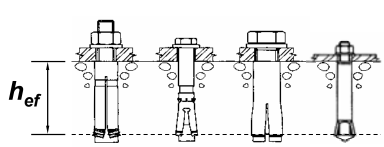
CAST-IN-PLACE ANCHORS



h_{ef} = Effective Embedment Depth

POST-INSTALLED ANCHORS



POST-INSTALLED ANCHORS

- *Capacity Sensitive to Installation*
- *Variable Load-Displacement Behavior, Particularly in Cracked Concrete*
- *Strength Reduction Factor, ϕ, Based on Reliability/Variability*
- *Need for Testing Procedures and Evaluation Criteria*

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ACI 355.2-04 – QUALIFICATION OF POST-INSTALLED MECHANICAL ANCHORS IN CONCRTE

- *Testing Requirements in Uncracked Concrete, and in Cracked Concrete*
  - *Reference Test*
  - *Reliability Tests*
  - *Service-Condition Tests*

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ACI 355.2 - QUALIFICATION

	% of Reference Capacity
• Category 1	80 & Over
• Category 2	70-79
• Category 3	60-69
(Anchor Unqualified)	< 60

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DESIGN PROCEDURE

Concrete Capacity Design (CCD)

- ***Basis for ACI 318 Appendix D***

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THE CCD METHOD (RD.4.2.2)

"… predicts the load capacity of an anchor or group of anchors by using a basic equation for tension, or for shear for a single anchor in cracked concrete, and multiplied by factors that account for the number of anchors, edge distance, spacing, eccentricity and absence of cracking."

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D.2.1 - SCOPE

- ***Anchors Used to Transmit Tension, Shear, or Both***
- ***Safety Levels (LF & ϕ) for In-Service Conditions***
- ***Not Intended for Handling and Construction Loads***

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D.2.2 - SCOPE

- ***Provisions for: Cast-in-Place Anchors &***
  Post-Installed Anchors
- ***Excluded:***
  - ***Specialty Inserts***
  - ***Through Bolts***
  - ***Multiple Anchors Connected to Single Plate at the Embedded End of the Anchors***
  - ***Adhesive & Grouted Anchors***
  - ***Powder/Pneumatic Actuated Nails or Bolts***

D.2.3 - SCOPE

- ***Geometry of Headed Studs and Bolts to Prevent Pullout***
- ***Pullout Strength in Uncracked Concrete*** $\geq 1.4N_p$
  - N_p ***per Eq. (D-15)***

D.2.3 - SCOPE

- ***Geometry of L- & J-Bolts (Without Benefit of Friction) to Prevent Pullout***
- ***Pullout Strength in Uncracked Concrete*** $\geq 1.4N_p$
  - N_p ***per Eq. (D-16)***

D.2.3 - SCOPE

[Post-Installed Anchors Do Not Have Predictable Pullout Capacities]

- ***Post-Installed Anchors Must Meet:***
  - ***ACI 355.2 Qualification Tests***

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D.2.4 - SCOPE

- ***High-Cycle Fatigue or Impact Excluded***
- ***Seismic Load Effects Covered in D.3.3***

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D.3.1-2 - GENERAL REQUIREMENTS

- ***Factored Loads from Elastic Analysis***
- ***Plastic Analysis Permitted if Ductile Steel Elements Used – Must Consider Deformation Compatibility***
- ***Load Combinations per 9.2 and ϕ per D.4.4***
- ***Load Combinations per C.2 and ϕ per D.4.5***

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D.3.3.1-3 - GENERAL REQUIREMENTS

- ***Intermediate/High Seismic Risk Zones***
  - ***Anchors in Plastic Hinge Zones Excluded***
  - ***Post-Installed Anchors Must Pass ACI 355.2 Simulated Seismic Tests***
  - ***Design Strength: $0.75\phi N_n$ and $0.75\phi V_n$***

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D.3.3.4-5 - GENERAL REQUIREMENTS

- ***Intermediate/High Seismic Risk Zones***
  - ***Anchor Design Governed by Strength of Ductile Steel Element, or***
  - ***Attachment to Undergo Ductile Yielding at a Load $\leq$ 75% Minimum Anchor Design Strength***

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D.1 - DEFINITIONS

<u>Attachment</u> — The structural assembly, external to the surface of the concrete, that transmits loads to or receives loads from the anchor.

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D.3.4 - GENERAL REQUIREMENTS

- *Modify N_n and V_n for Anchors in Lightweight Aggregate Concrete*
  - *0.75 (All-Lightweight)*
  - *0.85 (Sand-Lightweight)*
  - *Linear Interpolation for Partial Sand Replacement*

D.3.5 - GENERAL REQUIREMENTS

- *For Calculation Purposes:*
  - $f_c' \leq$ *10,000 psi for Cast-In Anchors*
  - $f_c' \leq$ *8000 psi for Post-Installed*
- *Post-Installed Anchors in Concrete with f_c' > 8000 psi Must be Tested*

D.4.1 - FAILURE MODES

- *Tensile Loading*
  - *Anchor Steel Strength*
  - *Concrete Breakout*
  - *Pullout*
  - *Concrete Side-Face Blowout*

D.4.1 - FAILURE MODES

- ***Shear Loading***
  - ***Anchor Steel Strength***
  - ***Concrete Breakout***
  - ***Concrete Pryout***
- ***Preclude Splitting Failure (D.8)***

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FACTORS AFFECTING STRENGTH

- ***Edge Effects***
- ***Group Effects***
- ***Eccentricity***
- ***Cracked Vs. Uncracked Concrete***
- ***Supplementary Reinforcement Intersecting Potential Concrete Failure Prism***

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D.1 - DEFINITIONS

<u>Supplementary reinforcement</u>
Reinforcement proportioned to tie a potential concrete failure prism to the structural member.

- ***See References D.8, D.11, and D.12 (Page 423)***

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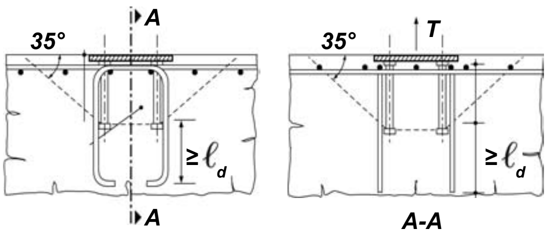
SUPPLEMENTARY REINFORCEMENT FOR TENSION



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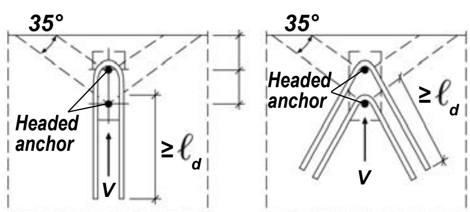
SUPPLEMENTARY REINFORCEMENT FOR SHEAR



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D4.1 - STRENGTH OF ANCHORS

$$\phi N_n \geq N_{ua} \qquad \text{(D-1)}$$
$$\phi V_n \geq V_{ua} \qquad \text{(D-2)}$$

- ***Lowest ϕN_n and ϕV_n from Applicable Failure Modes***
- ***Interaction for Combined N_{ua} and V_{ua}***

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D.4.2 - NOMINAL STRENGTH

- ***Design Models in Agreement with Test Results***
  - ***Include Supplementary Reinf. Benefit***
- ***Based on 5% Fractile of Basic Individual Anchor Strength***
  - ***90% Confidence that 95% of Actual Strengths Will Exceed Nominal Strength***
- ***Diameter $\leq$ 2 in. and $h_{ef} \leq$ 25 in.***

RD.4.2.1 - SUPPLEMENTARY REINFORCEMENT

"… reinforcement oriented in the direction of load and proportioned to resist the total load within the breakout prism, and fully anchored on both sides of the breakout planes, may be provided instead of calculating breakout capacity."

D.4.4 - ϕ FOR L.F. FROM 9.2

Anchor Steel Strength Governs

(a) Ductile Steel Element
- ***Tension ϕ = 0.75***
- ***Shear ϕ = 0.65***

(b) Brittle Steel Element
- ***Tension ϕ = 0.65***
- ***Shear ϕ = 0.60***

D.1 - DEFINITIONS

- ***Brittle Steel Element***
  - ***Elongation < 14%***
  - ***Reduction in Area < 30%***
  - ***Or Both of the Above Criteria***
- ***Ductile Steel Element***
  - ***Elongation $\geq$ 14%***
  - ***Reduction in Area $\geq$ 30%***

  Note: ASTM A 307 Considered Ductile

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D.4.4 - ϕ FOR L.F. FROM 9.2

Where Concrete Governs Strength

***Condition A** Supplementary Reinf. Crosses Concrete Failure Surface (Concrete Breakout only)*

***Condition B** No Supplementary Reinf., or Pullout or Pryout Strength Governs*

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D.4.4 - ϕ FOR L.F. FROM 9.2

(c) Concrete Governs Strength

	Condition A	Condition B
Shear	0.75	0.70
Tension		
Cast-In		
- Headed Anchor and Hooked Bolt	0.75	0.70
Post-Installed		
- Category 1	0.75	0.65
- Category 2	0.65	0.55
- Category 3	0.55	0.45

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D.4.4 – POST-INSTALLED ANCHORS

Category	*Sensitivity to Installation*	*Reliability*
1	*Low*	*High*
2	*Medium*	*Medium*
3	*High*	*Low*

RD4.4 – ACI 355.2 TEST PARAMETERS

- *Variability in Anchor Torque During Installation*
- *Tolerance on Drilled Hole Size*
- *Energy Level Used in Setting Anchors*
- *Increased Crack Widths, if Applicable*

D.4.5 - ϕ FOR L.F. PER APP. C

Anchor Steel Governs Strength

(a) Ductile Steel Element
- *Tension* $\phi = 0.80$
- *Shear* $\phi = 0.75$

(b) Brittle Steel Element
- *Tension* $\phi = 0.70$
- *Shear* $\phi = 0.65$

D.4.5 - ϕ FOR L.F. PER APP. C

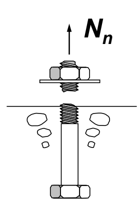
(c) Concrete Governs Strength

	Condition A	Condition B
Shear	0.85	0.75
Tension *Cast-In* - *Headed Anchor and Hooked Bolt*	0.85	0.75
Post-Installed		
- *Category 1*	0.85	0.75
- *Category 2*	0.75	0.65
- *Category 3*	0.65	0.55

D.5 - DESIGN FOR TENSILE LOADING

- *D.5.1 – Steel Strength*
- *D.5.2 – Concrete Breakout Strength*
- *D.5.3 – Pullout Strength*
- *D.5.4 – Concrete Side-Face Blowout Strength of a Headed Anchor*

D.5.1 - STEEL FAILURE (TENSION)



D.5.1 - STEEL STRENGTH (TENSION)

$N_{sa} = nA_{se}f_{uta}$ (D-3)

where $f_{uta} \leq 1.9\ f_y$

$\leq 125{,}000$ psi

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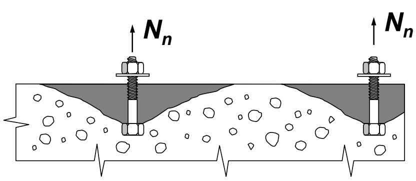
D.5.2 - CONCRETE BREAKOUT (TENSION)



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D.1 - DEFINITIONS

Concrete Breakout Strength

The strength corresponding to a volume of concrete surrounding the anchor or group of anchors separating from the member.

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D.1 - DEFINITIONS

Projected area

The area on the free surface of the concrete member that is used to represent the larger base of the assumed rectilinear failure surface.

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D.5.2.1 - CONCRETE BREAKOUT STRENGTH OF SINGLE ANCHOR (TENSION)

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \psi_{ed,N} \psi_{c,N} \psi_{cp.N} N_b \qquad (D-4)$$

- N_b: Basic single anchor strength
- $\psi_{cp.N}$: Accounts for Post-Installed Anchors
- $\psi_{c,N}$: Accounts for cracking
- $\psi_{ed,N}$: Accounts for edge effects
- $\frac{A_{Nc}}{A_{Nco}}$: Accounts for projected area of failure surface

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D.5.2.1 - CONCRETE BREAKOUT STRENGTH OF A GROUP (TENSION)

$$N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \qquad (D-5)$$

- N_b: Basic single anchor strength
- $\psi_{cp,N}$: Account for Post-Installed Anchor
- $\psi_{c,N}$: Accounts for cracking
- $\psi_{ed,N}$: Accounts for edge effects
- $\psi_{ec,N}$: Accounts for eccentricity
- $\frac{A_{Nc}}{A_{Nco}}$: Accounts for projected area of failure surface

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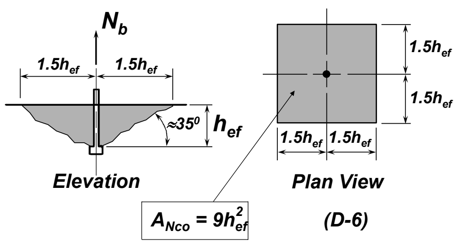
D.5.2.1 - PROJECTED AREA A_{No}



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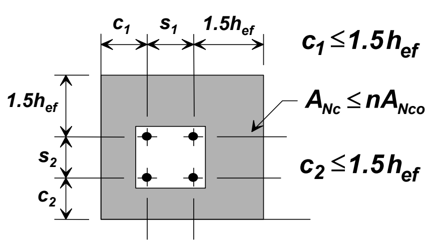
D.5.2.1 - PROJECTED AREA A_N



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D.5.2.2 - BASIC CONC. BREAKOUT

- ***Single Anchor in Tension in Cracked Concrete***

$$N_b = k\sqrt{f_c'}\,h_{ef}^{1.5} \qquad \text{(D-7)}$$

- k = 24 for Cast-in Anchors

- k =17 for Post-Installed Anchors (or Different "k" per ACI 355.2)

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D.5.2.2 - BASIC CONC. BREAKOUT

- Alternatively for Headed Studs/Bolts with:

$$11 \text{ in.} \leq h_{eff} \leq 25 \text{ in.}$$

$$N_b = 16\sqrt{f'_c}\,h_{ef}^{5/3} \qquad \text{(D-8)}$$

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D.5.2.3 - ANCHOR CLOSE TO 3 OR 4 EDGES

Where 3 or more Edge Distances $\leq 1.5h_{ef}$
→ Use h_{ef} in Eq.(D-4) through (D-11) Equal to the Larger of:

- $c_{a,max}/1.5$, and
- (1/3) Maximum Spacing Between Anchors

where $c_{a,max}$ = maximum distance from Anchor to Edge

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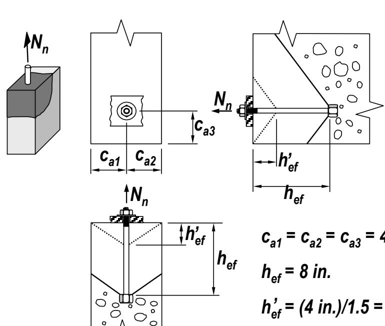

$c_{a1} = c_{a2} = c_{a3} = 4$ in.

$h_{ef} = 8$ in.

$h'_{ef} = (4 \text{ in.})/1.5 = 2.67$ in.

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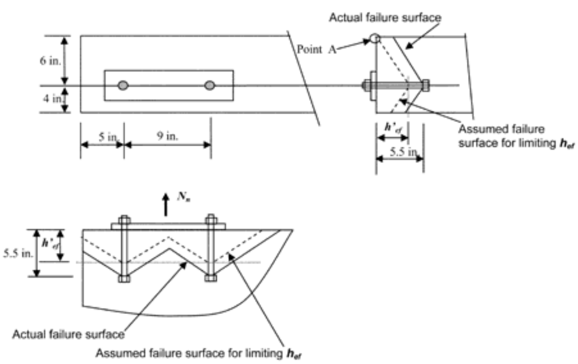


D.5.2.4 - ECCENTRICITY EFFECT

- ***For Anchor Groups***

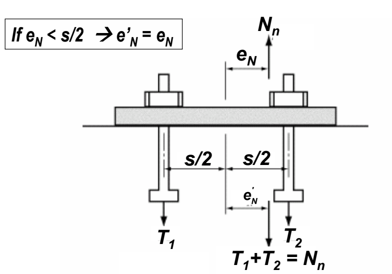
$$\psi_{ec,N} = \frac{1}{\left(1 + \frac{2e'_N}{3h_{ef}}\right)} \leq 1.0 \qquad (D-9)$$

where $e'_N \leq s/2$

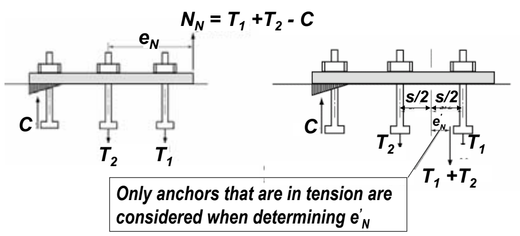
- ***Biaxial Eccentricity?***

→ $\psi_{ec,N} = (\psi_{ec,N})_x\,(\psi_{ec,N})_y$

RD5.2.4 - ECCENTRICITY



RD5.2.4(b) - ECCENTRICITY



D.5.2.5 - EDGE EFFECT

– If $c_{a,min} \geq 1.5h_{ef}$

$$\psi_{ed,N} = 1.0 \qquad (D-10)$$

– If $c_{a,min} < 1.5h_{ef}$

$$\psi_{ed,N} = 0.7 + 0.3\frac{c_{a,min}}{1.5h_{ef}} \qquad (D-11)$$

D.5.2.6 - CRACKING EFFECT

- ***For Uncracked Concrete ($f_t < f_r$ at Service Load)***
  - ***Cast-In Anchors*** $\psi_{c,N} = 1.25$
  - ***Post-Installed Anchors*** $\psi_{c,N} = 1.40$ ***where k_c = 17 in Eq. (D-7)***
  - ***Where Testing Performed for Anchors used only in Uncracked Concrete, and k_c Determined Based on ACI 355.2 Product Evaluation Report →*** $\psi_{c,N} = 1.00$

D.5.2.6 - CRACKING EFFECT

- *Where Testing Performed for Anchors Used in Cracked and Uncracked Concrete, k_c and $\psi_{c,N}$ Must be Based on ACI 355.2 Product Evaluation Report*

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D.5.2.6 - CRACKING EFFECT

- *For Cracked Concrete (f_t < f_r at Service Load)*
  - *Cast-In Anchors* $\psi_{c,N} = 1.0$
  - *Post-Installed Anchors Qualified per ACI 355.2* $\psi_{c,N} = 1.0$
  - *Provide Crack Control Reinf. per 10.6.4*

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D.5.2.7 – POST-INSTALLED ANCHORS IN UNCRACKED CONCRETE

- If $c_{a,min} \geq c_{ac}$

$$\psi_{cp,N} = 1.0 \qquad (D-12)$$

- If $c_{a,min} < c_{ac}$

$$\psi_{cp,N} = \frac{c_{a,min}}{c_{ac}} \geq \frac{1.5 h_{ef}}{c_{ac}} \qquad (D-13)$$

where c_{ac} defined in D.8.6

For cast – in anchors $\psi_{cp,N} = 1.0$

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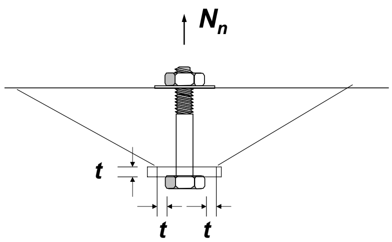
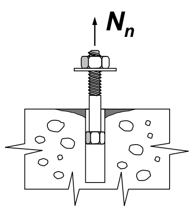
D.5.2.8 – PLATE WASHER



D.5.3 - PULLOUT STRENGTH



D.5.3 - PULLOUT STRENGTH

$$N_{pn} = \psi_{c,P} N_p \qquad \text{(D-14)}$$

- ***Headed Stud/Bolt***

$$N_p = 8A_{brg}f_c' \qquad \text{(D-15)}$$

- ***J-Bolt or L-Bolt***

$$N_p = 0.9f_c' e_h d_o \qquad \text{(D-16)}$$

where $3d_0 \leq e_h \leq 4.5d_0$

D.5.3.6 - PULLOUT STRENGTH

- ***For Uncracked Concrete ($f_t < f_r$ at Service Load)*** $\psi_{c,p} = 1.4$
- ***For Cracked Concrete*** $\psi_{c,p} = 1.0$

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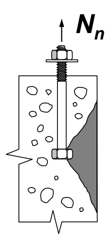
D.5.4 - SIDE-FACE BLOWOUT



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D.1 - DEFINITIONS

Side-Face Blowout Strength

The strength of fasteners with deeper embedment but thinner side cover corresponding to concrete spalling on the side face around the embedded head while no major breakout occurs at the top concrete surface.

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D.5.4.1 - SIDE-FACE BLOWOUT

- ***Single** Headed Fastener with Deep Embedment, Close to Edge (c_{a1} < $0.4h_{ef}$)*

$$N_{sb} = 160 c_{a1} \sqrt{A_{brg}} \sqrt{f_c'} \qquad (D-17)$$

- *If Perpendicular Distance c_{a2} < $3c_{a1}$ from Edge, Modify N_{sb} by:*

$$(1 + c_{a2} / c_{a1}) / 4$$

where $1.0 \le c_{a2}/c_{a1} \le 3.0$

D.5.4.2 - SIDE-FACE BLOWOUT

- ***For Multiple** Headed Anchors with Deep Embedment, Close to Edge (c_{a1} < $0.4h_{ef}$) and s < $6c_{a1}$*

$$N_{sbg} = \left(1 + \frac{s}{6c_{a1}}\right) N_{sb} \qquad (D-18)$$

where

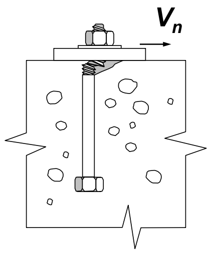
s = Spacing of Outer Anchors Along Edge

N_{sb} from Eq. (D-17) Without Modification for Perpendicular Edge Distance

D.6 - DESIGN FOR SHEAR LOADING

- *D.6.1 – Steel Strength*
- *D.6.2 – Concrete Breakout Strength*
- *D.6.3 – Concrete Pryout Strength*

D.6.1 - STEEL FAILURE (SHEAR)



D.6.1.2 - STEEL STRENGTH (SHEAR)

(a) Cast-in Headed Stud Anchors

$V_{sa} = nA_{se}f_{uta}$ (D-19)

where $f_{uta} \leq 1.9f_y$

$\leq$ 125,000 psi

- *With Built-Up Grout Pads, Use* $0.8V_{sa}$

D.6.1.2 - STEEL STRENGTH (SHEAR)

(b) Cast-in Headed and Hooked Bolts, and Post-Installed Anchors Without Sleeves Extending in Shear Plane

$V_{sa} = nA_{se}(0.6f_{uta})$ (D-20)

where $f_{uta} \leq 1.9f_y$

$\leq$ 125,000 psi

- *With Built-Up Grout Pads, Use* $0.8V_{sa}$

D.6.1.2 - STEEL STRENGTH (SHEAR)

(c) Post-Installed Anchors with Sleeves Extending in Shear Plane V_{sa} Based on:

- ***ACI 355.2 or***
- ***Eq. (D-20)***

- ***With Built-Up Grout Pads, Use $0.8V_{sa}$***

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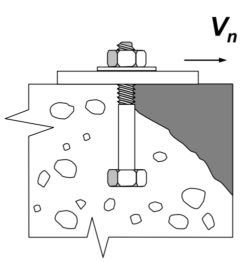
D.6.2 - CONCRETE BREAKOUT (SHEAR)



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D.6.2.1(a) - CONCRETE BREAKOUT STRENGTH - SINGLE ANCHOR (SHEAR)

$$V_{cb} = \frac{A_{Vc}}{A_{Vco}} \psi_{ed,V} \psi_{c,V} V_b \qquad (D-21)$$

Basic single anchor strength

Accounts for cracking

Accounts for edge effects

Accounts for projected area of failure surface

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D.6.2.1(b) - CONCRETE BREAKOUT STRENGTH - GROUP ANCHOR (SHEAR)

$$V_{cbg} = \frac{A_{Vc}}{A_{Vco}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} V_b \qquad (D-22)$$

- V_b: Basic single anchor strength
- $\psi_{c,V}$: Accounts for cracking
- $\psi_{ed,V}$: Accounts for edge effects
- $\psi_{ec,V}$: Accounts for eccentricity
- $\frac{A_{Vc}}{A_{Vco}}$: Accounts for projected area of failure surface

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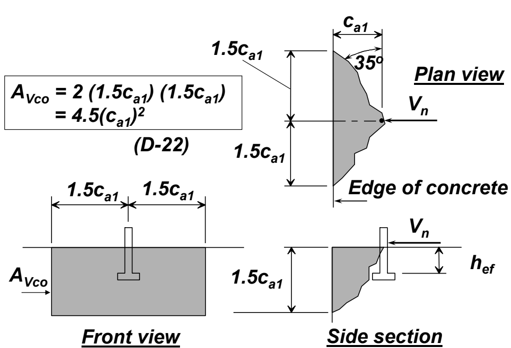

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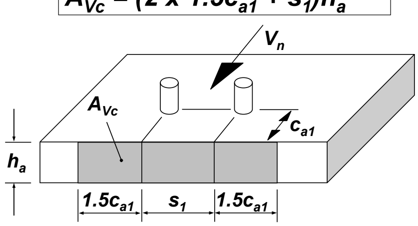
If $h_a < 1.5c_{a1}$ and $s_1 < 3c_{a1}$

$$\boxed{A_{Vc} = (2 \times 1.5c_{a1} + s_1)h_a}$$



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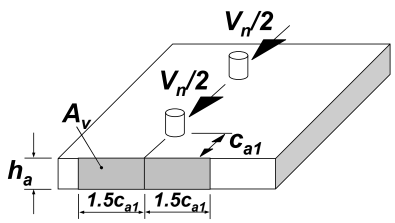
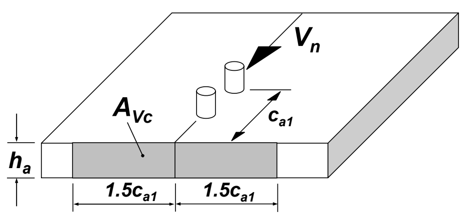
If $h_a < 1.5c_{a1}$

$\boxed{A_{Vc} = (2 \times 1.5c_{a1}) \times h_a}$



If $h_a < 1.5c_{a1}$

$\boxed{A_{Vc} = (2 \times 1.5c_{a1})h_a}$



D.6.2.1(c)-(d) - CONCRETE BREAKOUT STRENGTH (SHEAR)

- ***For Shear Force Parallel to Edge ($\psi_{ed,V} = 1$)***
  - ***$V_{cb} = 2[V_{cb}$ per Eq. (D-21)]***
  - ***$V_{cbg} = 2[V_{cbg}$ per Eq. (D-22)]***
- ***At Corner, Use Smaller of:***
  - ***Strength Perpendicular to Edge***
  - ***Strength Parallel to Edge***

D.6.2.2 - BASIC CONC. BREAKOUT

- *Single Anchor in Shear in Cracked Concrete*

$$V_b = 7\left(\frac{\ell_e}{d_o}\right)^{0.2}\sqrt{d_o}\sqrt{f'_c}\left(c_{a1}\right)^{1.5} \qquad (D-24)$$

- *$\ell_e = h_{ef}$ for Anchors with Constant Stiffness Over h_{ef}*
- *$\ell_e = 2d_o$ for Torque-Controlled Expansion Anchors with a Distance Sleeve Separated from Expansion Sleeve*
- *$\ell_e \le 8d_o$*

D.6.2.3 - BASIC CONC. BREAKOUT

- *If Anchors Rigidly Welded to Attachment, and*
- *Minimum Attachment Thickness Not Less Than (a) 3/8 in., or (b) Anchor Diameter/2*

$$V_b = 8\left(\frac{\ell_e}{d_o}\right)^{0.2}\sqrt{d_o}\sqrt{f'_c}\left(c_{a1}\right)^{1.5} \qquad (D-25)$$

- *ℓ_e as defined in D.6.2.2*

D.6.2.3 - BASIC CONC. BREAKOUT

- ***For Group of Anchors, Strength Based on c_{a1} for Row Farthest from Edge***
- ***Center-to-Center Anchor Spacing $\ge$ 2.5 in.***
- ***If $c_{a2} \le 1.5h_{ef}$ Provide Supplementary Reinforcement***

D.6.2.4 – ANCHORS CLOSE TO 3 OR 4 EDGES

Where 3 or more Edge Distances $\leq 1.5c_{a1}$
→ Effective c_{a1} Used in Eq.(D-23) through (D-28) Not to Exceed the Largest of:

- ***$C_{a2}/1.5$***
- ***$h_a/1.5$***
- ***(1/3) Maximum Spacing Between Anchors***

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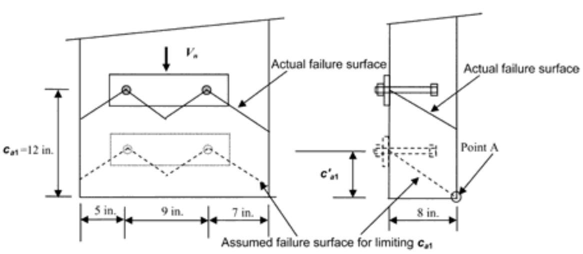
D.6.2.5 - ECCENTRICITY EFFECT



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D.6.2.5 - ECCENTRICITY EFFECT

- ***For Group of Anchors***

$$\psi_{ec,V} = \frac{1}{\left[1 + \frac{2e'_V}{3c_{a1}}\right]} \qquad (D-25)$$

where $e'_V \leq s/2$

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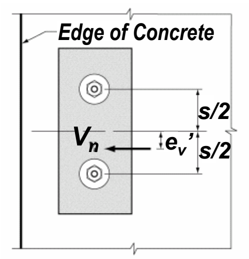
D.6.2.5 - ECCENTRICITY EFFECT



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D.6.2.6 - EDGE EFFECT

- If $c_{a2} \geq 1.5\ c_{a1}$

  $\psi_{ed,V} = 1.0$ (D-27)

- If $c_{a2} < 1.5c_{a1}$

$$\psi_{ed,V} = 0.7 + 0.3 \frac{c_{a2}}{1.5c_{a1}} \qquad (D-28)$$

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D.6.2.7 - CRACKING EFFECT

- For Uncracked Concrete ($f_t < f_r$) at Service Load $\psi_{c,V} = 1.4$
- For Cracked Concrete
  - $\psi_{c,V} = 1.0$ No Reinf.* or < No. 4 Bar
  - $\psi_{c,V} = 1.2$ With Reinf.* $\geq$ No. 4 Bar
  - $\psi_{c,V} = 1.4$ With Reinf.* $\geq$ No. 4 Bar (Enclosed Within Stirrups w/Spacing $\leq$ 4 in.)

* Edge or Supplementary Reinforcement

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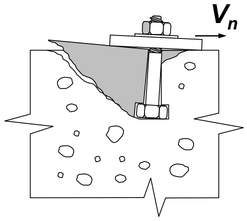
D.6.3 - CONCRETE PRYOUT



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D.1 - DEFINITIONS

<u>Concrete Pryout Strength</u>

The strength corresponding to formation of a concrete spall behind a short, stiff anchor with an embedded base that is displaced in the direction opposite to the applied shear force.

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D.6.3 - CONCRETE PRYOUT

Single Anchor	$V_{cp} = k_{cp}N_{cb}$	***(D-29)***
Group of Anchors	$V_{cpg} = k_{cp}N_{cb}$	***(D-30)***

where

- k_{cp} ***= 1.0 for*** h_{ef} ***< 2.5 in.***
- k_{cp} ***= 2.0 for*** $h_{ef} \geq$ ***2.5 in.***
- N_{cb} ***Computed from Eq. (D-4)***

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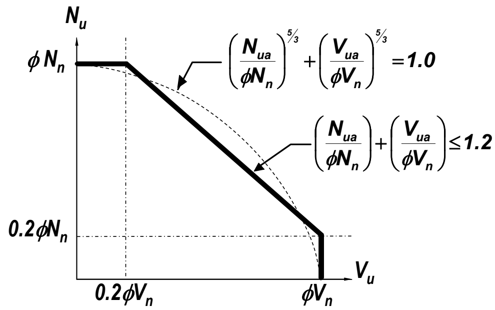
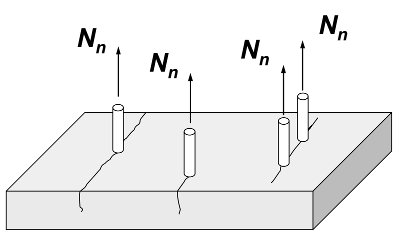
D.7 - TENSION/SHEAR INTERACTION



D.8 - PRECLUDE SPLITTING FAILURE



D.8 - PRECLUDE SPLITTING FAILURE

- ***At Design Stage, Specific Products May not be Known***
- ***In Absence of Supplementary Reinf. for Crack Control, D.8 Sets Min. Cover, Spacings, Member Thickness***
- ***Lesser Values Permitted per ACI 355.2***

D.8.1 – ANCHOR SPACING

	Center-to-Center
• ***Untorqued***	
– ***Cast-in***	$\boldsymbol{4d_0}$
• ***Torqued***	
– ***Cast-in***	$\boldsymbol{6d_0}$
– ***Post-Installed***	$\boldsymbol{6d_0}$

D.8.2 – EDGE DISTANCE

Cast-in Headed Anchors

- ***Untorqued:*** ***Min. Cover per 7.7***
- ***Torqued:*** $\boldsymbol{6d_o}$

D.8.3 – EDGE DISTANCE

Post-Installed Anchors

Largest of:

- ***Min. Cover per 7.7***
- ***Minimum Edge Distance for Product per ACI 355.2***
- ***2 Times Max. Aggregate Size***

D.8.3 – EDGE DISTANCE

Post-Installed Anchors

Without Product-Specific 355.2 Info:

- *Undercut Anchors* $6d_o$
- *Torque-Controlled Anchors* $8d_o$
- *Displacement-Controlled Anchors* $10d_o$

D.8.4 – EDGE DISTANCE

Post-Installed Anchors

- ***If Edge Distance or Spacing Less than per D.8.1 to D.8.3, and Anchors Will Remain Untorqued***
  - ***Compute Fictitious Diameter d_o' to Meet Requirements of D.8.1 and D.8.3***
  - ***Limit Applied Forces to Strength of Anchor With Fictitious Diameter d_o'***

D.8.5 - PRECLUDE SPLITTING FAILURE

Expansion & Undercut Anchors

Without Product-Specific 355.2 Info:

- ***h_{ef} Not to Exceed the Larger of:***
  - *2/3 Member Thickness*
  - *Member Thickness Less 4 in.*

D.8.6 – EDGE DISTANCE

Post-Installed Anchors

Without Tension Test Data per 355.2:

- *Undercut Anchors* $2.5h_{ef}$
- *Torque-Controlled Anchors* $4h_{ef}$
- *Displacement-Controlled Anchors* $4h_{ef}$

D.8.7 - PROJECT DRAWINGS AND SPECIFICATIONS

- ***Specify Use of Anchors With a Minimum Edge Distance as Assumed in Design***

D.9 - ANCHOR INSTALLATION

- ***Fasteners to be Installed in Accordance with***
  - ***Project Drawings***
  - ***Project Specifications***