ALLOWABLE STRESS DESIGN (ASD) METHOD

SIMPSON Strong-Tie ANCHOR SYSTEMS®

In allowable stress design (ASD), the Designer must size the anchorage such that the service load does not exceed the allowable load for any anchor:

$$T_{service} \leq T_{allowable}$$
$$V_{service} \leq V_{allowable}$$

The Designer must read the allowable load from the applicable table and adjust the allowable load for all applicable design parameters for the anchor, such as spacing, edge distance, in-service temperature or allowable-stress increase for short-term loads. Load-adjustment factors for anchors are applied cumulatively. For adhesive anchors, the designer must also ensure that the service load does not exceed the allowable load of the steel insert.

For anchors subjected to simultaneous tension and shear loading, the following equation must be satisfied, where the value of *n* is product-specific. Use a value of n=1 unless otherwise specified in the applicable products' load table.

$$\left(\frac{T_{service}}{T_{allowable}}\right)^n + \left(\frac{V_{service}}{V_{allowable}}\right)^n \leq 1.0$$

Linear interpolation of allowable loads between embedment depths and/or compressive strengths shown in the load tables is permitted. Linear interpolation of load-adjustment factors in the edge distance and spacing tables is also permitted.

The allowable loads in this catalog are derived from full-scale testing, calculations, and/or experience. In general, the allowable load is determined by taking the average ultimate load from full scale tests and dividing by a safety factor (Ω).

$$T_{allowable} = \frac{\overline{T}_{ultimate}}{\Omega} \; ; \; V_{allowable} = \frac{\overline{V}_{ultimate}}{\Omega}$$

For some anchors, the average ultimate load and/or allowable load is also controlled by anchor displacement limits.

The allowable loads for steel inserts used with adhesive anchors is determined as follows:

For threaded rod: $T_{allowable} = 0.33\, F_u A_g \; ; \; V_{allowable} = 0.17 F_u A_g$

For Grade 60 rebar: $T_{allowable} = (24{,}000 \text{ psi}) A_g \; ; \; V_{allowable} = 0.17(90{,}000 \text{ psi}) A_g$

Where:

A_g = Gross cross-sectional area of the insert

Threaded Insert Steel Type	F_u (psi)
A307, Grade C	58,000
A193, Grade B7	125,000
304/316 Stainless (Diam. ≤ 5/8")	100,000
304/316 Stainless (Diam ≥ ¾")	85,000

Where:

F_u = Ultimate tensile strength of steel insert

ULTIMATE STRENGTH DESIGN (USD) METHOD (UNDER ACI 318 APPENDIX D, ICC-ES AC193, AND ICC-ES AC308)

In ultimate strength design (USD), the Designer must size the anchorage such that the required strength (i.e. factored load) does not exceed the lowest design strength of the anchor or anchor group considering all possible failure modes.

$$N_{ua} \leq \phi N_n$$
$$V_{ua} \leq \phi V_n$$

Calculations are performed in accordance with the applicable design standards: ICC-ES AC193 and ACI 318 Appendix D for mechanical anchors and ICC-ES AC308 for adhesive and torque-controlled adhesive anchors. The additional design provisions of AC308 are shown elsewhere in this catalog.

The nominal strengths and design data in this catalog are derived from full-scale testing and calculations in accordance with ACI 355.2, ICC-ES AC193 and ICC-ES AC308. In general, nominal strengths are 5% fractile strengths calculated using the average ultimate load, and standard deviation of full-scale test results. A 5% fractile strength is the nominal strength for which there is a 90% confidence that there is a 95% probability of the actual strength exceeding the nominal strength.

For anchors that are designed using ACI 318 Appendix D, AC193, or AC308, it is possible to convert design strengths (i.e. ϕN_n or ϕV_n) to allowable loads using the following approach from AC193 (dated February 2008) and AC308 (dated February 2008):

$$T_{allowable,\,ASD} = \frac{\phi N_n}{\alpha} \quad \text{and} \quad V_{allowable,\,ASD} = \frac{\phi V_n}{\alpha}$$

Where:

$T_{allowable,ASD}$ = Allowable tension load
$V_{allowable,ASD}$ = Allowable shear load

ϕN_n = Lowest design strength of an anchor or anchor group in tension as determined per ACI 318 Appendix D, AC193, AC308 and IBC Section 1908.1.16.

ϕV_n = Lowest design strength of an anchor or anchor group in shear as determined per ACI 318 Appendix D, AC193, AC308 and IBC Section 1908.1.16.

α = Conversion factor calculated as a weighted average of the load factors for the controlling load combination. In addition, α shall include all applicable factors to account for non-ductile failure modes and required over-strength.

Interaction shall be calculated as follows:

For tension loads, $T \leq 0.2 T_{allowable}$, the full allowable load in shear shall be permitted.

For shear loads, $V \leq 0.2 V_{allowable}$, the full allowable load in tension shall be permitted.

For all other cases: $\frac{T}{T_{allowable}} + \frac{V}{V_{allowable}} \leq 1.2$

Ultimate-strength design calculations are performed in accordance with ICC-ES AC308, which makes the following amendments to ACI 318 Appendix D:

3.3 Strength design - amendments to ACI 318:

3.3.1 **Adhesive anchors:** This section provides amendments to ACI 318 Appendix D as required for the strength design of adhesive anchors. In conformance with ACI 318, all equations are expressed in inch-pound units.

3.3.1.1 Add Section D.4.1.2, D.4.1.4, D.5.2.9, D.5.3.7, D.5.3.8, D.5.3.9, D.5.3.10, D.5.3.11, D.5.3.12, D.5.3.13, and D.6.3.2 to ACI 318 as follows:

D.4.1.2 – In Eq. (D-1) and (D-2), ϕN_n and ϕV_n are the lowest design strengths determined from all appropriate failure modes. ϕN_n is the lowest design strength in tension of an anchor or group of anchors as determined from consideration of ϕN_{nsa}, either ϕN_a or ϕN_{ag} and either ϕN_{cb} or ϕN_{cbg}. ϕV_n is the lowest design strength in shear of an anchor or a group of anchors as determined from consideration of: ϕV_{sa}, either ϕV_{cb} or ϕV_{cbg}, and either ϕV_{cp} or ϕV_{cpg}.

D.4.1.4 – For adhesive anchors installed overhead and subjected to tension resulting from sustained loading, Eq. (D-1) shall also be satisfied taking $\phi N_n = 0.75\phi N_a$ for single anchors and $\phi N_n = 0.75\phi N_{ag}$ for groups of anchors, whereby N_{ua} is determined from the sustained load alone, e.g., the dead load and that portion of the live load acting that may be considered as sustained. Where shear loads act concurrently with the sustained tension load, interaction of tension and shear shall be checked in accordance with Section D.4.1.3.

D.5.2.9 - The limiting concrete strength of adhesive anchors in tension shall be calculated in accordance with D.5.2.1 to D.5.2.8 where the value of k to be used in Eq. (D-7) shall be

$k = 17$ *where analysis indicates cracking at service-load levels in the anchor vicinity (cracked concrete)*

$k = 24$ *where analysis indicates no cracking ($f_t < f_r$) at service-load levels in the anchor vicinity (uncracked concrete)*

The value of k shall be permitted to be increased to $k = 24$ (cracked concrete) and $k = 30$ (uncracked concrete) based on the results of tests in accordance with AC308.

D.5.3.7 - The nominal strength of an adhesive anchor N_a or group of adhesive anchors N_{ag} in tension shall not exceed

(a) for a single anchor

$$N_a = \frac{A_{Na}}{A_{Na0}} \psi_{ed,N_a} \psi_{p,N_a} N_{a0} \qquad \text{(D-16a)}$$

(b) for a group of anchors

$$N_{ag} = \frac{A_{Na}}{A_{Na0}} \psi_{ed,N_a} \psi_{g,Na} \psi_{ec,Na} \psi_{p,Na} N_{a0} \qquad \text{(D-16b)}$$

where

A_{Na} is the projected area of the failure surface for the anchor or group of anchors that shall be approximated as the base of the rectilinear geometrical figure that results from projecting the failure surface outward a distance $c_{cr,Na}$ from the center lines of the anchor, or in the case of a group of anchors, from a line through a row of adjacent anchors. A_{Na} shall not exceed nA_{Na0} where n is the number of anchors in tension in the group. (Refer to ACI 318 Figures RD.5.2.1(a) and RD.5.2.1(b) and replace the terms $1.5h_{ef}$ and $3.0h_{ef}$ with $c_{cr,Na}$ and $s_{cr,Na}$, respectively.)

A_{Na0} is the projected area of the failure surface of a single anchor without the influence of proximate edges in accordance with Eq. (D-16c):

$$A_{Na0} = (s_{cr,Na})^2 \qquad \text{(D-16c)}$$

with

$s_{cr,Na}$ = as given by Eq. (D-16d)

D.5.3.8 - The critical spacing $s_{cr,Na}$ and critical edge distance $c_{cr,Na}$ shall be calculated as follows:

$$s_{cr,Na} = 20 \cdot d \cdot \sqrt{\frac{\tau_{k,uncr}}{1{,}450}} \leq 3 \cdot h_{ef} \qquad \text{(D-16d)}$$

$$c_{cr,Na} = \frac{s_{cr,Na}}{2} \qquad \text{(D-16e)}$$

D.5.3.9 - The basic strength of a single adhesive anchor in tension in cracked concrete shall not exceed

$$N_{a0} = \tau_{k,cr} \cdot \pi \cdot d \cdot h_{ef} \qquad \text{(D-16f)}$$

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D.5.3.10 - The modification factor for the influence of the failure surface of a group of adhesive anchors is

$$\Psi_{g,Na} = \Psi_{g,Na0} + \left[\left(\frac{s}{s_{cr,Na}}\right)^{0.5} (1 - \Psi_{g,Na0})\right] \qquad (D\text{-}16g)$$

where

$$\Psi_{g,Na0} = \sqrt{n} - \left[(\sqrt{n} - 1)\left(\frac{\tau_{k,cr}}{\tau_{k,max,cr}}\right)^{1.5}\right] \geq 1.0 \qquad (D\text{-}16h)$$

n is the number of tension loaded adhesive anchors in a group

$\tau_{k,cr}$ is the characteristic bond strength in cracked concrete having strength f'_c evaluated from tests per AC308.

$$\tau_{k,max,cr} = \frac{k_{c,cr}}{\pi \cdot d} \sqrt{h_{ef} \cdot f'_c} \qquad (D\text{-}16i)$$

$k_{c,cr} = 17$

whereby the value of $k_{c,cr}$ shall be permitted to be increased to a maximum value based on the results of tests in cracked concrete in accordance with AC308

D.5.3.11 - The modification factor for eccentrically loaded adhesive anchor groups is

$$\Psi_{ec,Na} = \frac{1}{1 + \frac{2e'_N}{s_{cr,Na}}} \leq 1.0 \qquad (D\text{-}16j)$$

Eq. (D-16j) is valid for $e'_N \leq \frac{s}{2}$

If the loading on an anchor group is such that only some anchors are in tension, only those anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (D-16j).

In the case where eccentric loading exists about two othogonal axes, the modification factor $\Psi_{ec,Na}$ shall be computed for each axis individually and the product of these factors used as $\Psi_{ec,Na}$ in Eq. (D-16b).

D.5.3.12 - The modification factor for edge effects for single adhesive anchors or anchor groups loaded in tension is

$$\Psi_{ed,Na} = 1.0 \quad \text{when} \quad c_{a,min} \geq c_{cr,Na} \qquad (D\text{-}16l)$$

$$\Psi_{ed,Na} = \left(0.7 + 0.3 \frac{c_{a,min}}{c_{cr,Na}}\right) \leq 1.0 \qquad (D\text{-}16m)$$

D.5.3.13 - When an adhesive anchor or a group of adhesive anchors is located in a region of a concrete member where analysis indicates no cracking at service load levels, the nominal strength N_a or N_{ag} of a single adhesive anchor or a group of adhesive anchors shall be calculated according to Eq. (D-16a) and Eq. (D-16b) with $\tau_{k,uncr}$ substituted for $\tau_{k,cr}$ in the calculation of the basic strength N_{a0} in accordance with Eq. (D-16f) $\tau_{k,uncr}$ shall be established based on tests in accordance with AC308. The factor $\Psi_{g,Na0}$ shall be calculated in accordance with Eq. (D-16h) whereby the value of $\tau_{k,max,uncr}$ shall be calculated in accordance with Eq. (D-16n) and substituted for $\tau_{k,max,cr}$ in Eq. (D-16h)

$$\tau_{k,max,uncr} = \frac{k_{c,uncr}}{\pi \cdot d} \sqrt{h_{ef} \cdot f'_c} \qquad (D\text{-}16n)$$

D.5.3.14 - When an adhesive anchor or a group of adhesive anchors is located in a region of a concrete member where analysis indicates no cracking at service load levels, the modification factor $\Psi_{p,Na}$ shall be taken as

$$\Psi_{p,Na} = 1.0 \quad \text{when} \quad c_{a,min} \geq c_{ac} \qquad (D\text{-}16o)$$

$$\Psi_{p,Na} = \max \frac{|c_{a,min};\, c_{cr,Na}|}{c_{ac}} \quad \text{when } c_{a,min} < c_{ac} \qquad (D\text{-}16p)$$

where

c_{ac} shall be determined by testing in accordance with AC308.

For all other cases $\Psi_{p,Na} = 1.0$.

D.6.3.2 - The nominal pryout strength of an adhesive anchor V_{cp} or group of adhesive anchors V_{cpg} shall not exceed

(a) for a single adhesive anchor

$$V_{cp} = \min\left|k_{cp} \cdot N_a \,;\, k_{cp} \cdot N_{cb}\right| \qquad (D\text{-}30a)$$

(b) for a group of adhesive anchors

$$V_{cpg} = \min\left|k_{cp} \cdot N_{ag} \,;\, k_{cp} \cdot N_{cbg}\right| \qquad (D\text{-}30b)$$

where

$k_{cp} = 1.0$ for $h_{ef} < 2.5$ in.

$k_{cp} = 2.0$ for $h_{ef} \geq 2.5$ in.

N_a is calculated in accordance with Eq. (D-16a)

N_{ag} is calculated in accordance with Eq. (D-16b)

N_{cb}, N_{cbg} are determined in accordance with D.5.2.9

D.8.7 - For adhesive anchors that will remain untorqued, the minimum edge distance shall be based on minimum cover requirements for reinforcement in 7.7. For adhesive anchors that will be torqued, the minimum edge distance and spacing shall be taken as $6d_o$ and $5d_o$, respectively, unless otherwise determined in accordance with AC308.

3.3.2 **Torque-controlled adhesive anchors:** This section provides amendments to ACI 318 Appendix D as required for the strength design of torque-controlled adhesive anchors.

3.3.2.1 Add Section D.5.3.7 to ACI 318 as follows:

D.5.3.7 - For torque-controlled adhesive anchors, the value of N_p shall be based on the 5 percent fractile of tests performed and evaluated in accordance with AC308.

D.8.7 - For torque-controlled adhesive anchors the minimum edge distance shall be taken as $8d_o$ unless otherwise determined by testing in accordance with AC308.

NOTE: Bond strength determination: Bond strength values are a function of the special-inspection level provided and installation conditions. Bond strength values must be modified with the factor K_{sat} for cases where the holes are drilled in water-saturated concrete as follows:

Special Inspection Level	Permissible Installation Condition	Bond Strength	Associated Strength Reduction Factor
Continuous	Dry Concrete	τ_k	$\Phi_{dry,ci}$
Continuous	Water-saturated	τ_k x $K_{sat,ci}$	$\Phi_{sat,ci}$
Periodic	Dry Concrete	τ_k	$\Phi_{dry,pi}$
Periodic	Water-saturated	τ_k x $K_{sat,pi}$	$\Phi_{sat,pi}$

Where applicable, the modified bond strengths must be used in lieu of $\tau_{k,cr}$ or $\tau_{k,uncr}$ in AC308 Equations (D-16a) and (D-16b). The resulting nominal bond strength must be multiplied by the strength-reduction factor for the special-inspection level listed above. The various factors are given in Table 5 of ESR-2508 and page 35 of this catalog.

Structural Post-Installed Anchor Design Methods Permitted by Building Codes

Building Code	Base Material	Permitted Design Methods[3]		
		Traditional ASD	ACI 318 App. D/ ICC-ES AC193	ICC-ES AC308
2006 IBC/IRC	Concrete[1]	No	Yes	Yes
	Masonry[2]	Yes	N/A[4]	N/A[4]
2003 IBC/IRC	Concrete[1]	No	Yes	Yes
	Masonry[2]	Yes	N/A[4]	N/A[4]
2000 IBC/IRC	Concrete[1]	Yes	Yes	Yes
	Masonry[2]	Yes	N/A[4]	N/A[4]
1997 UBC	Concrete[1]	Yes	Yes	Yes
	Masonry[2]	Yes	N/A[4]	N/A[4]

1. "Concrete" includes all concrete base materials such as concrete on metal deck and precast concrete shapes.
2. "Masonry" includes all masonry base materials such as hollow and grout-filled CMU and unreinforced brick masonry.
3. Code interpretations vary. Confirm with the local Building Official.
4. Not applicable since masonry is beyond the scope of this design method.

Building codes and material standards have traditionally allowed Designers to take a one third allowable-stress increase on the calculated design capacities of some building materials and components when designing for forces generated from wind and/or seismic events. Newer codes and standards only allow the allowable stress increase to be taken when using an alternate set of load combinations. The table below summarizes when allowable-stress increases are permitted.

1/3 Allowable-Stress Increase for Structural Post-Installed Anchors

Building Code	Base Material	Is 1/3 Allowable Stress Increase Permitted for Post-Installed Anchors Designed with Traditional ASD?
2006 IBC/IRC	Concrete[1]	N/A[3]
	Masonry[2]	Yes[4]
2003 IBC/IRC	Concrete[1]	N/A[3]
	Masonry[2]	Yes[4]
2000 IBC/IRC	Concrete[1]	Yes[4]
	Masonry[2]	Yes[4]
1997 UBC	Concrete[1]	Yes[4]
	Masonry[2]	Yes[4]

1. "Concrete" includes all concrete base materials such as reinforced concrete, concrete on metal deck and precast concrete shapes.
2. "Masonry" includes all masonry base materials such as hollow and grout-filled CMU and unreinforced clay-brick masonry.
3. Not applicable since this code does not use traditional ASD for post-installed anchors.
4. Only when indicated in the applicable load table in this catalog and when alternative basic load combinations as prescribed in the code are used.

Structural Post-Installed Anchor Selection Guide

Adhesive Anchors	Design Methods Covered		Base Materials Covered							Code Listings[2]
	Traditional ASD[1]	ICC-ES AC308	Concrete		Conc. over Mtl. Deck		CMU		URM[4]	
	ASD	(USD & ASD)	Uncracked	Cracked	Uncracked	Cracked	Grout-Filled	Hollow		
SET-XP™		X	X	X	X[3]	X[3]				ICC-ES
IXP™		X	X	X						ICC-ES Pending
SET	X		X		X[3]		X	X	X	ICC-ES
ET	X		X		X[3]		X	X	X	ICC-ES
Acrylic-Tie®	X		X		X[3]		X	X	X	ICC-ES
VGC	X		X		X[3]					
EDOT™	X		X							

1. Allowable loads for traditional ASD are derived from applicable test methods such as ASTM E488, ASTM E1512 and legacy ICC-ES acceptance criteria AC58 and AC60.
2. Code listings may not be available for all products/applications cited in the table. To verify code listed products/applications refer to "code reports" at www.simpsonanchors.com or contact Simpson Strong-Tie at 1-800-999-5099 (U.S. and Canada).
3. Installed into top surface.
4. Unreinforced clay brick masonry.

Mechanical Anchors	Design Methods Covered		Base Materials Covered						Code Listings[2]
	Traditional ASD[1]	ACI 318 App. D/ ICC-ES AC193	Concrete		Conc. over Mtl. Deck		CMU		
	ASD	(USD & ASD)	Uncracked	Cracked	Uncracked	Cracked	Grout-Filled	Hollow	
Torq-Cut™		X	X	X	X	X			ICC-ES Pending
Strong-Bolt™		X	X	X	X	X			ICC-ES
Titen HD®	X	X	X	X	X	X	X	X	ICC-ES
Wedge-All®	X		X		X		X		ICC-ES
Sleeve-All™	X		X				X		
Drop-In™	X		X		X				
Blue Banger Hanger®	X		X		X				
Easy-Set	X		X						
Titen® Screw	X		X				X	X	

1. Allowable loads for traditional ASD are derived from applicable test methods such as ASTM E488, ASTM E1512 and legacy ICC-ES acceptance criteria AC01, AC70, and AC106.
2. Code listings may not be available for all products/applications cited in the table. To verify code listed products/applications refer to "code reports" at www.simpsonanchors.com or contact Simpson Strong-Tie at 1-800-999-5099 (U.S. and Canada).