

EXAMPLE CALCULATION *Adhesive Anchors (Traditional ASD)*

Example calculation for a grouping of adhesive anchors using ASD:

Design a connection comprised of four 3/4" diameter all-thread rods installed in $f'_c = 2,000$ psi concrete using SET adhesive as shown. The anchor grouping is subject to an applied tension load of 3,000 lb. and an applied shear load of 1,000 lb. acting simultaneously.

ADDITIONAL DATA:

- All-thread rod material: ASTM A307.
- All-thread rod embedment depth: 6 3/4"
- All-thread rod spacing: $S_1=S_3=8"$, $S_2=11.3"$ (use 11")
($S_{critical} = 27" > S_{actual}$, therefore reduced efficiency.)
- All-thread rod edge distance: $C_1=C_2=3"$
($C_{critical} = 10 1/8" > C_{actual}$, therefore reduced efficiency.)

SOLUTION:

Unadjusted allowable tension loads:

Based on adhesive bond strength = $T_{bond} = 10,525$ lbs.

Based on steel strength = $T_{steel} = 8,460$ lbs.

Unadjusted allowable shear loads:

Based on concrete strength = $V_{conc} = 6,310$ lbs.

Based on steel strength = $V_{steel} = 4,360$ lbs.

Calculate reduced efficiency factors for all-thread rod installed at an edge distance of 3" using tables on pages 48–49:

Tension: $C_1=C_2=3"$, $f_c = 0.56$ from f_c - Tension Table

Shear: $C_1=C_2=3"$, $f_c = 0.29$ from f_c - Shear Table

Calculate reduced efficiency factors for all-thread rod installed at a spacing of 8" using tables on pages 50–51:

Tension: $S_1=S_3=8"$, $f_s = 0.91$ from f_s - Tension Table

$S_2=11"$, $f_s = 0.925$ from f_s - Tension Table

Shear: $S_1=S_3=8"$, $f_s = 0.95$ from f_s - Shear Table

$S_2=11"$, $f_s = 1.00$ from f_s - Shear Table

Reduce allowable tension value based on bond strength. The reduction factors are cumulative due to the influence of two reduced edge distance conditions and three reduced spacing conditions:

$$\begin{aligned} (T_{bond})_{net} &= (f_c)(f_s)(T_{bond}) \\ &= (0.56 \times 0.56)(0.91 \times 0.91 \times 0.925)(10,525 \text{ lbs.}) \\ &= 2,528 \text{ lbs.} \end{aligned}$$

Allowable tension value is the lesser of:

Tension based on net bond strength = **2,528 lbs.** (governs) or

Tension based on steel strength = 8,460 lbs.

For a group of 4 anchors the combined allowable tension value is:

$$= (4 \text{ anchors})(2,528 \text{ lbs./anchor}) = \mathbf{10,112 \text{ lbs.} > 3,000 \text{ lbs.}}$$

(design tension) O.K.

(Note: If high in-service temperature is expected, the allowable based on bond/concrete should be multiplied by a strength reduction factor found in the adhesive's temperature sensitivity table.)

Reduce allowable shear value based on concrete strength. The reduction factors are cumulative due to the influence of two reduced edge-distance conditions and three reduced spacing conditions:

$$\begin{aligned} (V_{conc})_{net} &= (f_c)(f_s)(V_{conc}) \\ &= (0.29 \times 0.29)(.95 \times .95 \times 1.00)(6,310 \text{ lbs.}) \\ &= 478 \text{ lbs.} \end{aligned}$$

Allowable shear value is the lesser of:

Shear based on net concrete strength = **478 lbs.** (governs) or

Shear based on steel strength = 4,360 lbs.

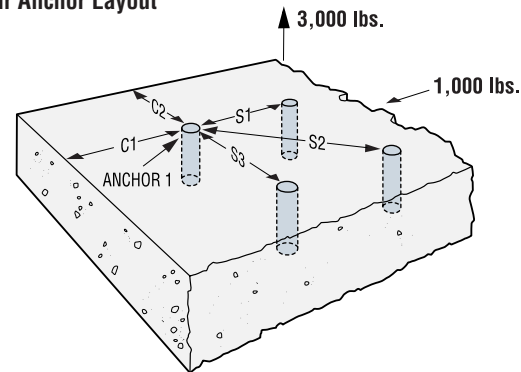
For a group of 4 anchors the combined allowable shear value is:

$$= (4 \text{ anchors})(478 \text{ lbs./anchor}) = \mathbf{1,912 \text{ lbs.} > 1,000 \text{ lbs.}}$$

(design shear) O.K.

(Note: If high in-service temperature is expected, the allowable shear based on bond/concrete should be multiplied by a strength reduction factor found in the adhesive's temperature sensitivity table.)

Four Anchor Layout



The allowable tension (or shear) value for a group of anchors is equal to the lowest (minimum) tension (or shear) value for a single anchor within the group multiplied by the number of anchors within the group.

CHECK COMBINED TENSION AND SHEAR INTERACTION:

For adhesive anchors, use the straight-line method ($n=1.0$, see Figure 1) when calculating the interaction of both tension and shear upon the anchor per the following equation:

$$(\text{Design shear/allowable shear})^n + (\text{Design tension/allowable tension})^n \leq 1.0, n=1.0$$

Design shear (V) = 1,000 lbs.

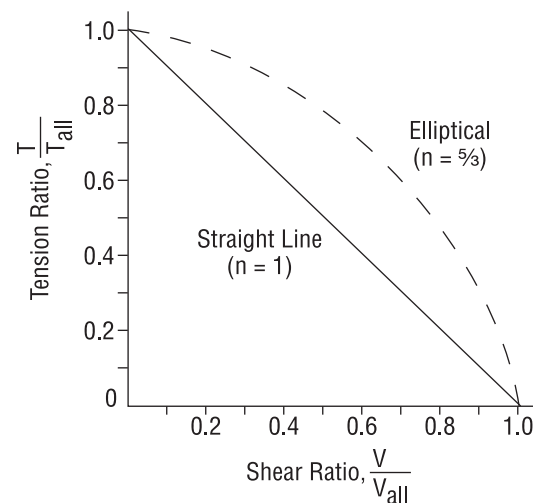
Allowable shear (V_{all}) = 1,912 lbs.

Design tension (T) = 3,000 lbs.

Allowable tension (T_{all}) = 10,112 lbs.

$$(1,000/1,912)^{1.0} + (3,000/10,112)^{1.0} = 0.82 \leq 1.0 \text{ O.K.}$$

Figure 1



Would you like help with these calculations?
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Simpson Strong-Tie® Anchor Designer™ software.



EXAMPLE CALCULATION *Mechanical Anchors (Traditional ASD)*



Example calculation for a group of (2) Titen HD® anchors using ASD:

Design a connection comprised of two (2) 3/4" diameter Titen HD® anchors installed in the face of an 8" normal weight grouted CMU wall as shown. The anchor group has an applied tension load of 600 lbs. and an applied shear load of 500 lbs. acting simultaneously.

ADDITIONAL DATA:

- Embedment depth = 5 1/2"
- Spacing = $S_{act} = S1 = 8"$.
- Critical spacing for 3/4" dia. anchor at embedment = $S_{cr} = 12"$.
- $S_{act} < S_{cr}$, therefore use spacing reduction factor for S1.
- End distance = $C_{act} = C1 = 4"$
Edge distance = $C_{act} = C2 = 12"$
- Critical edge distance = $C_{cr} = 12"$.
- Critical end distance = $C_{cr} = 12"$.
- $C1 < C_{cr}$, therefore use perpendicular-to-edge reduction factor for C1.
- $C2 > C_{cr}$, therefore no edge reduction factor for C2.

SOLUTION:

TENSION

Determine uninfluenced allowable tension load in the face of an 8" normal wt. concrete grouted CMU wall:

Uninfluenced allowable tension = 1,600 lbs.

Calculate reduced efficiency factors for Edge Distance:

$$C_{act} = C1 = 4"$$

$$C_{act} = C2 = 12"$$

$$f_{cC1} = 0.66 = \text{Load adjustment factor (page 130)}$$

Calculate reduced efficiency factor for spacing:

$$S_{act} = S1 = 8"$$

$$f_{sS1} = 0.67 = \text{Load adjustment factor (page 130)}$$

Calculate allowable tension load per anchor:

$$\text{Allowable tension} = (\text{uninfluenced allowable tension}) (f_{cC1})(f_{sS1})$$

$$\text{Allowable tension} = (1,600 \text{ lbs.})(0.66)(0.67) = 708 \text{ lbs. per anchor}$$

For a group of 2 anchors the combined allowable tension value is:

$$= (2 \text{ anchors})(708 \text{ lbs./anchor}) = \mathbf{1,416 \text{ lbs.} > 600 \text{ lbs.}}$$

(design tension) O.K.

SHEAR

Determine uninfluenced allowable shear load in the face of an 8" normal wt. concrete grouted CMU wall:

Uninfluenced allowable shear = 3,000 lbs.

Calculate reduced efficiency factor for end distance:

$$C_{act} = C1 = 4"$$

$$C_{act} = C2 = 12"$$

$$f_{cC1} = 0.21 = \text{Load adjustment factor (page 130)}$$

Calculate reduced efficiency factor for spacing:

$$S_{act} = S1 = 8"$$

$$f_{sS1} = 0.75 = \text{Load adjustment factor (page 130)}$$

Calculate allowable shear load per anchor:

$$\text{Allowable shear} = (\text{uninfluenced allowable shear}) (f_{cC1})(f_{sS1})$$

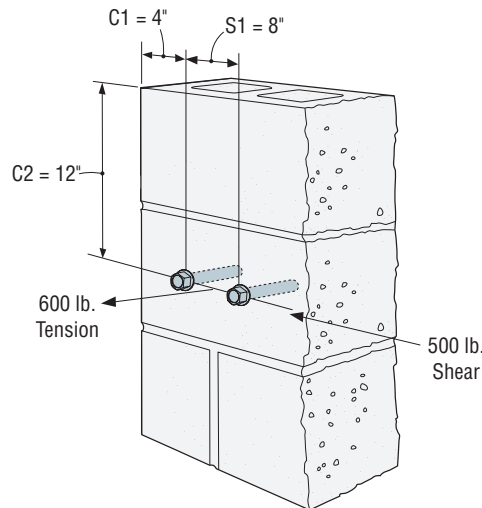
$$\text{Allowable shear} = (3,000 \text{ lbs.})(0.21)(0.75) = 473 \text{ lbs. per anchor}$$

For a group of 2 anchors the combined allowable shear value is:

$$= (2 \text{ anchors})(473 \text{ lbs./anchor}) = \mathbf{946 \text{ lbs.} > 500 \text{ lbs.}}$$

(design shear) O.K.

Two Anchor Layout



The allowable tension (or shear) value for a group of anchors is equal to the lowest (minimum) tension (or shear) value for a single anchor within the group multiplied by the number of anchors within the group.

CHECK COMBINED TENSION AND SHEAR INTERACTION:

For the Titen HD® in grouted CMU, use the straight-line method ($n = 1$, see Figure 1) when calculating the interaction of both tension and shear upon the anchor per the following equation:

$$(\text{Design shear/Allowable shear})^n + (\text{Design tension/Allowable tension})^n \leq 1.0, n = 1$$

Design shear (V) = 500 lbs.

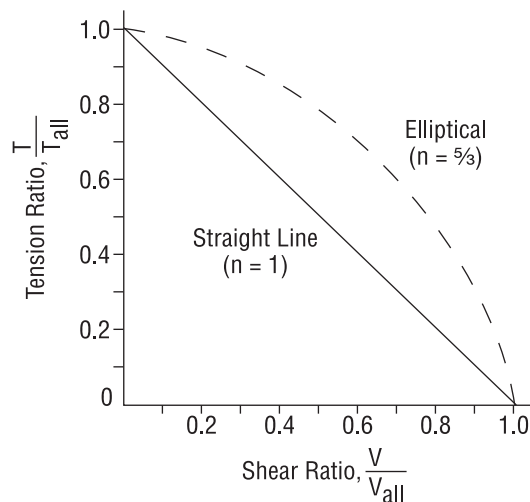
Allowable shear (V_{all}) = 945 lbs.

Design tension (T) = 600 lbs.

Allowable tension (T_{all}) = 1,416 lbs.

$$(600/1,416)^1 + (500/945)^1 = 0.95 \leq 1.0 \text{ O.K.}$$

Figure 1



Note: The elliptical method permits greater allowable tension and shear loads to be used than the straight-line method.

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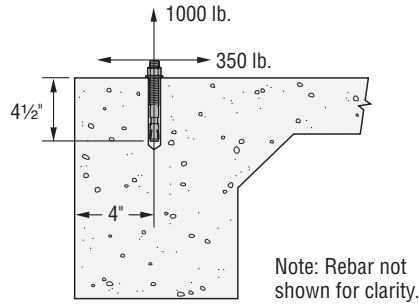


EXAMPLE CALCULATION *Mechanical Anchors (ACI 318 App. D/ICC-ES AC193)*

Example calculation for a single Strong-Bolt™ anchor using USD:

Determine if a single 1/2" diameter Strong-Bolt™ torque-controlled expansion anchor with a minimum 5" embedment ($h_{ef} = 4\frac{1}{2}$ inches) installed 4" from the edge of a 12" deep spandrel beam is adequate for a service tension load of 1,000 lb. for wind and a reversible service shear load of 350 lb. for wind. The anchor will be in the tension zone, away from other anchors in $f'_c = 3,000$ psi normal-weight concrete.

Reference the appropriate tables in this catalog for Strong-Bolt anchor performance values as determined from testing in accordance with ACI 355.2 and ICC-ES AC193.



Calculations and Discussion

REFERENCE

Note: Calculations are performed in accordance with ACI 318-05.

- Determine the factored tension and shear design loads:

ACI 318, 9.2.1

$$N_{UA} = 1.6W = 1.6 \times 1,000 = 1,600 \text{ lb.}$$

$$V_{UA} = 1.6W = 1.6 \times 350 = 560 \text{ lb.}$$

- Design considerations:

D.4.1.2

This is a combined tension and shear interaction problem where values for both ϕN_n and ϕV_n need to be determined. ϕN_n is the lesser of the design tension strength controlled by: steel (ϕN_{sa}), concrete breakout (ϕN_{cb}), or pull-out (ϕN_{pn}). ϕV_n is the lesser of the design shear strength controlled by: steel (ϕV_{sa}), concrete breakout (ϕV_{cb}), or pryout (ϕV_{cp}).

- Steel capacity under tension Loading:

D.5.1

$$\phi N_{sa} \geq N_{UA}$$

Eq. (D-1)

$$N_{sa} = 13,500 \text{ lb.}$$

This catalog

$$\phi = 0.75$$

This catalog

$$n = 1 \text{ (single anchor)}$$

Calculating for ϕN_{sa} :

$$\phi N_{sa} = 0.75 \times 1 \times 13,500 = 10,125 \text{ lb.} > 1,600 \text{ lb.} - \text{OK}$$

∴ 1/2 in. diameter anchor is adequate

Calculations and Discussion

REFERENCE

- Concrete breakout capacity under tension loading:

D.5.2

$$\phi N_{cb} \geq N_{UA}$$

Eq. (D-1)

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$$

Eq. (D-4);

where:

$$N_b = k_c \sqrt{f'_c} h_{ef}^{1.5}$$

Eq. (D-7)

substituting:

$$\phi N_{cb} = \phi \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} k_c \sqrt{f'_c} h_{ef}^{1.5}$$

where:

$$k_c = k_{cr} = 17$$

This catalog

(Anchor is installed in a tension zone, therefore, cracking is assumed at service loads)

$$\Psi_{cp,N} = 1.0$$

D.5.2.7

$$\Psi_{ed,N} = 0.7 + 0.3 \frac{c_{a,min}}{1.5h_{ef}} \text{ when } c_{a,min} < 1.5h_{ef}$$

Eq. (D-11)

by observation, $c_{a,min} = 4 < 1.5h_{ef}$

$$\Psi_{ed,N} = 0.7 + 0.3 \frac{(4)}{1.5(4.5)} = 0.88$$

$\Psi_{c,N} = 1.0$ assuming cracking at service loads ($f_t > f_r$)

D.5.2.6

$\phi = 0.65$ for Condition B (no supplementary reinforcement provided)

This catalog

$$A_{Nco} = 9h_{ef}^2 = 9(4.5)^2 = 182.25 \text{ in.}^2$$

Eq. (D-6)

$$A_{Nc} = (c_{a1} + 1.5h_{ef})(2 \times 1.5h_{ef}) = (4 + 1.5(4.5))(2 \times 1.5(4.5)) = 145.13 \text{ in.}^2$$

Fig. RD.5.2.1(a)

$$\frac{A_{Nc}}{A_{Nco}} = \frac{145.13}{182.25} = 0.8$$

Calculating for ϕN_{cb} :

$$\phi N_{cb} = 0.65 \times 0.8 \times 1.0 \times 0.88 \times 1.0 \times 17 \times$$

$$\sqrt{3,000} \times (4.5)^{1.5} = 4,067 \text{ lb.} > 1,600 \text{ lb.} - \text{OK}$$

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EXAMPLE CALCULATION *Mechanical Anchors (ACI 318 App. D/ICC-ES AC193)*

Continued from previous page.

CALCULATIONS AND DISCUSSION REFERENCE

5. Pullout capacity: *D.5.3*

Pullout capacity, $N_{pn,cr}$, is established by reference tests in cracked concrete by the reliability test of ACI 355.2. Data from the anchor prequalification testing must be used. Reference Strong-Bolt™ anchor "characteristic tension design values" table for the 5 percent fractile value, $N_{pn,cr}$.

$$\phi N_{pn} \geq N_{ua} \quad \text{Eq. (D-1)}$$

$$N_{pn,cr} = 2,995 \times \left(\frac{3,000}{2,500}\right)^{0.5} = 3,281 \text{ lb.} \quad \text{This catalog}$$

$$\phi = 0.65 \quad \text{This catalog}$$

$$\phi N_{pn} = 0.65 \times 3,281 = 2,133 \text{ lb.} > 1,600 \text{ lb.} - \text{OK}$$

6. Check all failure modes under tension loading: *D.4.1.2*

Summary:

$$\text{Steel capacity} = 10,125 \text{ lb.}$$

$$\text{Concrete breakout capacity} = 4,067 \text{ lb.}$$

$$\text{Pullout capacity} = 2,133 \text{ lb.} \leftarrow \text{Controls}$$

$\therefore \phi N_n = 2,133 \text{ lb.}$ as pullout capacity controls

7. Steel capacity under shear loading: *D.6.1*

$$\phi V_{sa} \geq V_{ua} \quad \text{Eq. (D-2)}$$

$$V_{sa} = 6,560 \text{ lb.} \quad \text{This catalog}$$

$$\phi = 0.65 \quad \text{This catalog}$$

Calculating for ϕV_{sa} :

$$\phi V_{sa} = 0.65 \times 6,560 = 4,264 \text{ lb.} > 560 \text{ lb.} - \text{OK}$$

\therefore 1/2 in. diameter anchor is adequate

8. Concrete breakout capacity under shear loading: *D.6.2*

$$\phi V_{cb} \geq V_{ua} \quad \text{Eq. (D-2)}$$

$$V_{cb} = \frac{A_{VC}}{A_{VCO}} \Psi_{ed,V} \Psi_{c,V} V_b \quad \text{Eq. (D-21)}$$

where:

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

substituting:

$$\phi V_{cb} = \phi \frac{A_{VC}}{A_{VCO}} \Psi_{ed,V} \Psi_{c,V} 7 \left(\frac{\ell_e}{d_o}\right)^{0.2} \sqrt{d_o} \sqrt{f'_c} c_{a1}^{1.5}$$

where:

$$\phi = 0.70 \text{ for Condition B} \\ \text{(no supplementary reinforcement provided)} \quad \text{D4.4(c)(i)}$$

$$A_{VCO} = 4.5c_{a1}^2 \quad \text{Eq. (D-23)}$$

$$= 4.5(4)^2$$

$$\therefore A_{VCO} = 72 \text{ in.}^2$$

$$A_{VC} = 2(1.5c_{a1})(1.5c_{a1}) \quad \text{Fig. RD.6.2.1(a)}$$

$$= 2(1.5(4))(1.5(4))$$

$$\therefore A_{VC} = 72 \text{ in.}^2$$

$$\frac{A_{VC}}{A_{VCO}} = \frac{72}{72} = 1 \quad \text{D.6.2.1}$$

$$\Psi_{ed,V} = 1.0 \text{ since } c_{a2} > 1.5c_{a1} \quad \text{Eq. (D-27)}$$

$$\Psi_{c,V} = 1.0 \text{ assuming cracking} \\ \text{at service loads (} f_t > f_r \text{)} \quad \text{D.6.2.7}$$

$$d_o = 0.5 \text{ in.}$$

$$\ell_e = 8d_o = 8(0.5) = 4" \quad \text{D.6.2.2}$$

$$c_{a1} = 4 \text{ in.}$$

$$\phi V_{cb} = 0.70 \times 1 \times 1.0 \times 1.0 \times 7 \times \left(\frac{4}{0.5}\right)^{0.2} \times \sqrt{0.5}$$

$$\times \sqrt{3,000} \times (4)^{1.5} = 2,301 \text{ lb.} > 560 \text{ lb.} - \text{OK}$$

CALCULATIONS AND DISCUSSION REFERENCE

9. Concrete pryout strength: *D.6.3*

$$\phi n V_{cp} \geq V_{ua} \quad \text{Eq. (D-2)}$$

$$V_{cp} = k_{cp} N_{cb} \quad \text{Eq. (D-29)}$$

where:

$$n = 1$$

$$k_{cp} = 2.0 \text{ and } \phi = 0.70 \quad \text{This catalog}$$

$$k_{cp} N_{cb} = 2.0 \times \frac{4,067}{0.65} = 12,514 \text{ lb.} \quad \text{D.6.3.1}$$

$$\phi n V_{cp} = 0.70 \times 1 \times 12,514 = 8,760 \text{ lb.} > 560 \text{ lb.} - \text{OK}$$

10. Check all failure modes under shear Loading: *D.4.1.2*

Summary:

$$\text{Steel capacity} = 4,264 \text{ lb.}$$

$$\text{Concrete breakout capacity} = 2,301 \text{ lb.} \leftarrow \text{Controls}$$

$$\text{Pryout capacity} = 8,760 \text{ lb.}$$

$\therefore \phi V_n = 2,301 \text{ lb.}$ as concrete breakout capacity controls

11. Check interaction of tension and shear forces: *D.7*

If $0.2 \phi V_n \geq V_{ua}$, then the full tension design strength is permitted. *D.7.1*

By observation, this is not the case.

If $0.2 \phi N_n \geq N_{ua}$, then the full shear design strength is permitted *D.7.2*

By observation, this is not the case.

Therefore:

$$\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2 \quad \text{Eq. (D-31)}$$

$$\frac{1,600}{2,133} + \frac{560}{2,301} = 0.75 + 0.24 = 0.99 < 1.2 - \text{OK}$$

12. Summary

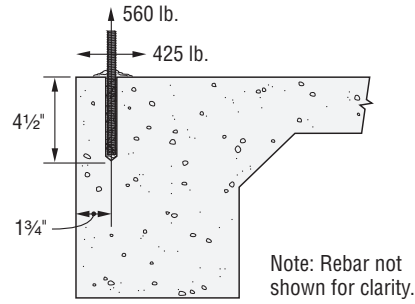
A single 1/2" diameter Strong-Bolt™ anchor at a 5" embedment depth is adequate to resist the applied service tension and shear loads of 1,000 lb. and 350 lb., respectively.

EXAMPLE CALCULATION *Adhesive Anchors (ICC-ES AC308)*

Example calculation for a single SET-XP™ epoxy adhesive anchor using USD:

Determine if a single 1/2" diameter ASTM A193 Grade B7 anchor rod in SET-XP™ epoxy adhesive anchor with a minimum 4 1/2" embedment ($h_{ef} = 4 1/2"$) installed 1 3/4" from the edge of a 12" deep spandrel beam is adequate for a service tension load of 560 lb. for wind and a reversible service shear load of 425 lb. for wind. The anchor will be in uncracked dry concrete, away from other anchors in $f'_c = 3,000$ psi normal-weight concrete. The anchor will be subjected to a maximum short-term temperature of 110°F and a maximum long-term temperature of 75°F. Continuous inspection will be provided

Reference the appropriate tables in this catalog for SET-XP epoxy adhesive anchor performance values as determined from testing in accordance with ICC-ES AC308.



CALCULATIONS AND DISCUSSION

REFERENCE

Note: Calculations are performed in accordance with ICC-ES AC308 and ACI 318-05.

- Determine the factored tension and shear design loads:

ACI 318, 9.2.1

$$N_{ua} = 1.6W = 1.6 \times 560 = 900 \text{ lb.}$$

$$V_{ua} = 1.6W = 1.6 \times 425 = 680 \text{ lb.}$$

- Design considerations:

D.4.1.2

This is a combined tension and shear interaction problem where values for both ϕN_n and ϕV_n need to be determined. ϕN_n is the lesser of the design tension strength controlled by: steel (ϕN_{sa}), concrete breakout (ϕN_{cb}), or adhesive (ϕN_a). ϕV_n is the lesser of the design shear strength controlled by: steel (ϕV_{sa}), concrete breakout (ϕV_{cb}), or pryout (ϕV_{cp}).

- Steel capacity under tension loading:

D.5.1

$$\phi N_{sa} \geq N_{ua}$$

Eq. (D-1)

$$N_{sa} = 17,750 \text{ lb.}$$

This catalog

$$\phi = 0.75$$

This catalog

$$n = 1 \text{ (single anchor)}$$

Calculating for ϕN_{sa} :

$$\phi N_{sa} = 0.75 \times 1 \times 17,750 = 13,313 \text{ lb.} > 900 \text{ lb.} - \text{OK}$$

CALCULATIONS AND DISCUSSION

REFERENCE

- Concrete breakout capacity under tension loading:

D.5.2

$$\phi N_{cb} \geq N_{ua}$$

Eq. (D-1)

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$$

Eq. (D-4);

where:

$$N_b = k_C \sqrt{f'_c} h_{ef}^{1.5}$$

Eq. (D-7)

substituting:

$$\phi N_{cb} = \phi \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} k_C \sqrt{f'_c} h_{ef}^{1.5}$$

where:

$$k_C = k_{uncr} = 24$$

This catalog

$$c_{a,min} = 1.75" = c_{min} - \text{OK}$$

$$c_{ac} = 3h_{ef} = 3(4.5) = 13.5"$$

This catalog

$$\Psi_{cp,N} = \frac{c_{a,min}}{c_{ac}} = 0.13 \geq \frac{1.5h_{ef}}{c_{ac}} = 0.5$$

Eq. (D-13)

$$\Psi_{cp,N} = 0.5$$

$$\Psi_{ed,N} = 0.7 + 0.3 \frac{c_{a,min}}{1.5h_{ef}} \text{ when } c_{a,min} < 1.5h_{ef}$$

Eq. (D-11)

by observation, $c_{a,min} < 1.5h_{ef}$

$$\Psi_{ed,N} = 0.7 + 0.3 \frac{1.75}{1.5(4.5)} = 0.78$$

$$\Psi_{c,N} = 1.0 \text{ since } k_C = k_{uncr} = 24$$

D.5.2.6

$$\phi = 0.65 \text{ for Condition B}$$

This catalog

(no supplementary reinforcement provided)

$$\begin{aligned} A_{Nco} &= 9h_{ef}^2 \\ &= 9(4.5)^2 \\ &= 182.25 \text{ in.}^2 \end{aligned}$$

Eq. (D-6)

$$\begin{aligned} A_{Nc} &= (c_{a1} + 1.5h_{ef})(2 \times 1.5h_{ef}) \\ &= (1.75 + 1.5(4.5))(2 \times 1.5(4.5)) \\ &= 114.75 \text{ in.}^2 \end{aligned}$$

Fig. RD.5.2.1(a)

$$\frac{A_{Nc}}{A_{Nco}} = \frac{114.75}{182.25} = 0.63$$

Calculating for ϕN_{cb} :

$$\phi N_{cb} = 0.65 \times 0.63 \times 1.0 \times 0.78 \times 0.5 \times 24 \times$$

$$\sqrt{3,000} \times (4.5)^{1.5} = 2,004 \text{ lb.} > 900 \text{ lb.} - \text{OK}$$

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EXAMPLE CALCULATION *Adhesive Anchors (ICC-ES AC308)*

Continued from previous page.

CALCULATIONS AND DISCUSSION	REFERENCE
5. Adhesive anchor capacity under tension loading:	AC308 Section 3.3
$\phi N_a \geq N_{ua}$	Eq. (D-1)
$N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,Na} \psi_{p,Na} N_{a0}$	Eq. (D-16a)
$N_{a0} = \tau_{k,uncr} \pi d h_{ef} = 2,422 \pi (0.5)(4.5) = 17,120 \text{ lb.}$	Eq. (D-16f)
$S_{cr,Na} = 20d \sqrt{\frac{\tau_{k,uncr}}{1,450}} \leq 3h_{ef}$	Eq. (D-16d)
$S_{cr,Na} = (20)(0.5) \sqrt{\frac{2,422}{1,450}} = 12.92" \leq 3h_{ef} = 13.5"$	
$S_{cr,Na} = 12.92"$	
$c_{cr,Na} = \frac{S_{cr,Na}}{2} = \frac{12.92}{2} = 6.46"$	Eq. (D-16e)
$A_{Na0} = (S_{cr,Na})^2 = (12.92)^2 = 166.93"{}^2$	Eq. (D-16c)
$A_{Na} = (c_{a1} + c_{cr,Na})(S_{cr,Na}) = (1.75 + 6.46)(12.92) = 106.07"{}^2$	
$\psi_{ed,Na} = (0.7 + 0.3 \frac{c_{a,min}}{c_{cr,Na}}) \leq 1.0$ Since $c_{a,min} < c_{cr,Na}$	Eq. (D-16m)
$\psi_{ed,Na} = (0.7 + 0.3 \frac{1.75}{6.46}) = 0.78$	
$\psi_{p,Na} = \max \left[\frac{c_{a,min}; c_{cr,Na}}{c_{ac}} \right]$ when $c_{a,min} < c_{ac}$	Eq. (D-16p)
$\psi_{p,Na} = \max \left[\frac{1.75; 6.46}{13.5} \right] = \frac{6.46}{13.5} = 0.48$	
$\phi = 0.65$ for dry concrete	This catalog
Calculating for ϕN_a :	
$\phi N_a = 0.65 \times \frac{106.07}{166.93} \times 0.78 \times 0.48 \times 17,120 = 2,647 \text{ lb.} > 900 \text{ lb.} - \text{OK}$	
6. Check all failure modes under tension loading:	D.4.1.2
Summary:	
Steel capacity = 13,313 lb.	
Concrete breakout capacity = 2,004 lb. ← Controls	
Adhesive capacity = 2,647 lb.	
∴ $\phi N_n = 2,004 \text{ lb. as concrete breakout capacity controls}$	
7. Steel capacity under shear loading:	D.6.1
$\phi V_{sa} \geq V_{ua}$	Eq. (D-2)
$V_{sa} = 10,650 \text{ lb.}$	This catalog
$\phi = 0.65$	This catalog
Calculating for ϕV_{sa} :	
$\phi V_{sa} = 0.65 \times 10,650 = 6,923 \text{ lb.} > 680 \text{ lb.} - \text{OK}$	

CALCULATIONS AND DISCUSSION	REFERENCE
8. Concrete breakout capacity under shear loading:	D.6.2
$\phi V_{cb} \geq V_{ua}$	Eq. (D-2)
$V_{cb} = \frac{A_{Vc}}{A_{Vco}} \psi_{ed,V} \psi_{c,V} V_b$	Eq. (D-21)
where:	
$V_b = 7 \left(\frac{\ell_e}{d_o} \right)^{0.2} \sqrt{d_o} \sqrt{f'_c} c_{a1}^{1.5}$	Eq. (D-24)
substituting:	
$\phi V_{cb} = \phi \frac{A_{Vc}}{A_{Vco}} \psi_{ed,V} \psi_{c,V} 7 \left(\frac{\ell_e}{d_o} \right)^{0.2} \sqrt{d_o} \sqrt{f'_c} c_{a1}^{1.5}$	
where:	
$\phi = 0.70$ for Condition B (no supplementary reinforcement provided)	D4.4(c)(i)
$A_{Vco} = 4.5c_{a1}^2$ $= 4.5(1.75)^2$ ∴ $A_{Vco} = 13.78 \text{ in.}{}^2$	Eq. (D-23)
$A_{Vc} = 2(1.5c_{a1})(1.5c_{a1})$ $= 2(1.5(1.75))(1.5(1.75))$ ∴ $A_{Vc} = 13.78 \text{ in.}{}^2$	Fig. RD.6.2.1(a)
$\frac{A_{Vc}}{A_{Vco}} = \frac{13.78}{13.78} = 1$	D.6.2.1
$\psi_{ed,V} = 1.0$ since $c_{a2} > 1.5c_{a1}$	Eq. (D-27)
$\psi_{c,V} = 1.4$ for uncracked concrete	D.6.2.7
$d_o = 0.5 \text{ in.}$	
$\ell_e = 8d_o = 8(0.5) = 4"$	D.6.2.2
$c_{a1} = 1.75 \text{ in.}$	
$\phi V_{cb} = 0.70 \times 1 \times 1.0 \times 1.4 \times 7 \times \left(\frac{4}{0.5} \right)^{0.2} \times \sqrt{0.5}$ $\times \sqrt{3,000} \times (1.75)^{1.5} = 932 \text{ lb.} > 680 \text{ lb.} - \text{OK}$	
9. Concrete pryout capacity per AC308	
$V_{cp} = \min[k_{cp}N_a; k_{cp}N_{cb}]$	Eq. (D-30a)
$k_{cp} = 2.0$ for $h_{ef} \geq 2.5"$	
$N_a = 4,072 \text{ lb.}$ from adhesive-capacity calculation without ϕ factor	
$N_{cb} = 3,083 \text{ lb.}$ from concrete-breakout calculation without ϕ factor	
$V_{cp} = (2.0)(3,083) = 6,166 \text{ lb. controls}$	
$\phi = 0.7$	This catalog
$\phi V_{cp} = (0.7)(6,166) = 4,316 \text{ lb.} > 680 \text{ lb.} - \text{OK}$	

EXAMPLE CALCULATION *Adhesive Anchors (ICC-ES AC308)*

Continued from previous page.

CALCULATIONS AND DISCUSSION **REFERENCE**10. Check all failure modes under shear loading: *D.4.1.2*

Summary:

Steel capacity = 6,923 lb.

Concrete breakout capacity = 932 lb. ← **Controls**

Pryout capacity = 4,316 lb.

∴ $\phi V_n = 932$ lb. as concrete breakout capacity controls11. Check interaction of tension and shear forces: *D.7*If $0.2 \phi V_n \geq V_{ua}$, then the full tension design strength is permitted. *D.7.1*

By observation, this is not the case.

If $0.2 \phi N_n \geq N_{ua}$, then the full shear design strength is permitted *D.7.2*

By observation, this is not the case.

Therefore:

$$\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2 \quad \text{Eq. (D-31)}$$

$$\frac{900}{2,004} + \frac{680}{932} = 0.45 + 0.73 = 1.18 < 1.2 - \text{OK}$$

12. Summary

A single 1/2" diameter ASTM A193 Grade B7 anchor rod in SET-XP™ epoxy adhesive at a 4 1/2" embedment depth is adequate to resist the applied service tension and shear loads of 560 lb. and 425 lb., respectively.

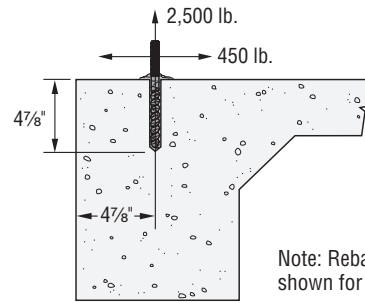
EXAMPLE CALCULATION *Torque Controlled Adhesive Anchors (ICC-ES AC308)*



Example calculation for a single IXP™ anchor with SET-XP™ epoxy using USD:

Determine if a single 1/2" diameter IXP™ torque-controlled adhesive anchor with SET-XP™ epoxy with a minimum 4 7/8" embedment ($h_{ef} = 4 7/8"$) installed 4 7/8" from the edge of a 12" deep spandrel beam is adequate for a service tension load of 2,500 lb. for wind and a reversible service shear load of 450 lb. for wind. The anchor will be in the tension zone, away from other anchors in $f'_c = 3,000$ psi normal-weight concrete. The anchor will be subjected to a maximum short-term temperature of 180°F and a maximum long-term temperature of 75°F. Continuous inspection will be provided.

Reference the appropriate tables in this catalog for IXP anchor with SET-XP epoxy performance values as determined from testing in accordance with ICC-ES AC308.



CALCULATIONS AND DISCUSSION REFERENCE

Note: Calculations are performed in accordance with ICC-ES AC308 and ACI 318-05.

- Determine the factored tension and shear design loads: ACI 318, 9.2.1
 $N_{ua} = 1.6W = 1.6 \times 2,500 = 4,000$ lb.
 $V_{ua} = 1.6W = 1.6 \times 450 = 720$ lb.

- Design considerations: D.4.1.2

This is a combined tension and shear interaction problem where values for both ϕN_n and ϕV_n need to be determined. ϕN_n is the lesser of the design tension strength controlled by: steel (ϕN_{sa}), concrete breakout (ϕN_{cb}), or pull-out (ϕN_{pn}). ϕV_n is the lesser of the design shear strength controlled by: steel (ϕV_{sa}), concrete breakout (ϕV_{cb}), or pryout (ϕV_{cp}).

- Steel capacity under tension loading: D.5.1
 $\phi N_{sa} \geq N_{ua}$ Eq. (D-1).
 $N_{sa} = 11,075$ lb. This catalog
 $\phi = 0.75$ This catalog

$n = 1$ (single anchor)

Calculating for ϕN_{sa} :

$$\phi N_{sa} = 0.75 \times 1 \times 11,075 = 8,306 \text{ lb.} > 4,000 \text{ lb.} - \text{OK}$$

\therefore 1/2 in. diameter anchor is adequate

CALCULATIONS AND DISCUSSION REFERENCE

- Concrete breakout capacity under tension loading: D.5.2

$$\phi N_{cb} \geq N_{ua} \quad \text{Eq. (D-1)}$$

$$N_{cb} = \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b \quad \text{Eq. (D-4);}$$

where:

$$N_b = k_c \sqrt{f'_c} h_{ef}^{1.5} \quad \text{Eq. (D-7)}$$

substituting:

$$\phi N_{cb} = \phi \frac{A_{Nc}}{A_{Nco}} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} k_c \sqrt{f'_c} h_{ef}^{1.5}$$

where:

$$k_c = k_{cr} = 17 \quad \text{This catalog}$$

(Anchor is installed in a tension zone, therefore, cracking is assumed at service loads)

$$\Psi_{cp,N} = 1.0 \quad \text{D.5.2.7}$$

$$\Psi_{ed,N} = 0.7 + 0.3 \frac{c_{a,min}}{1.5 h_{ef}} \quad \text{when } c_{a,min} < 1.5 h_{ef} \quad \text{Eq. (D-11)}$$

by observation, $c_{a,min} = 4 7/8 < 1.5 h_{ef}$

$$\Psi_{ed,N} = 0.7 + 0.3 \frac{(4 7/8)}{1.5(4 7/8)} = 0.90$$

$\Psi_{c,N} = 1.0$ assuming cracking at service loads ($f_t > f_r$)

D.5.2.6

$\phi = 0.65$ for Condition B This catalog

(no supplementary reinforcement provided)

$$A_{Nco} = 9 h_{ef}^2 = 9(4 7/8)^2 = 213.89 \text{ in.}^2 \quad \text{Eq. (D-6)}$$

$$A_{Nc} = (c_{a1} + 1.5 h_{ef})(2 \times 1.5 h_{ef}) = (4 7/8 + 1.5(4 7/8))(2 \times 1.5(4 7/8)) = 178.24 \text{ in.}^2 \quad \text{Fig. RD.5.2.1(a)}$$

$$\frac{A_{Nc}}{A_{Nco}} = \frac{178.24}{213.89} = 0.83$$

Calculating for ϕN_{cb} :

$$\phi N_{cb} = 0.65 \times 0.83 \times 1.0 \times 0.90 \times 1.0 \times 17 \times$$

$$\sqrt{3,000} \times (4 7/8)^{1.5} = 4,866 \text{ lb.} > 4,000 \text{ lb.} - \text{OK}$$

Would you like help with these calculations? Visit www.simpsonanchors.com to download the Simpson Strong-Tie® Anchor Designer™ software.



EXAMPLE CALCULATION *Torque Controlled Adhesive Anchors (ICC-ES AC308)*

Continued from previous page.

Calculations and Discussion	Reference
5. Pullout capacity:	D.5.3
Pullout capacity, $N_{pn,cr}$, is established by reference tests in cracked concrete by the reliability test of AC 308. Pullout capacity does not need to be calculated for IXP™ with SET-XP™ epoxy since steel failure controls over pullout capacity.	
6. Check all failure modes under tension loading:	D.4.1.2
Summary:	
Steel capacity	= 8,306 lb.
Concrete breakout capacity	= 4,866 lb. ← Controls
Pullout capacity	= N/A
∴ $\phi N_n = 4,866$ lb. as concrete breakout capacity controls	
7. Steel capacity under shear loading:	D.6.1
$\phi V_{sa} \geq V_{ua}$	Eq. (D-2)
$V_{sa} = 10,450$ lb.	This catalog
$\phi = 0.65$	This catalog
Calculating for ϕV_{sa} :	
$\phi V_{sa} = 0.65 \times 10,450 = 6,793$ lb. > 720 lb. – OK	
∴ ½ in. diameter anchor is adequate	
8. Concrete breakout capacity under shear loading:	D.6.2
$\phi V_{cb} \geq V_{ua}$	Eq. (D-2)
$V_{cb} = \frac{A_{VC}}{A_{VCO}} \Psi_{ed,V} \Psi_{c,V} V_b$	Eq. (D-21)
where:	
$V_b = 7 \left(\frac{\ell_e}{d_o} \right)^{0.2} \sqrt{d_o} \sqrt{f'_c} c_{a1}^{1.5}$	Eq. (D-24)
substituting:	
$\phi V_{cb} = \phi \frac{A_{VC}}{A_{VCO}} \Psi_{ed,V} \Psi_{c,V} 7 \left(\frac{\ell_e}{d_o} \right)^{0.2} \sqrt{d_o} \sqrt{f'_c} c_{a1}^{1.5}$	
where:	
$\phi = 0.70$ for Condition B (no supplementary reinforcement provided)	D.4.4(c)(i)
$A_{VCO} = 4.5c_{a1}^2$ = 4.5(4⅞)²	Eq. (D-23)
∴ $A_{VCO} = 106.95$ in.²	
$A_{VC} = 2(1.5c_{a1})(1.5c_{a1})$ = 2(1.5(4⅞))(1.5(4⅞))	Fig. RD.6.2.1(a)
∴ $A_{VC} = 106.95$ in.²	
$\frac{A_{VC}}{A_{VCO}} = \frac{106.95}{106.95} = 1$	D.6.2.1
$\Psi_{ed,V} = 1.0$ since $c_{a2} > 1.5c_{a1}$	Eq. (D-27)
$\Psi_{c,V} = 1.0$ assuming cracking at service loads ($f_t > f_r$)	D.6.2.7
$d_o = 0.5$ in.	
$\ell_e = 8d_o = 8(0.5) = 4"$	D.6.2.2
$c_{a1} = 4⅞$ in.	
$\phi V_{cb} = 0.70 \times 1 \times 1.0 \times 1.0 \times 7 \times \left(\frac{4}{0.5} \right)^{0.2} \times \sqrt{0.5}$ $\times \sqrt{3,000} \times (4⅞)^{1.5} = 3,096$ lb. > 720 lb. – OK	

Calculations and Discussion	Reference
9. Concrete pryout strength:	D.6.3
$\phi n V_{cp} \geq V_{ua}$	Eq. (D-2)
$V_{cp} = k_{cp} N_{cb}$	Eq. (D-29)
where:	
$n = 1$	
$k_{cp} = 2.0$ and $\Phi = 0.70$	This catalog
$k_{cp} N_{cb} = 2.0 \times \frac{4,866}{0.65} = 14,972$ lb.	D.6.3.1
$\phi n V_{cp} = 0.70 \times 1 \times 14,972 = 10,480$ lb. > 720 lb. – OK	
10. Check all failure modes under shear loading:	D.4.1.2
Summary:	
Steel capacity	= 6,793 lb.
Concrete breakout capacity	= 3,096 lb. ← Controls
Pryout Capacity	= 10,480 lb.
∴ $\phi V_n = 3,096$ lb. as concrete breakout capacity controls	
11. Check interaction of tension and shear forces:	D.7
If $0.2 \phi V_n \geq V_{ua}$, then the full tension design strength is permitted.	
By observation, this is not the case.	
If $0.2 \phi N_n \geq N_{ua}$, then the full shear design strength is permitted	
By observation, this is not the case.	
Therefore:	
$\frac{N_{ua}}{\phi N_n} + \frac{V_{ua}}{\phi V_n} \leq 1.2$	Eq. (D-31)
$\frac{4,000}{4,866} + \frac{720}{3,096} = 0.82 + 0.23 = 1.05 < 1.2$ – OK	
12. Summary	
A single ½" diameter IXP anchor with SET-XP epoxy at a 4⅞" embedment depth is adequate to resist the applied service tension and shear loads of 2,500 lb. and 450 lb., respectively.	