DESIGN OF CURTAIN WALL HSS TUBE EMBEDS IN CONCRETE

PER ACI 318-19 CHAPTER 17

The Allfasteners HSS Tube Embed (HTE) may be used as anchorage to secure an exterior façade, known as a curtain wall, to a building's main concrete structural system. For the Allfasteners HTE, ACI 318-19 Chapter 17 can be used to design these connections as it applies to typical cast-in headed studs welded to structural members anchored in concrete to transmit loads by means of tension, shear, or a combination of tension and shear. References in this discussion are to ACI 318-19, unless indicated otherwise.

Once anchored into the concrete, The HSS tube is a rigid closed shape structural member which allows for self-drilling structural screws to attach the exposed face of the tube to the curtain wall's connection hardware.

APPLICABILITY & METHODOLOGY

It should be noted that Section 17.1.5 does state that the chapter "does not apply to specialty inserts," however, the Allfasteners HTE is notably different from these. As mentioned in commentary R17.1.5, specialty inserts include a "wide variety of shapes and configurations." For example, those made from cold rolled sheet steel with open shape profiles, such as channels, have a relatively low stiffness compared to the closed geometry of HSS tubing. For this reason, specialty inserts made with channels require the use of manufacturer technical design guides that provide guidance and strength data based on testing of the product.

Since the Allfasteners HTE is a rigid member, it functions the same as a plate welded to a headed stud. Per chapter 2.3 Terminology, cast-in anchors covered in ACI 318-19 include headed bolts, hooked J-bolts and L-bolts, and headed studs. An illustration can be found in Figure R2.1(A) and in the diagram below.

(a) (b) (c) (d)

Cast-in anchors: (a) hex head bolt with washer; (b) L-bolt; (c) J-bolt; (d) welded headed stud.

Section 17.1.2 reinforces the applicability to headed studs, stating: "Provisions of this chapter shall apply to the following anchor types (a) through (g): (a) Headed studs and headed bolts having a geometry that has been demonstrated to result in a pullout strength in uncracked concrete equal to or exceeding 1.4Np, where Np is given in Eq. (17.6.3.2.2a)."

Furthermore, per commentary R17.1.2, "Typical cast-in headed studs and headed bolts with head geometries consistent with ASME B1.1, B18.2.1, and B18.2.6 have been tested and proven to behave predictably; therefore, calculated pullout strengths are acceptable." This supports the design methodology used in this document, which is based on the formulas found in Chapter 17.

It can also be noted that per section 17.5.1.2, "Nominal strength for an anchor or anchor groups shall be based on design models that result in predictions of strength in substantial agreement with results of comprehensive tests." Allfasteners has conducted testing of this product through a third-party testing facility and has found the design methodology of Chapter 17 to be in line with test results, confirming that it is appropriate.

DESIGN CONSIDERATIONS

The design limits of section 17.3 must be followed as they pertain to concrete strength. The value of the compressive strength of concrete, f_c', is not to exceed 10 ksi for cast-in anchors such as the HTE.

Per section 17.5.2.1, anchor reinforcement may be designed per ACI 318-19 Chapter 25, and allows for the design strength of the anchor reinforcement to be used instead of the concrete breakout strength. This document will not discuss anchor reinforcement. If the engineer wishes to add reinforcement to their design, they should keep in mind that the strength reduction factors found in Tables 17.5.3(b) and 17.5.3(c) will be different from those outlined below.

This document provides guidance for designing with the Allfasteners HTE in concrete where supplementary reinforcement is not present. To this end per section 17.3.5, the edge distances, spacings, and thicknesses in section 17.9 must be maintained to control splitting failure, unless supplementary reinforcement is also designed. Based on the commentary in R17.6.4, concrete blowout is more of a concern for cast-in headed anchors such as those used in the Allfasteners HTE, and is accounted for below.

HTE CALCULATIONS

When designing HTEs in concrete, the following tension and shear failure modes must be checked to ensure that the loads placed on the studs (“stud reactions”) are less than the available strength in those modes. These failure modes are listed in Table 17.5.2, “Design strength requirements of anchors,” as well as the table below. The strength equations are based on ACI 318-19 Chapter 17.

TABLE 1: FAILURE MODES & PASSING CONDITIONS OF HTE

FAILURE MODE	PASSING CONDITION
Steel Strength in Tension	$\beta_{sa,N} = N_{ua,max} / (\phi_{sa,N} N_{sa}) \leq 1$
Concrete Breakout Strength in Tension	$\beta_{cbg,N} = N_{ua} / (\phi_{cbg,N} N_{cbg}) \leq 1$
Pullout Strength in Tension	$\beta_{pn,N} = N_{ua,max} / \phi_{pn,N} N_{pn}) \leq 1$
Concrete Side-Face Blowout Strength in Tension	$h_{ef} \leq 2.5c_a$
Steel Strength in Shear	$\beta_{sa,V} = V_{ua,max} / (\phi_{sa,V} V_{sa}) \leq 1$
Concrete Breakout Strength in Shear	$\beta_{Vcbg,VY} = V_{uaY} / (\phi_{cbg,V} V_{cbgY}) \leq 1$ $\beta_{Vcbg,VX} = V_{uaX} / (\phi_{cbg,V} V_{cbgX}) \leq 1$
Concrete Pryout Strength in Shear	$\beta_{Vcpg,VY} = V_{uaY} / (\phi_{cpg,V} V_{cpg}) \leq 1$ $\beta_{Vcpg,VX} = V_{uaX} / (\phi_{cpg,V} V_{cpg}) \leq 1$

HTE CALCULATIONS

STEEL STRENGTH IN TENSION

Steel strength in tension is N_{sa}, and is based on the anchor material and dimensions. Per Section 17.6.1, it is shown as:

$$N_{sa} = A_{se,N}\, f_{uta}$$

where,

$A_{se,N}$ is the effective cross-sectional area of the anchor in Allfasteners HTE. Since the anchor has a diameter of 0.5 in, this value is 0.19635 in^2.

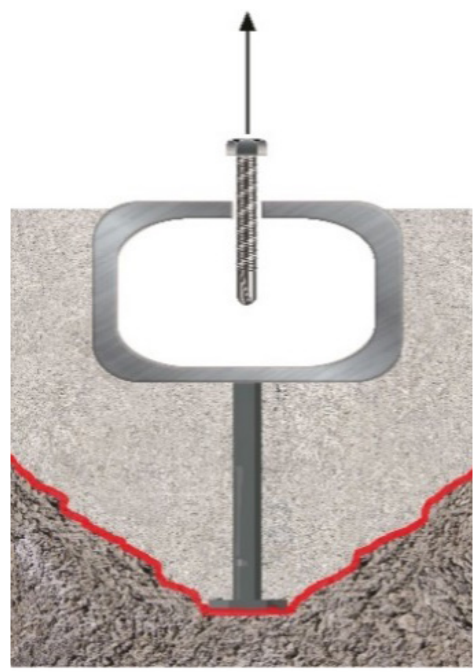
The ultimate strength f_{uta} is a material property of the steel. For the AWS type B headed stud component of the Allfasteners HTE, this value is 65 ksi.

Strength reduction factor $\phi_{sa,N}$ is dictated by ACI 318-19 Table 17.5.3(a). For ductile steel in tension, this value is 0.75.

The check is completed by confirming that the ratio of the maximum tensile load per stud, compared to the steel strength in tension multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{sa,N} = N_{ua,max} / (\phi_{sa,N}\, N_{sa}) \leq 1$$

CONCRETE BREAKOUT STRENGTH IN TENSION



Concrete breakout strength in tension is N_{cbg}, and applies to the group of headed studs welded to the HSS tube.

It is based on the nominal concrete breakout strength in tension, N_b, and several modification factors. For a group of anchors, this is equation 17.6.2.1b, and is expressed as:

$$N_{cbg} = (A_{Nc} / A_{Nco})\, \psi_{ec,N}\, \psi_{ed,N}\, \psi_{c,N}\, \psi_{cp,N}\, N_b$$

where,

A_{Nc} is the projected concrete failure area of the group of anchors and A_{Nco} is the projected concrete failure area of a single anchor if not limited by edge distance or spacing, described in section 17.6.2.1,

N_b is the basic concrete breakout strength, described in section 17.6.2.2,

And the modification factors are described in sections 17.6.2.3 to 17.6.2.6.

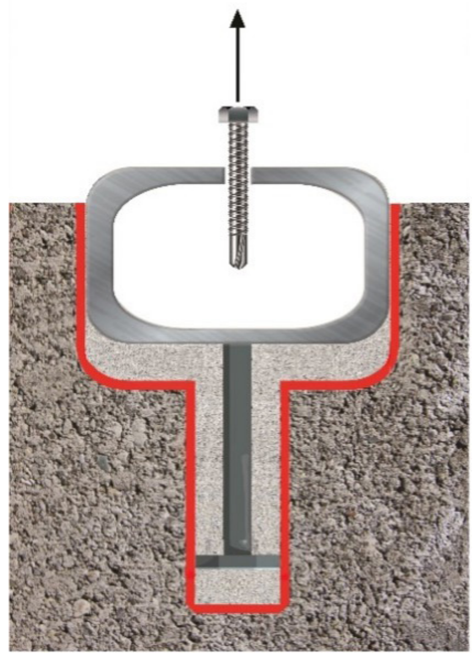
Strength reduction factor $\phi_{cbg,N}$ is dictated by ACI 318-19 Table 17.5.3(b). For cast-in anchors with supplementary reinforcement not present, this value is 0.70.

The check is completed by confirming that the ratio of the applied tensile load, compared to the concrete breakout strength in tension multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{cbg,N} = N_{ua} / (\phi_{cbg,N}\, N_{cbg}) \leq 1$$

HTE CALCULATIONS

PULLOUT STRENGTH IN TENSION



The nominal pullout strength of a single cast-in anchor is designated as N_{pn}, and per Section 17.6.3, is calculated as:

$N_{pn} = \psi_{c,P} N_p$

Where,

$\psi_{c,P}$ is a modification factor to account for the influence of cracking in anchor regions at service load levels. Per section 17.6.3.3.1, a value of 1.4 is used when no cracking would be present, and a value of 1.0 is used when cracking would be present.

N_p is calculated according to section 17.6.3.2.2a, which applies to cast-in headed studs. Here,

$N_p = 8A_{brg} f_c'$

where,

A_{brg} is the net bearing area of the head of the stud, and

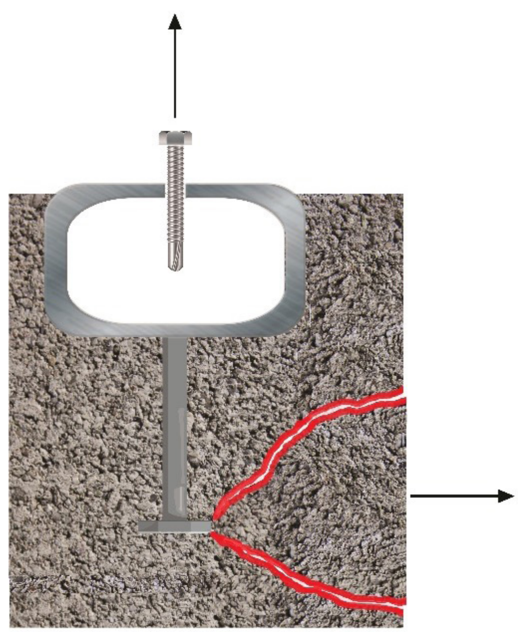
f_c' is the compressive strength of the concrete.

Strength reduction factor $\phi_{pn,N}$ is dictated by ACI 318-19 Table 17.5.3(c). For cast-in anchors in tension, for pullout, this value is 0.70.

The check is completed by confirming that the ratio of the maximum tensile load per stud, compared to the nominal pullout strength in tension multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{pn,N} = N_{ua,max} / (\phi_{pn,N} N_{pn}) \leq 1$$

CONCRETE SIDE-FACE BLOWOUT STRENGTH IN TENSION



Per section 17.6.4, the nominal side-face blowout strength, N_{sb} or N_{sbg}, applies when $h_{ef} > 2.5c_a$,

where,

h_{ef} is the effective embedment depth of the stud, and

c_a is the distance from the center of the stud shaft to the edge of concrete. This is typically represented as c_{a1} in one direction and c_{a2} in the perpendicular direction.

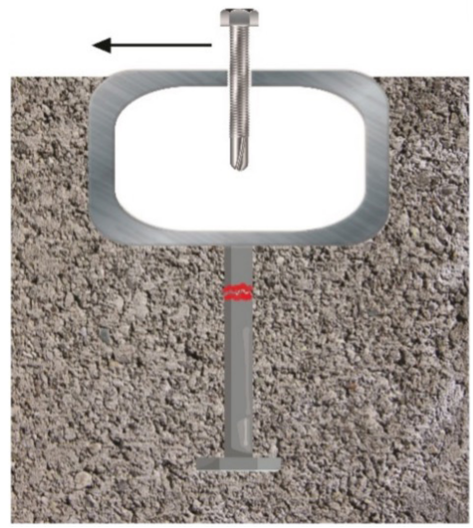
However, if the HTE installation is designed such that this is not the case, the value of N_{sb} does not need to be calculated. The check for side-face blowout can then be simplified to:

$h_{ef} \leq 2.5c_a$

It is typical to design the Allfasteners HTE installation such that side-face blowout is not applicable. However, if a small edge distance cannot be avoided, the side-face blowout strength may be calculated using the guidance in section 17.6.4.

HTE CALCULATIONS

STEEL STRENGTH IN SHEAR



Steel strength in shear is V_{sa}, and is based on the anchor material and dimensions.
Per Section 17.7.1, it is shown as:

$V_{sa} = A_{se,V} f_{uta}$

where,

$A_{se,V}$ Is the effective cross-sectional area of the anchor in Allfasteners HTE. Since the anchor has a diameter of 0.5 in, this value is 0.19635 in^2.

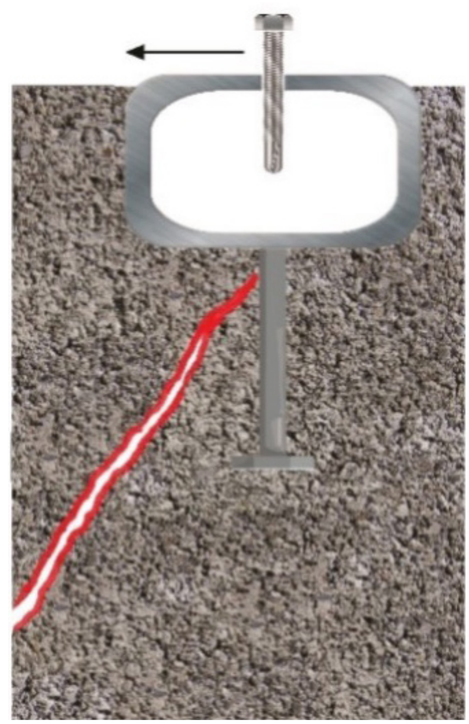
The ultimate strength f_{uta} is a material property of the steel. For the Allfasteners HTE, this value is 65 ksi.

Strength reduction factor $\phi_{sa,V}$ is dictated by ACI 318-19 Table 17.5.3(a). For ductile steel in shear, this value is 0.65.

The check is completed by confirming that the ratio of the maximum shear load per stud, compared to the steel strength in shear multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{sa,V} = V_{ua,max} / (\phi_{sa,V} V_{sa}) \leq 1$$

CONCRETE BREAKOUT STRENGTH IN SHEAR



Concrete breakout strength in shear perpendicular to the edge is Vcbg, and applies to the group of headed studs welded to the HSS tube.

It is based on the nominal concrete breakout strength in shear, Vb, and several modification factors. For a group of anchors, this is equation 17.7.2.1b, and is expressed as:

$V_{cbg} = (A_{Vc} / A_{Vco}) \psi_{ec,V} \psi_{ed,V} \psi_{c,V} \psi_{h,V} V_b$

where,

A_{Vc} is the projected concrete failure area of the group of anchors and A_{Vco} is the projected concrete failure area of a single anchor if not limited by corner influences, spacing, or member thickness, as described in section 17.7.2.1,

V_b is the basic concrete breakout strength, described in section 17.7.2.2,

And the modification factors are described in sections 17.7.2.3 to 17.7.2.6.

Strength reduction factor $\phi_{cbg,V}$ is dictated by ACI 318-19 Table 17.5.3(b). For cast-in anchors with supplementary reinforcement not present, this value is 0.70.

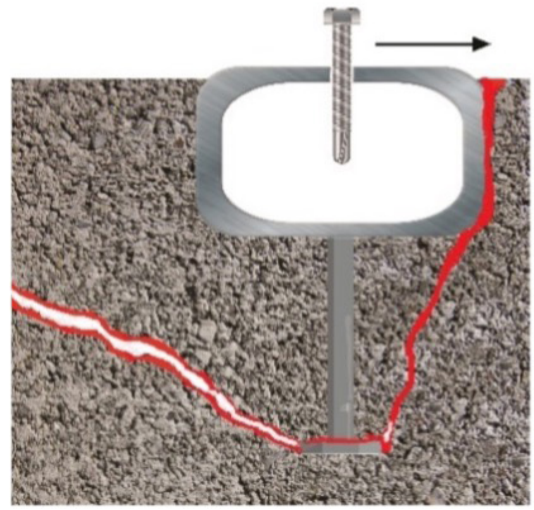
The checks for concrete breakout in shear must be taken in both the perpendicular and parallel direction. When parallel to the edge, V_{cbg} may be twice the value calculated by the above equation, with $\psi_{ed,V}$ set equal to 1.

The checks are completed by confirming that the ratio of the applied shear load, compared to the concrete breakout strength in shear multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{Vcbg,VY} = V_{uaY} / (\phi_{cbg,V} V_{cbgY}) \leq 1$$
$$\beta_{Vcbg,VX} = V_{uaX} / (\phi_{cbg,V} V_{cbgX}) \leq 1$$

HTE CALCULATIONS

CONCRETE PRYOUT STRENGTH IN SHEAR



The nominal pryout strength of an anchor group in shear is designated as V_{cpg}, and per equation 17.7.3.1b for an anchor group, is calculated as:

$V_{cpg} = k_{cp} N_{cpg}$

where,

k_{cp} is equal to 1 when $h_{ef} < 2.5$ inches, and is equal to 2 when $h_{ef} \geq 2.5$ inches, and

N_{cpg} is equal to N_{cbg}

Strength reduction factor $\phi_{cpg,V}$ is dictated by ACI 318-19 Table 17.5.3(c). For cast-in anchors with supplementary reinforcement not present, this value is 0.70.

The checks for concrete pryout in shear must be taken in both the perpendicular and parallel direction.

The checks are completed by confirming that the ratio of the applied shear load, compared to the concrete pryout strength in shear multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{Vcpg,VY} = V_{uaY} / (\phi_{cpg,V} V_{cpg}) \leq 1$$
$$\beta_{Vcpg,VX} = V_{uaX} / (\phi_{cpg,V} V_{cpg}) \leq 1$$

STEEL INTERACTION

If both tensile and shear forces are present, interaction effects must be considered. Per section 17.5.2.3, this can be done using an equation that provides results that are in agreement with testing; or, per section 17.8, it can be neglected if it satisfies the conditions set in sections 17.8.2 and 17.8.3. The conditions are further explained in the commentary R17.8, which provides the following tension-shear interaction expression:

$(N_{ua} / \phi N_n)^{\zeta} + (V_{ua} / \phi V_n)^{\zeta} \leq 1$

Where,

$\zeta = 5/3$, and

the ratios of steel strength in tension and shear have been determined above.

Using the variables listed above, this equation can also be expressed as follows, for the steel interaction:

$$[N_{ua,max} /(\phi_{sa,N} N_{sa})]^{\zeta} + [V_{ua,max} /(\phi_{sa,V} V_{sa})]^{\zeta} \leq 1$$

Or,

$$\beta_{sa,N}^{5/3} + \beta_{sa,V}^{5/3} \leq 1$$

HTE CALCULATIONS

CONCRETE INTERACTION

Similarly, equation 17.8.3 can be used to check the concrete interaction.

$(N_{ua} / \phi N_n) + (V_{ua} / \phi V_n) \leq 1.2$

Or, this can also be represented as:

Max Tension + Max Shear Y + Max Shear X ≤ 1.2

Or,

$(\beta_{cN} + \beta_{cVY} + \beta_{cVX}) / 1.2 \leq 1.0$

Where,

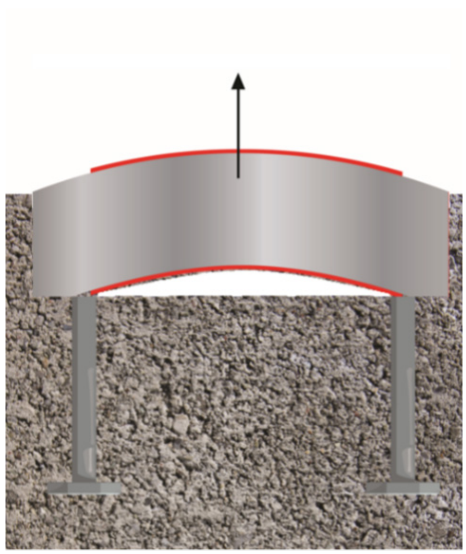
β_{cN} = the greater of $\beta_{cbg,N}$ and $\beta_{pn,N}$

β_{cVY} = the greater of $\beta_{Vcbg,VY}$ and $\beta_{cpg,VY}$

β_{cVX} = the greater of $\beta_{Vcbg,VX}$ and $\beta_{cpg,VX}$

TUBE IN BENDING

The capacity of the HTE can be checked by comparing the bending moment induced by the factored tensile loads to the plastic moment capacity of the section calculated per AISC 360 specifications. The greatest bending moment will occur at the point of loading between the studs.



SCREW CALCULATIONS

The screw connection can be designed using Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD), or the governing code, depending on the application. When designing with the ASD method, a Factor of Safety Ω is used; when designing with the LRFD method, a Strength Reduction Factor ϕ is used. Equations for each method are shown below.

Typical manufacturer values listed below for Ω and ϕ are conservative values; these should be adjusted to reflect the manufacturer data of the screws used in the application.

SCREW STEEL STRENGTH IN TENSION

Screw steel strength in tension is T_s, and is based on the anchor material and dimensions. It is shown as:

$T_s = A_n F_u$

where,

A_n Is the effective cross-sectional area of the screw in square inches, and

F_u is the manufacturer-specified ultimate capacity of the screw.

The value of Ω is provided by the manufacturer, and is typically 3.0.

The check in ASD is completed by confirming that the ratio of the tensile load on the screw, compared to the screw steel strength in tension divided by its factor of safety, is less than or equal to 100%. Or,

$$\beta_{s,T} = T / (A_n F_u / \Omega) \leq 1$$

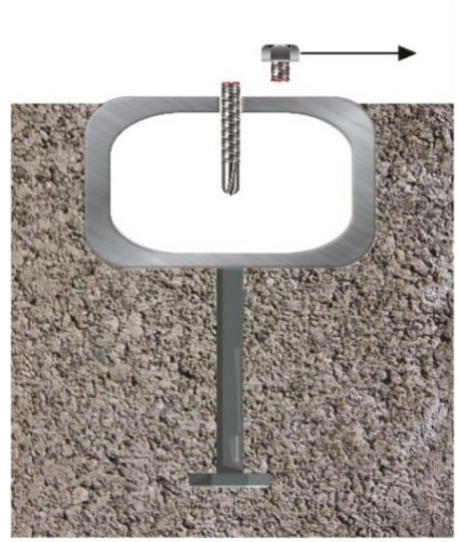
The value of ϕ is determined by dividing 1.5 by Ω, which is 0.5.

The check in LRFD is completed by confirming that the ratio of the tensile load on the screw, compared to the screw steel strength in tension multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{s,T} = T / (\phi A_n F_u) \leq 1$$

SCREW CALCULATIONS

SCREW STEEL STRENGTH IN SHEAR



Screw steel strength in shear is V_s, and is provided by the manufacturer.

V_{cap} is the vectored shear load per screw, found through the following equation:

$$V_{cap} = (V_y^2 + V_x^2)^{0.5}$$

where,

V_y = applied shear load in Y direction divided by quantity of screws, and

V_x = applied shear load in X direction divided by quantity of screws.

The value of Ω is provided by the manufacturer, and is typically 3.0.

The check in ASD is completed by confirming that the ratio of the shear load on the screw, compared to the screw steel strength in shear divided by its factor of safety, is less than or equal to 100%. Or,

$$\beta_{s,V} = V_s / (V_{cap} / \Omega) \leq 1$$

The value of ϕ is determined by dividing 1.5 by Ω, which is 0.5.

The check in LRFD is completed by confirming that the ratio of the shear load on the screw, compared to the screw steel strength in shear multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{s,V} = V_s / (\phi\, V_{cap}) \leq 1$$

SCREW CALCULATIONS

SCREW STRENGTH IN BENDING

The bending load on the screw is M_u, and is found through the following equation:

$M_u = r_c l_{ar} V$

where,

r_c = the restraint coefficient of the shim

l_{ar} = the shim height, the distance between the HTE and the location of the applied loads

V = the vectored shear, noted above

The maximum bending capacity is M_n, and is based on the anchor material and dimensions. It is found through the following equation:

$M_n = Z F_y$

where,

Z is the section modulus of the screw based on the root diameter, and

F_y is the manufacturer-specified yield strength of the screw.

The value of Ω is typically 1.67.

The check in ASD is completed by confirming that the ratio of the bending load on the screw, compared to the screw bending capacity divided by its factor of safety, is less than or equal to 100%. Or,

$$\beta_{s,B} = M_u / (M_n / \Omega) \leq 1$$

The value of ϕ is typically 0.9.

The check in LRFD is completed by confirming that the ratio of the bending load on the screw, compared to the screw bending capacity multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{s,B} = M_u / (\phi M_n) \leq 1$$

SCREW STEEL STRENGTH INTERACTION

The check is completed per the guidance shown in Section 17.8, using a coefficient of 2, for steel, using the following traditional approach:

$$(\beta_{s,T} + \beta_{s,B})^2 + (\beta_{s,V})^2 \leq 1$$

SCREW CALCULATIONS

SCREW PULLOUT STRENGTH IN TENSION

Screw pullout strength in tension is T_p, and is provided by the manufacturer. It is based on the thickness and strength of the material the screws are attaching to. In our case, this is the HSS tube, which has a thickness of 0.25" and a material grade of ASTM A500 grade C.

The value of Ω is provided by the manufacturer, and is typically 3.0.

The check in ASD is completed by confirming that the ratio of the tensile load on the screw, compared to the screw pullout strength in tension divided by its factor of safety, is less than or equal to 100%. Or,

$$\beta_{pullout} = T / (T_p / \Omega) \leq 1$$

The value of ϕ is determined by dividing 1.5 by Ω, which is 0.5.

The check in LRFD is completed by confirming that the ratio of the tensile load on the screw, compared to the screw pullout strength in tension multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{pullout} = T / (\phi\ T_p) \leq 1$$

SCREW BEARING STRENGTH

Screw bearing strength is determined per AISC 360-16 J3-6a.

$R_{by} = 2.4\ d\ t\ F_u$

Where,

t is the thickness of the Allfasteners HTE, which is 0.25 inches, and

F_u is given above.

The value of Ω is dictated by AISC 360, and is 2.0.

The check in ASD is completed by confirming that the ratio of the shear load per screw in the Y direction, compared to the bearing strength of the HTE divided by its factor of safety, is less than or equal to 100%. Or,

$$\beta_{Bearing,y} = V_y / (R_{by} / \Omega) \leq 1$$

The value of ϕ is dictated by AISC 360, and is 0.75.

The check in LRFD is completed by confirming that the ratio of the shear load per screw in the Y direction, compared to the bearing strength of the HTE multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{Bearing,y} = V_y / (\phi\ R_{by}) \leq 1$$

SCREW CALCULATIONS

SCREW TEAROUT STRENGTH

Screw tearout strength is determined per AISC 360-16 J3-6c.

$R_{ty} = 1.2\ l_c\ t\ F_u$

Where,

l_c is the maximum offset allowed in any direction, based on the tolerance placement markings of the “construction strip”

and t and F_u are given above.

The value of Ω is dictated by AISC 360, and is 2.0.

The check in ASD is completed by confirming that the ratio of the shear load per screw in the Y direction, compared to the tearout strength of the HTE divided by its factor of safety, is less than or equal to 100%. Or,

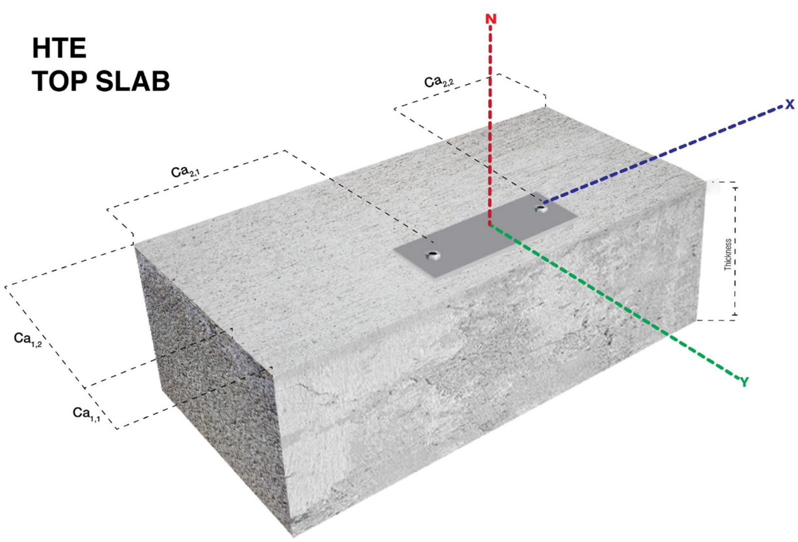
$$\beta_{Bearing,y} = V_y / (R_{ty} / \Omega) \leq 1$$

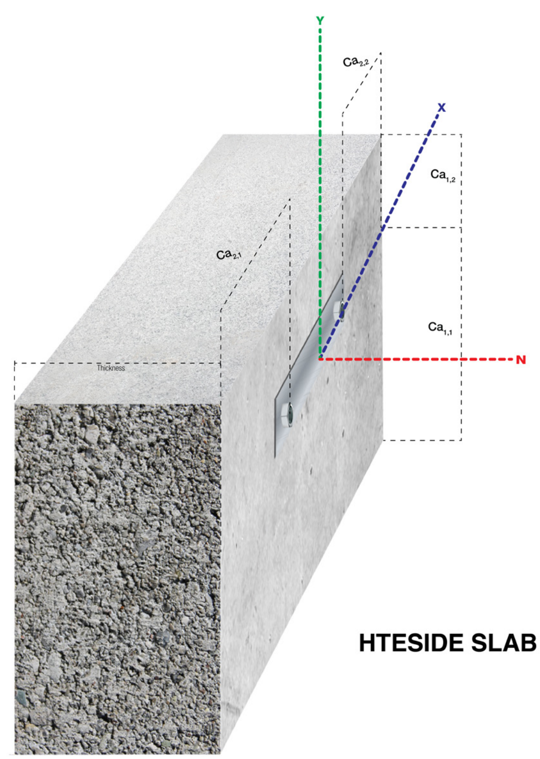
The value of ϕ is dictated by AISC 360, and is 0.75.

The check in LRFD is completed by confirming that the ratio of the shear load per screw in the Y direction, compared to the tearout strength of the HTE multiplied by its reduction factor, is less than or equal to 100%. Or,

$$\beta_{Bearing,y} = V_y / (\phi\ R_{ty}) \leq 1$$

HTE CAPACITIES





HTE CAPACITIES

TABLE 2: HTE CAPACITIES IN CRACKED CONCRETE

STUD COUNT: 2

Tube Length	inches	8"			12"			16"		
Stud Length	**inches**	3"	4"	5"	3"	4"	5"	3"	4"	5"
h_{ef}	inches	4.6875	5.6875	6.6875	4.6875	5.6875	6.6875	4.6875	5.6875	6.6875
Capacity in Tension	lbs	9,086	10,604	12,244	10,898	12,444	14,124	12,710	14,283	16,003
Capacity in Shear	lbs	2,876	2,876	2,876	3,452	3,452	3,452	3,452	3,452	3,452

TABLE 3: HTE CAPACITIES IN CRACKED CONCRETE

STUD COUNT: 3

Tube Length	inches	8"			12"			16"		
Stud Length	**inches**	3"	4"	5"	3"	4"	5"	3"	4"	5"
h_{ef}	inches				4.6875	5.6875	6.6875	4.6875	5.6875	6.6875
Capacity in Tension	lbs				10,898	12,444	14,124	12,710	14,283	16,003
Capacity in Shear	lbs				3,644	3,644	3,644	4,411	4,411	4,411

TABLE 4: HTE CAPACITIES IN UNCRACKED CONCRETE

STUD COUNT: 2

Tube Length	inches	8"			12"			16"		
Stud Length	**inches**	3"	4"	5"	3"	4"	5"	3"	4"	5"
h_{ef}	inches	4.6875	5.6875	6.6875	4.6875	5.6875	6.6875	4.6875	5.6875	6.6875
Capacity in Tension	lbs	11,358	13,255	15,306	13,623	15,554	17,655	15,887	17,853	19,144
Capacity in Shear	lbs	4,027	4,027	4,027	4,832	4,832	4,832	4,832	4,832	4,832

TABLE 5: HTE CAPACITIES IN UNCRACKED CONCRETE

STUD COUNT: 3

Tube Length	inches	8"			12"			16"		
Stud Length	**inches**	3"	4"	5"	3"	4"	5"	3"	4"	5"
h_{ef}	inches				4.6875	5.6875	6.6875	4.6875	5.6875	6.6875
Capacity in Tension	lbs				13,623	15,554	17,655	15,887	17,853	20,004
Capacity in Shear	lbs				5,101	5,101	5,101	6,175	6,175	6,175

NOTES:
1. f'_c = 4000 psi
2. $C_{a1,1}$ =3
3. Values apply to orientation of top of slab or side of slab, for shear force being in the Y-direction per diagrams.
4. Concrete breakout strength governs all capacities EXCEPT FOR uncracked concrete, 16" tube, (2) 5" studs.