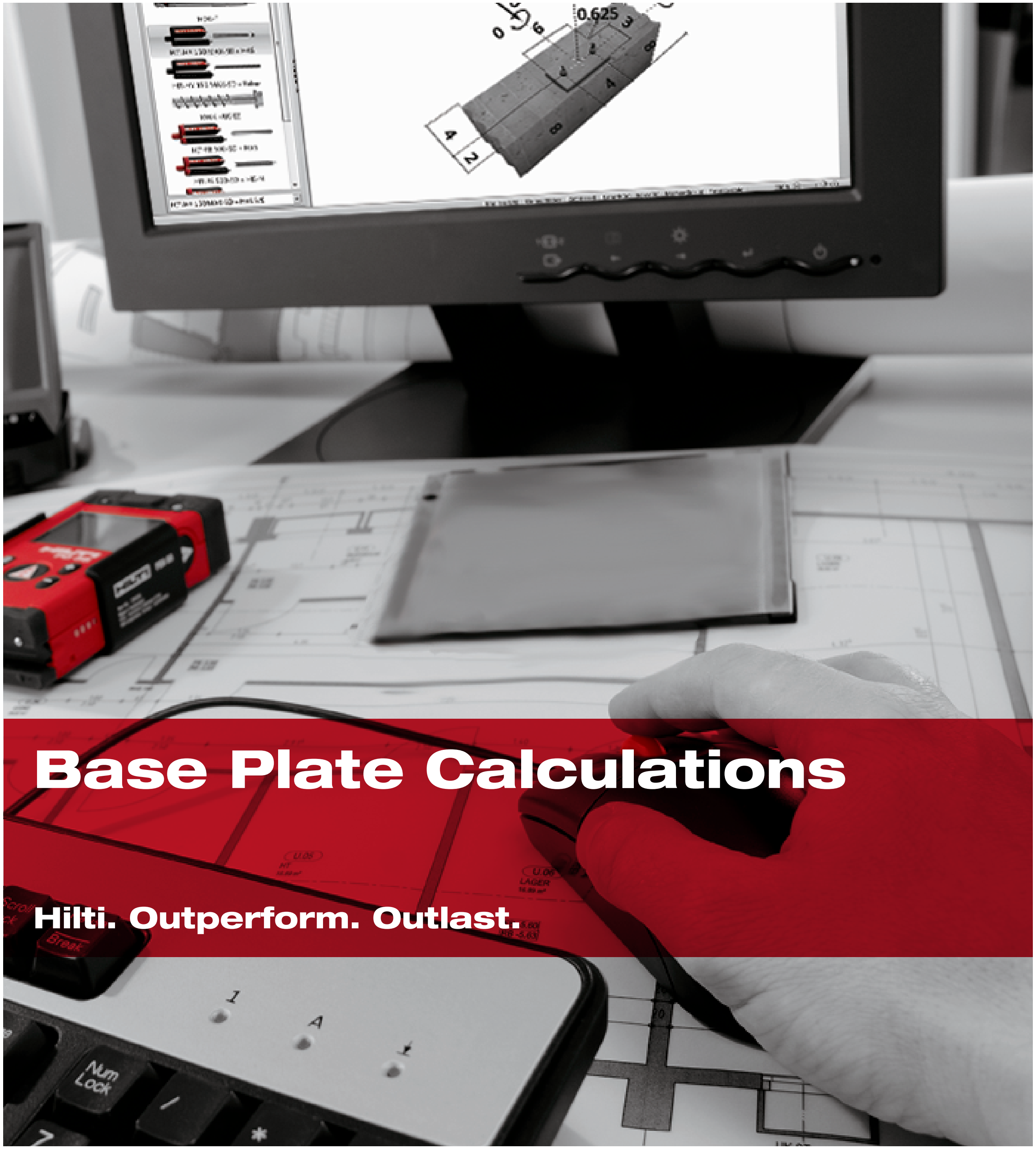


Base Plate Calculations

Hilti. Outperform. Outlast.

This section explains how PROFIS Anchor uses the base plate properties to determine forces acting on the anchors, and to consider the effects of eccentricity on the tension capacity of the anchorage.

PROFIS Anchor Design Assumptions for Base Plate Calculations

Design Assumptions

PROFIS Anchor base plate calculations are performed to determine the tension forces acting on anchors. The base plate dimensions are utilized in conjunction with the forces acting on the anchorage to determine which anchors are in tension, and the magnitude of the force acting on each anchor in tension. PROFIS Anchor calculations assume the base plate is rigid, which means that it assumes the stiffness of the base plate is greater than the stiffness of the anchors. This permits a linear elastic stress/strain distribution to be utilized in conjunction with compatibility equations and statics to locate the neutral axis. A finite element program is used to perform these calculations. PROFIS Anchor does not perform any analysis or design for anchors determined to be in compression. Analysis and design related to compression conditions such as buckling are beyond the scope of PROFIS Anchor.

PROFIS Anchor base plate calculations can be summarized as follows:

- Locate the neutral axis using the finite element program.
- Determine the compressive stress in the concrete beneath the base plate.
- Determine the resultant tension and resultant compression forces acting on the anchorage.
- Determine the force distribution on the anchors in tension.
- Determine the eccentricity of the resultant tension force with respect to the center of gravity for the anchors that are in tension.

PROFIS Anchor base plate calculations do not consider the following:

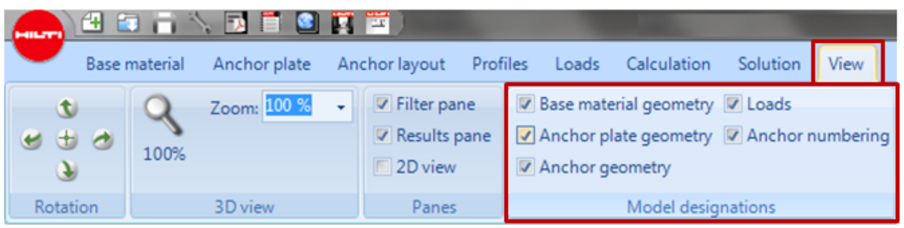
- PROFIS Anchor does not calculate a base plate thickness to resist the forces acting on the anchorage. Users can input any base plate thickness. A default base plate thickness is utilized by the finite element program to proportion the finite element nodes. The base plate is always assumed to be rigid in order to permit a linear elastic stress/strain distribution to be utilized.
- PROFIS Anchor does not consider the profile shape when locating the neutral axis. Users can input any profile shape, or no profile shape.
- PROFIS Anchor does not calculate the bearing strength of the concrete. It calculates the compressive stress in the concrete beneath the base plate for the length and width that have been input, and for the forces that have been input, assuming the base plate is rigid.

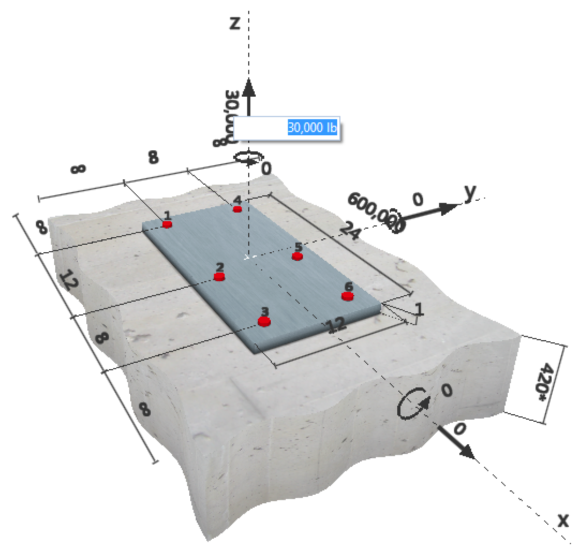
PROFIS Anchor is not intended to be used as a software program for base plate design !! Base plate calculations are performed to determine the tension forces acting on anchors.

Design Assumptions (continued)

1 Input data

Anchor type and diameter:	HIT-HY 200 + HAS 1
Effective embedment depth:	$h_{ef,act}$ = 15.000 in. ($h_{ef,limit}$ = - in.)
Material:	5.8
Evaluation Service Report:	ESR-3187
Issued I Valid:	4/1/2013 | 3/1/2014
Proof:	design method ACI 318 / AC308
Stand-off installation:	e_b = 0.000 in. (no stand-off); t = 1.000 in.
Anchor plate:	l_x x l_y x t = 24.000 in. x 12.000 in. x 1.000 in.; (Recommended plate thickness: not calculated)
Profile:	no profile
Base material:	cracked concrete, 4000, f_c' = 4000 psi; h = 420.000 in., Temp. short.long: 32/32 °F
Installation:	hammer drilled hole, installation condition: dry
Reinforcement:	tension: condition B, shear: condition B; no supplemental splitting reinforcement present edge reinforcement: none or < No. 4 bar
Seismic loads (cat. C, D, E, or F)	no





Part 1 Input data in the PROFIS Anchor design report shows the base plate geometry input by the user. The main screen shows the factored loads input by the user, and the anchorage geometry.

Geometry and loads, along with additional parameters, can be input as follows:

- **Base material** tab: input concrete compressive strength, geometry and installation parameters.
- **Anchor plate** tab: input base plate geometry and stand-off conditions.
- **Anchor layout** tab: input anchor geometry.
- **Profiles** tab: select a profile type and locate it on the base plate.
- **Loads** tab: select a design method (Strength Design or Allowable Stress Design) and load condition (seismic or non-seismic).

Anchor embedment depth is input via the **Results pane**.

For more information on how to navigate in PROFIS Anchor and utilize the various tabs, go to the **PROFIS Anchor tutorials**.

Geometry and loads can also be input directly via the main screen.

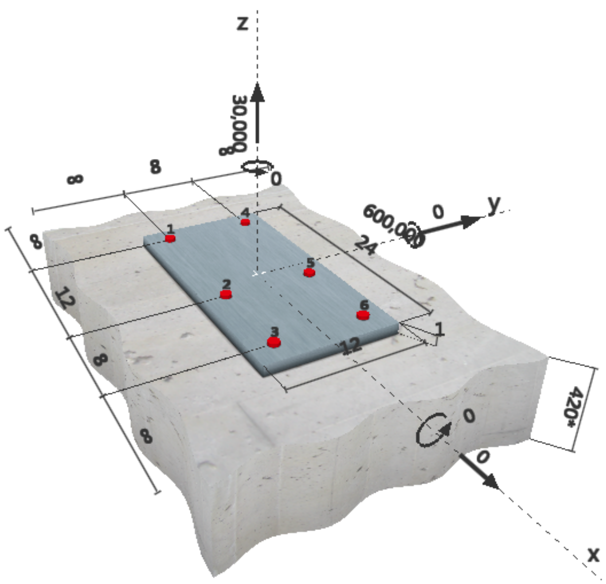
Click on the **View** tab and check the parameters in the box titled **Model designations** to show that parameter on the main screen.

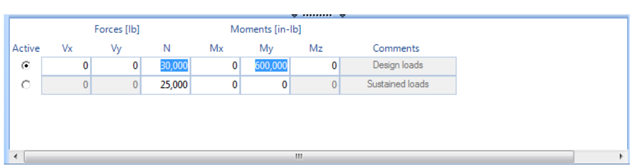
To input a parameter on the main screen, place the cursor over it and type in a value. Click the "**Enter**" key or double click on your left mouse to save the value.

PROFIS Anchor calculations for a selected design method assume the loads that have been input are consistent with the provisions for that method. It is the responsibility of the user to input loads that are relevant for the design method that has been selected. PROFIS Anchor does not apply load factors, nor does it convert strength design results into allowable loads.

Tension Forces on the Anchors

Result	Reference	Comments





		Forces [lb]			Moments [in-lb]		
Active	Vx	Vy	N	Mx	My	Mz	Comments
⦿	0	0	30,000	0	600,000	0	Design loads
○	0	0	25,000	0	0	0	Sustained loads

2 Load case/Resulting anchor forces

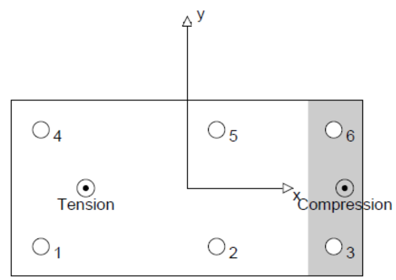
Load case: Design loads

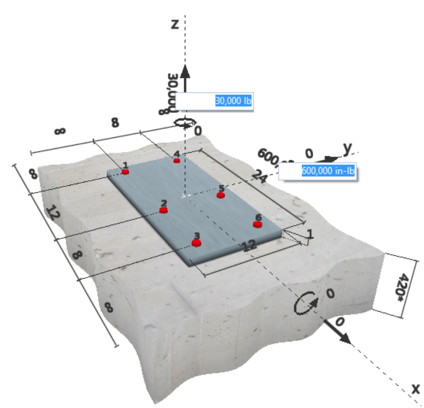
Anchor reactions [lb]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	19421	0	0	0
2	6656	0	0	0
3	0	0	0	0
4	19421	0	0	0
5	6656	0	0	0
6	0	0	0	0

max. concrete compressive strain:	0.23 [%]
max. concrete compressive stress:	986 [psi]
resulting tension force in (x/y)=(-6.937/0.000)	52154 [lb]
resulting compression force in (x/y)=(10.752/0.000):	22154 [lb]





The base plate neutral axis must be located in order to determine the following:

- which anchors are in tension and which anchors are in compression.
- the magnitude and location of the resultant tension and compression forces.
- the magnitude of the tension force acting on each anchor that is in tension.
- the eccentricity of the resultant tension force with respect to the center of gravity for the anchors that are in tension.

Using the forces, moments and base plate geometry that have been input, PROFIS Anchor calculates the resultant forces acting on the anchorage. **Part 2** of the design report shows the magnitude and location of the resultant tension and compression forces, as well as the magnitude of the tension force on each anchor that is in tension. PROFIS Anchor does not perform any calculations for anchors determined to be in compression. Resultant shear forces will also be shown if the forces that are input include shear forces in the x direction and/or y direction and/or torsion about the z axis. Refer to the Design Guide section on **Factored Loads** for more information about PROFIS Anchor resultant shear force calculations.

Given the applied axial forces, and the moments acting about the x/y axes of the base plate; statics can be used to develop equations for calculating the location of the neutral axis on the base plate. The application, however, is statically indeterminate since the location of the neutral axis and the magnitude of the resultant forces are unknown. Assuming the base plate is rigid, a linear-elastic stress/strain relationship can be assumed, and compatibility equations can be used to provide the additional equations necessary to solve for the neutral axis location.

Once the neutral axis has been located, the compressive stress in the concrete beneath the base plate can be calculated, and subsequently, the magnitude of the resultant tension and compression forces can be calculated. Once the resultant forces are known, the tension forces acting on each anchor can be calculated, and the eccentricity of the resultant tension force with respect to the anchors that are in tension can be calculated.

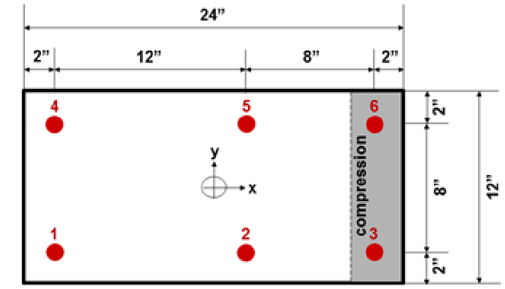
The following example will be used to explain how PROFIS Anchor calculates resultant tension and compression forces for an anchorage, and the corresponding tension forces on each anchor in tension. The example consists of the following:

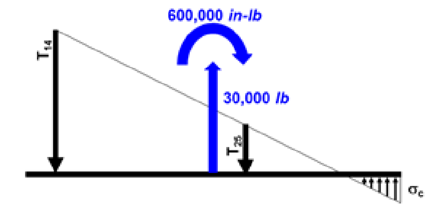
- six Hilti HAS 5.8 carbon steel threaded rods having a diameter = 1" and a tensile stress area (A_{se}) = 0.6057 in²/rod.
- the anchors are spaced at 12" and 8" in the x direction.
- the anchors are spaced at 8" in the y direction.
- baseplate having dimensions 12" x 2'-0" x 1".
- applied axial tension force = 30,000 lb.
- applied moment acting about the y axis = 600,000 in-lb.
- concrete compressive strength = 4000 lb/in²

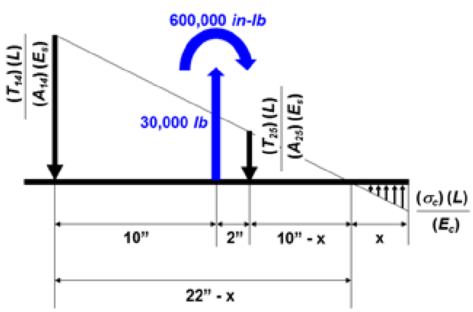
The images to the left show how loads can be input for PROFIS Anchor ACI 318-11 provisions.

Tension Forces on the Anchors (continued)

Result







Reference

Compatibility Equations

$$\frac{PL}{AE} \rightarrow \frac{(T_{14})(L)}{(A_{14})(E_s)} \rightarrow \frac{(T_{25})(L)}{(A_{25})(E_s)} \rightarrow \frac{(\sigma_c)(L)}{(E_c)}$$

T_{14}	=	tension force acting on anchors 1 and 4
A_{14}	=	tensile stress area for anchors 1 and 4
	=	(2) (0.6057 in²)
	=	1.2114 in²
T_{25}	=	tension force acting on anchors 2 and 5
A_{25}	=	tensile stress area for anchors 2 and 5
	=	(2) (0.6057 in²)
	=	1.2114 in²
σ_c	=	compression stress in the concrete beneath the base plate
E_s	=	29,000,000 lb/in²
E_c	=	30,000 Mpa*
	=	4,351,200 lb/in²
		*PROFIS Anchor does not calculate E_c per ACI 318 Part 8.5.1. It uses the European value for E_c = 30,000 MPa.
"L"	=	"Length" = unity

Comments

The location of the neutral axis, defined by "x" in the illustration to the left, is unknown. Likewise, the tension forces acting on the anchors, and the compressive stress in the concrete beneath the base plate are unknown. The application, therefore, is statically indeterminate; however, compatibility equations can be used to obtain the necessary equilibrium relationships that will permit determination of the tension forces acting on the anchors.

$$\frac{\frac{(T_{14})(L)}{(A_{14})(E_s)}}{(22 - x)} = \frac{\frac{(T_{25})(L)}{(A_{25})(E_s)}}{(10 - x)} = \frac{\frac{(\sigma_c)(L)}{(E_c)}}{(x)}$$

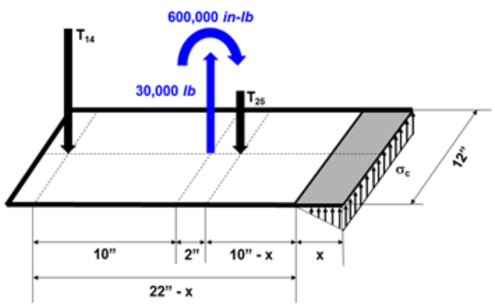
(Equation 1)

$$\frac{(T_{14})}{(A_{14})(E_s)} = \frac{(\sigma_c)(22 - x)}{(E_c)(x)} \rightarrow (T_{14}) = \frac{(\sigma_c)(22 - x)(A_{14})(E_s)}{(E_c)(x)} \rightarrow (T_{14}) = \frac{(8.064)(22 - x)(\sigma_c)}{(x)}$$

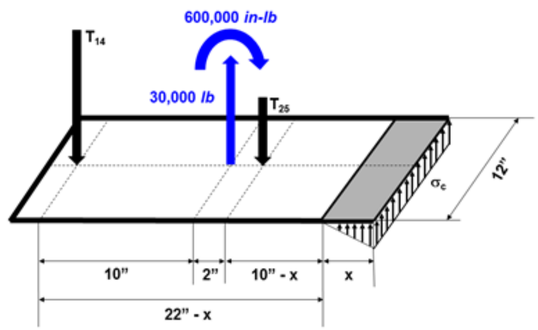
(Equation 2)

$$\frac{(T_{25})}{(A_{25})(E_s)} = \frac{(\sigma_c)(10 - x)}{(E_c)(x)} \rightarrow (T_{25}) = \frac{(\sigma_c)(10 - x)(A_{25})(E_s)}{(E_c)(x)} \rightarrow (T_{25}) = \frac{(8.064)(10 - x)(\sigma_c)}{(x)}$$

Tension Forces on the Anchors (continued)

Result	Reference	Comments
	**Compatibility Equations** $(T_{14}) = \frac{(8.064)(22-x)(\sigma_c)}{(x)}$ **(Equation 1)** $(T_{25}) = \frac{(8.064)(10-x)(\sigma_c)}{(x)}$ **(Equation 2)**	Using statics, and Equations 1 and 2, additional equations can be developed that express the compressive stress in the concrete beneath the base plate (σ_c) in terms of the neutral axis term (x). $\Sigma F_z = 0 + \uparrow$ $[(0.5)(\sigma_c)(x)(12)] + 30{,}000 - T_{14} - T_{25} = 0$ $[(0.5(\sigma_c)(x)(12)] + 30{,}000 - \frac{(8.064)(22-x)(\sigma_c)}{(x)} - \frac{(8.064)(10-x)(\sigma_c)}{(x)} = 0$ $(6\sigma_c)x^2 + (30{,}000)x - (177.408\sigma_c) + (8.064\sigma_c)x - (80.64\sigma_c) + (8.064\sigma_c)x = 0$ $(6\sigma_c)x^2 + (30{,}000)x - (258.05\sigma_c) + (16.128\sigma_c)x = 0$ $\sigma_c[6x^2 + (16.128)x - 258.05] = -(30{,}000)x$ $\sigma_c = \frac{-(30{,}000)x}{[6x^2 + (16.128)x - 258.05]}$ **(Equation 3)** $\Sigma M_y = 0 + \circlearrowleft$ $[(0.5)(\sigma_c)(x)(12)(0.67x)] + T_{14}(22-x) + T_{25}(10-x) - (30{,}000)(12-x) - 600{,}000 = 0$ $[(0.5(\sigma_c)(x)(12)(0.67x)] + \left(\frac{(8.064)(22-x)(\sigma_c)}{(x)}\right)(22-x) + \left(\frac{(8.064)(10-x)(\sigma_c)}{(x)}\right)(10-x) - (30{,}000)(12-x) - 600{,}000 = 0$ $(4\sigma_c)x^3 + (8.064\sigma_c)(22-x)^2 + (8.064\sigma_c)(10-x)^2 - (360{,}000)x + (30{,}000)x^2 - (600{,}000)x = 0$ $\sigma_c[4x^3 + (8.064)(22-x)^2 + (8.064)(10-x)^2] = (960{,}000)x - (30{,}000)x^2$ $\sigma_c = \frac{(960{,}000)x - (30{,}000)x^2}{4x^3 + (8.064)(22-x)^2 + (8.064)(10-x)^2}$ **(Equation 4)**

Tension Forces on the Anchors (continued)

Result	Reference	Comments
		Set **Equation 3** equal to **Equation 4** and solve for "x", the location of the neutral axis. This is a trial and error process using various values for x until the value calculated for **Equation 3** equals the value calculated for **Equation 4**. Once the value for x is known, the concrete compressive stress (σ_c) beneath the base plate can be calculated. Once σ_c is known, the tension forces acting on the anchors (T_{14} and T_{25}) can be calculated. Finally, once T_{14} and T_{25} are known; the tension forces acting on anchors 1 and 4, 2 and 5 can be calculated. The resultant tension force equals the sum of the tension forces acting on anchors 1, 2, 4 and 5. This value will be compared to the calculated tension capacities for concrete breakout strength and bond strength ($\Phi N_N > N_{ua}$). The highest tension force acting on a single anchor, i.e. the highest force acting on anchors 1, 2, 4 and 5, will be compared to the calculated tension capacity for steel strength ($\Phi N_{sa} > N_{ua,i}$).

(Equation 3) = **(Equation 4)**

$$\frac{-(30{,}000)x}{[6x^2 + (16.128)x - 258.05]} = \frac{(960{,}000)x - (30{,}000)x^2}{[4x^3 + (8.064)(22 - x)^2 + (8.064)(10 - x)^2]}$$

Try x = 3.75 in.

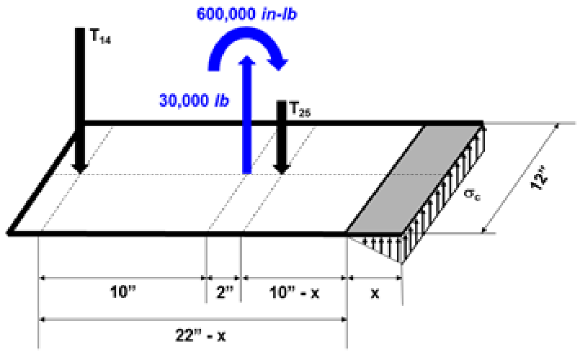
$$\frac{-(30{,}000)(3.75)}{(6)(3.75)^2 + (16.128)(3.75) - 258.05} = \frac{(960{,}000)(3.75) - (30{,}000)(3.75)^2}{(4)(3.75)^3 + (8.064)(22 - 3.75)^2 + (8.064)(10 - 3.75)^2}$$

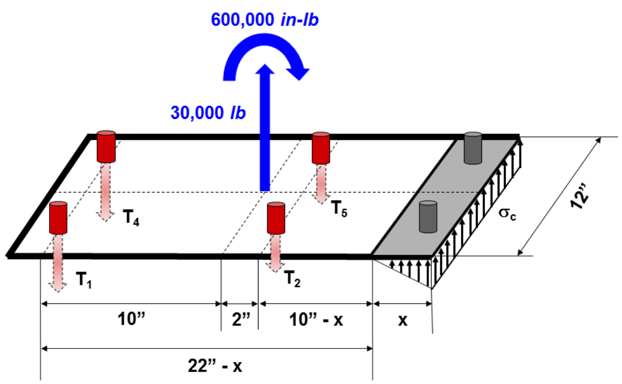
units are lb/in^2 993.86 = 989.53 OK

Tension Forces on the Anchors (continued)

Result	Reference	Comments

Result





Reference

Compatibility Equations

$$(T_{14}) = \frac{(8.064)\,(22 - x)\,(\sigma_c)}{(x)}$$ **(Equation 1)**

$T_{14} = T_1 + T_4$ where $T_1 = T_4$

$$(T_{25}) = \frac{(8.064)\,(10 - x)\,(\sigma_c)}{(x)}$$ **(Equation 2)**

$T_{25} = T_2 + T_5$ where $T_2 = T_5$

Comments

Solve for the tension forces acting on anchors 1, 2, 4 and 5. Assume the value for σ_c = the average of the calculation results when x = 3.75.

$$\sigma_c = \frac{993.86 \text{ lb/in}^2 + 989.53 \text{ lb/in}^2}{2} = 992 \text{ lb/in}^2$$

From **(Equation 1)** using x = 3.75 in and σ_c = 992 lb/in²:

$$T_{14} = \frac{(8.064 \text{ in}^2)\,(22 \text{ in} - 3.75 \text{ in})\,(992 \text{ lb/in}^2)}{3.75 \text{ in}} = 38{,}930 \text{ lb}$$

$$T_1 = T_4 = \frac{T_{14}}{2} \rightarrow T_1 = T_4 = 19{,}465 \text{ lb}$$

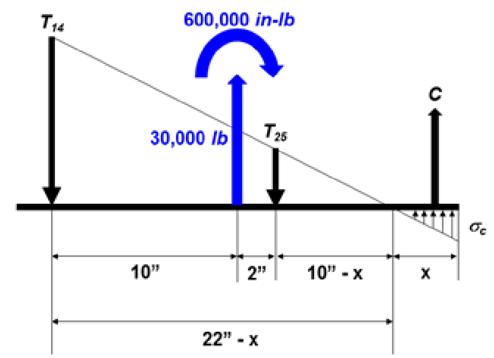
From **(Equation 2)** using x = 3.75 in and σ_c = 992 lb/in²:

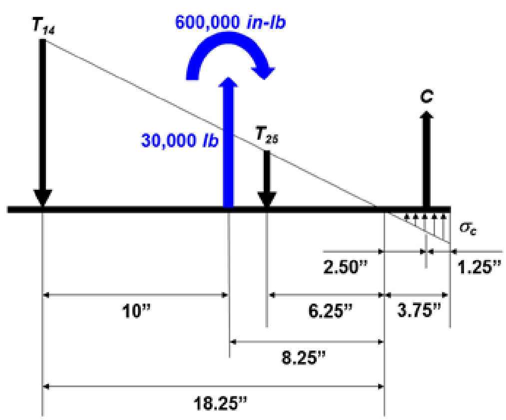
$$T_{25} = \frac{(8.064 \text{ in}^2)\,(10 \text{ in} - 3.75 \text{ in})\,(992 \text{ lb/in}^2)}{3.75 \text{ in}} = 13{,}332 \text{ lb}$$

$$T_2 = T_5 = \frac{T_{25}}{2} \rightarrow T_2 = T_5 = 6{,}666 \text{ lb}$$

Tension Forces on the Anchors (continued)

Result





Reference

T_{14} = 38,930,lb

T_{25} = 13,332 lb

C = (0.5) (σ_c) (x) (base plate width)

= (0.5) (992 lb/in^2) (3.75 in) (12 in)

= 22,320 lb

Comments

Check for static equilibrium using the values calculated for T_{14} and T_{25}. The resultant compression force (C) equals the volume under the base plate in the compression zone.

ΣF: 30,000 lb + C = T_{14} + T_{25}

30,000 lb + 22,320 lb = 38,930 lb + 13,332 lb

52,320 lb = 52,262 lb

difference = 58 lb → 0% OK

ΣM: (T_{14}) (18.25 in) + (T_{25}) (6.25 in) + (C) (2.50 in) = (30,000 lb) (8.25 in) + 600,000 in-lb

710,472 in-lb + 83,325 in-lb + 55,800 in-lb = 247,500 in-lb + 600,000 in-lb

849,597 in-lb = 847,500 in-lb

difference = 2097 in-lb → 0.25% OK

2 Load case/Resulting anchor forces

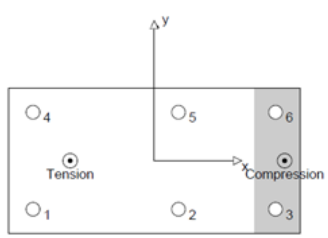
Load case:Design loads

Anchor reactions [lb]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	19421	0	0	0
2	6656	0	0	0
3	0	0	0	0
4	19421	0	0	0
5	6656	0	0	0
6	0	0	0	0

max. concrete compressive strain: 0.23 [%]
max. concrete compressive stress: 986 [psi]
resulting tension force in (x/y)=(-6.937/0.000) 52154 [lb]
resulting compression force in (x/y)=(-10.752/0.000): 22154 [lb]



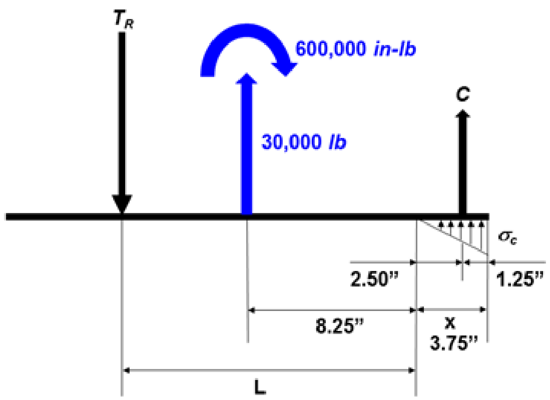
The PROFIS Anchor design report shows the resultant forces acting on the anchors in tension, as well as the resultant compression force and concrete compressive stress calculated using the above design assumptions. Refer to **Part 2 Load case/Resulting anchor forces** in the design report.

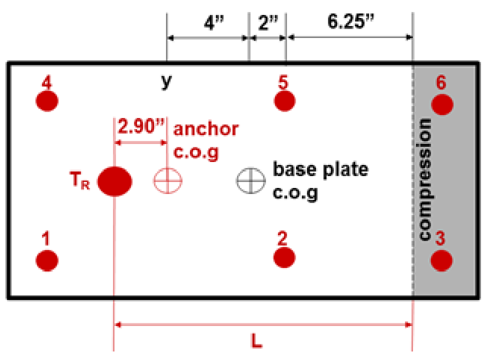
Part 2 of the design report also shows the location of the resultant tension and compression forces with respect to the center of gravity for the base plate. PROFIS Anchor does not perform any calculations for anchors determined to be in compression.

For more information about resultant shear force calculations, go to the Design Guide section titled **Factored Load Calculations**.

Tension Eccentricity Calculations

Result





2 Load case/Resulting anchor forces

Load case:Design loads

Anchor reactions [lb]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	19421	0	0	0
2	6656	0	0	0
3	0	0	0	0
4	19421	0	0	0
5	6656	0	0	0
6	0	0	0	0

max. concrete compressive strain: 0.23 [%]
max. concrete compressive stress: 986 [psi]
resulting tension force in (x/y)=(-6.937/0.000) 52154 [lb]
resulting compression force in (x/y)=(10.752/0.000): 22154 [lb]

Reference

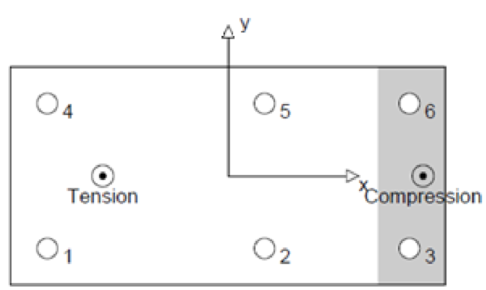
T_{14} = 38,930,lb

T_{25} = 13,332 lb

C = (0.5) (σ_c) (x) (baseplate width)

= (0.5) (992 lb/in²) (3.75 in) (12 in)

= 22,320 lb



Comments

The tension eccentricity (e'_N) calculated for concrete breakout strength and bond strength is defined as the distance of the resultant tension force from the centroid of the anchors that are in tension. The resultant tension force for this application equals T_{14} + T_{25}. The resultant force location can be determined as follows. Refer to the section **Tension Forces on the Anchors** for an explanation of how σ_c, x, T_{14} and T_{25} were calculated.

T_R = T_{14} + T_{25}
= 38,930 lb + 13,332 lb
= 52,262 lb

ΣM: (T_R) (L) + (C) (2.50 in) = (30,000 lb) (8.25 in) + 600,000 in-lb
(52,262 lb) (L) = 247,500 in-lb + 600,000 in-lb - 55,800 in-lb
L = 15.15 in

L- (4 in + 2 in + 6.25) = 2.90 in

T_R is located 2.90" in the -x direction from the center of gravity for the anchors that are in tension. Therefore, the tension eccentricity (**e'_N**) equals 2.90 in. The PROFIS Anchor design report will denote this value as **$e_{c1,N}$** because it corresponds to eccentricity in the x direction. The design report denotes tension eccentricity in the y direction as **$e_{c2,N}$** . Tension eccentricity is used to calculate the modification factors **$\psi_{ec,N}$** and **$\psi_{ec,Na}$** for concrete breakout strength in tension and bond strength respectively.

T_R is also located 6.90" in the -x direction from the center of gravity for the base plate.

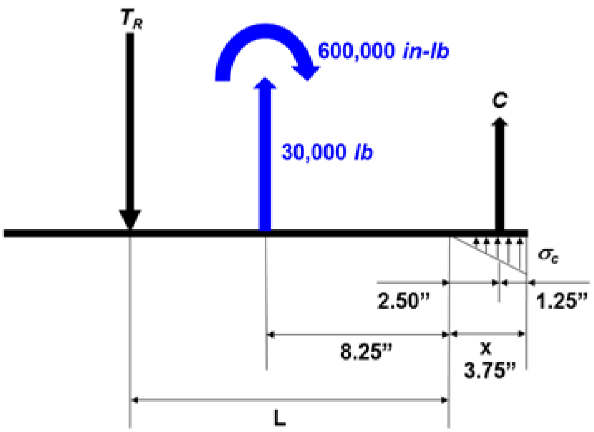
e'_N = 2.90 in

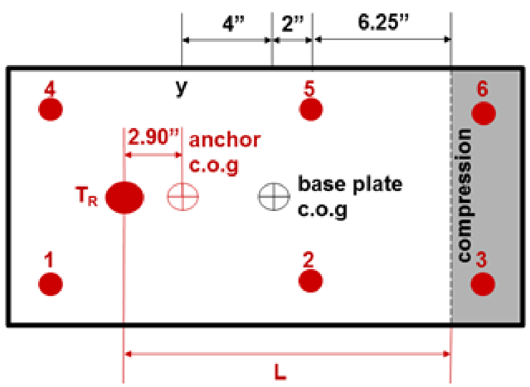
2.90 in + 4 in = 6.90 in

Part 2 Load case/Resulting anchor forces in the PROFIS Anchor design report shows the location of T_R with respect to the center of gravity for the base plate. The coordinates used to define the location of resultant forces are given with respect to the center of gravity of the base plate. Therefore, the coordinates for T_R are given in **Part 2** of the design report as (-6.937, 0.000) because tension eccentricity only exists in the x direction. The difference in values shown in the design report versus the calculations above are the result of the hand calculation results being rounded.

Tension Eccentricity Calculations (continued)

Result





Reference

ACI 318-11 Appendix D

Concrete Breakout Strength in Tension

D.5.2.4 — The modification factor for anchor groups loaded eccentrically in tension, $\psi_{ec,N}$, shall be computed as

$$\psi_{ec,N} = \left(\frac{1}{1 + \frac{2e'_N}{3h_{ef}}} \right) \leq 1 \qquad \text{(D-8)}$$

but $\psi_{ec,N}$ shall not be taken greater than 1.0.

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-8) and for the calculation of N_{cbg} according to Eq. (D-4).

Bond Strength in Tension

D.5.5.3 — The modification factor for adhesive anchor groups loaded eccentrically in tension, $\psi_{ec,Na}$, shall be computed as

$$\psi_{ec,Na} = \left(\frac{1}{1 + \frac{e'_N}{c_{Na}}} \right) \leq 1 \qquad \text{(D-23)}$$

but $\psi_{ec,Na}$ shall not be taken greater than 1.0.

If the loading on an adhesive anchor group is such that only some adhesive anchors are in tension, only those adhesive anchors that are in tension shall be considered when determining the eccentricity e'_N for use in Eq. (D-23) and for the calculation of N_{ag} according to Eq. (D-19).

Comments

Once the value for tension eccentricity ($\mathbf{e'_N}$) is known, the modification factors $\boldsymbol{\psi_{ec,N}}$ and $\boldsymbol{\psi_{ec,Na}}$ can be calculated for concrete breakout strength in tension and bond strength respectively. ACI 318-11 D.5.2.4 and D.5.5.3 both have an additional clause, not shown to the left, which addresses eccentricity with respect to both the x and y axes. For these cases, $\boldsymbol{\psi_{ec}}$ is is calculated for each eccentricity condition and the results are multiplied together. This value is then used in equation (D-4) for calculating nominal concrete breakout strength, and equation (D-19) for calculating nominal bond strength, as relevant to the application.

Modification factor for Concrete Breakout Strength in Tension

assumes h_{ef} = 15.00"

$$\psi_{ec,N} = \left(\frac{1}{1 + \frac{(2)\,(2.90")}{(3)\,(15.00")}} \right) \leq 1 \qquad \text{(D-8)}$$

$$\psi_{ec,N} = 0.886$$

Modification factor for Bond Strength in Tension

assumes c_{Na} = 13.07"

$$\psi_{ec,Na} = \left(\frac{1}{1 + \frac{2.90"}{13.07"}} \right) \leq 1 \qquad \text{(D-23)}$$

$$\psi_{ec,Na} = 0.818$$

Tension Eccentricity Calculations (continued)

Result	Reference	Comments
3.4 Concrete Breakout Strength		Concrete breakout strength calculations in tension are given in Part 3.4 of the PROFIS Anchor design report. The illustration to the left has been edited from the design report to show parameters relevant to eccentricity when concrete breakout strength is being calculated in tension.
$N_{cbg} = \left(\frac{A_{Nc}}{A_{Nc0}}\right) \psi_{ec,N}\,\psi_{ed,N}\,\psi_{c,N}\,\psi_{cp,N}\,N_b$	ACI 318-11 Eq. (D-4)	Tension eccentricity in the x direction is designated $\mathbf{e_{c1,N}}$. The corresponding eccentricity modification factor is designated $\boldsymbol{\psi_{ec1,N}}$.
$\psi_{ec,Na} = \left(\frac{1}{1 + \frac{2e'_N}{3h_{ef}}}\right) \leq 1.0$	ACI 318-11 Eq. (D-8)	Tension eccentricity in the y direction is designated $\mathbf{e_{c2,N}}$. The corresponding eccentricity modification factor is designated $\boldsymbol{\psi_{ec2,N}}$.

If eccentricity exists in both the x and y directions, the values calculated for $\boldsymbol{\psi_{ec1,N}}$ and $\boldsymbol{\psi_{ec,2,N}}$ will be multiplied together, and the resulting value would be used in Equation (D-4) to calculate the nominal concrete breakout strength in tension.

This design example only has eccentricity with respect to the x direction. Therefore, only values for $\mathbf{e_{c1,N}}$ and $\boldsymbol{\psi_{ec1,N}}$ are calculated in Part 3.4 of the design report, and the value for $\boldsymbol{\psi_{ec1,N}}$ is used to calculate the nominal concrete breakout strength per Equation (D-4).

Note that the value for the resultant tension force (= 52,154 lb) corresponds to the value shown for the parameter N_{ua}, since the resultant tension force equals the total factored tension force acting on the anchors in the group.

Variables

h_{ef} [in.]	$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	$c_{a,min}$ [in.]	$\psi_{c,N}$
15.000	2.937	0.000	∞	1.000

Calculations

A_{Nc} [in.^{2}]	A_{Nc0} [in.^{2}]	$\psi_{ec1,N}$	$\psi_{ec2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]
3021.00	2025.00	0.885	1.000	1.000	1.000	62462

Results

N_{cbg} [lb]	$\Phi_{concrete}$	ΦN_{cbg} [lb]	N_{ua} [lb]
82424	0.650	53576	52154

Tension Eccentricity Calculations (continued)

Result	Reference	Comments
3.2 Bond Strength		Bond strength calculations in tension are given in Part 3.2 of the PROFIS Anchor design report. The illustration to the left has been edited from the design report to show parameters relevant to eccentricity when bond strength is being calculated in tension.
$N_{ag} = \left(\frac{A_{Na}}{A_{Na0}}\right) \psi_{ec1,Na}\, \psi_{ec2,Na}\, \psi_{ed,Na}\, \psi_{cp,Na}\, N_{ba}$	ACI 318-11 Eq. (D-19)	Tension eccentricity in the x direction is designated $\mathbf{e_{c1,N}}$. The corresponding eccentricity modification factor is designated $\boldsymbol{\psi_{ec1,Na}}$.
$c_{Na} = 10 d_a \sqrt{\frac{\tau_{uncr}}{1100}}$	ACI 318-11 Eq. (D-21)	Tension eccentricity in the y direction is designated $\mathbf{e_{c2,N}}$. The corresponding eccentricity modification factor is designated $\boldsymbol{\psi_{ec2,Na}}$.
$\psi_{ec,Na} = \left(\frac{1}{1 + \frac{e'_N}{c_{Na}}}\right) \leq 1.0$	ACI 318-11 Eq. (D-23)	If eccentricity exists in both the x and y directions, the values calculated for $\boldsymbol{\psi_{ec1,Na}}$ and $\boldsymbol{\psi_{ec,2,Na}}$ will be multiplied together, and the resulting value would be used in Equation (D-19) to calculate the nominal bond strength in tension. This design example only has eccentricity with respect to the x direction. Therefore, only values for $\mathbf{e_{c1,N}}$ and $\boldsymbol{\psi_{ec1,Na}}$ are calculated in Part 3.2 of the design report, and the value for $\boldsymbol{\psi_{ec1,Na}}$ is used to calculate the nominal bond strength per Equation (D-19). Note that the value for the resultant tension force (= 52,154 lb) corresponds to the value shown for the parameter N_{ua}, since the resultant tension force equals the total factored tension force acting on the anchors in the group.

Variables

$\tau_{k,c,uncr}$ [psi]	d_a [in.]	h_{ef} [in.]	$c_{a,min}$ [in.]	$\tau_{k,c}$ [psi]
1880	1.000	15.000	∞	904

$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	c_{ac} [in.]	κ_{bond}	λ_a
2.937	0.000	25.427	1.00	1.000

Calculations

c_{Na} [in.]	A_{Na} [in.^{2}]	A_{Na0} [in.^{2}]	$\psi_{ed,Na}$
13.013	1293.85	677.34	1.000

$\psi_{ec1,Na}$	$\psi_{ec2,Na}$	$\psi_{cp,Na}$	N_{ba} [lb]
0.816	1.000	1.000	42614

Results

N_{ag} [lb]	ϕ_{bond}	ϕN_{ag} [lb]	N_{ua} [lb]
66411	0.650	43167	52154