ANCHOR BOLT DESIGN **Combined Tension and Shear**

Result Summary

Anchor Rod Embedment, Spacing and Edge Distance		OK
Min Rquired Anchor Reinft. Development Length	ratio=0.87	OK
Overall	ratio=**0.75**	OK
Seismic Design	Tension=	OK
	Shear=	OK

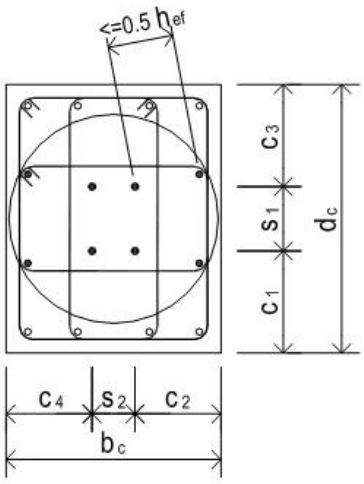
Design Code Reference

Anchor bolt design based on	**Code Abbreviation**
ACI 318-11 Building Code Requirements for Structural Concrete and Commentary Appendix D	ACI 318-11
PIP STE05121 Anchor Bolt Design Guide-2006	PIP STE05121
AISC Design Guide 1: Base Plate and Anchor Rod Design 2nd Ed	AISC Design Guide 1

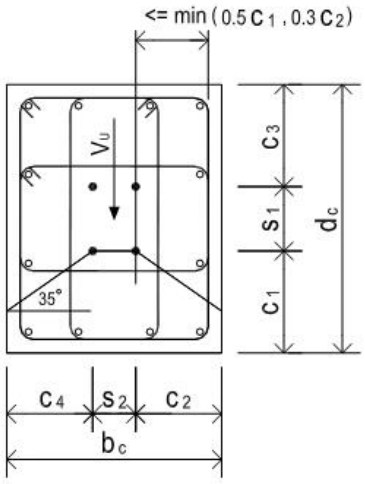
Code Reference

Anchor Bolt Data

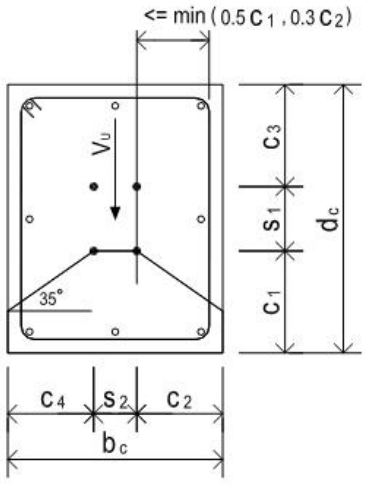
Factored tensile force	N_u= 20.00	[kips]			
Factored shear force	V_u= 25.00	[kips]			
Concrete strength	f'_c= 5.2	[ksi]			
Anchor bolt material	= F1554 Grade 36				
Anchor tensile strength	f_{uta}=58.0	[ksi]			ACI 318-11
	Anchor is ductile steel element				D.1
Anchor bolt diameter	d_a = 1	[in]			
Anchor bolt has sleeve	= No				PIP STE05121
			Min Required		
Anchor bolt embedment depth	h_{ef}= 14.00	[in]	12.00	OK	Page A -1 Table 1
Pedestal height	h_a= 18.00	[in]	17.00	OK	
Pedestal width	b_c= 16.00	[in]			
Pedestal depth	d_c= 16.00	[in]			



Ver. Reinft For Tension



Hor. Ties For Shear - 4 Legs



Hor. Ties For Shear - 2 Legs

PIP STE05121

Anchor bolt edge distance c_1	c_1= 5.00 [in]	4.50	OK	Page A -1 Table 1
Anchor bolt edge distance c_2	c_2= 5.00 [in]	4.50	OK	
Anchor bolt edge distance c_3	c_3= 5.00 [in]	4.50	OK	
Anchor bolt edge distance c_4	c_4= 5.00 [in]	4.50	OK	
Outermost bolt line spacing s_1	s_1= 6.00 [in]	4.00	OK	Page A -1 Table 1
Outermost bolt line spacing s_2	s_2= 6.00 [in]	4.00	OK	

ACI 318-11

To be considered effective for resisting anchor tension, vertical reinforcing bars shall be located within $0.5h_{ef}$ from the outmost anchor's centerline — RD.5.2.9

Avg ver. bar center to anchor rod center distance d_{ar}= 4.00 [in]

No of ver. rebar that are effective for resisting anchor tension n_v= 4.0

Ver. rebar size No. 8 =1.000 [in] dia single rebar area A_s=0.790 [in^2]

Ver. rebar top anchorage option: 180 Degree Hook or Hairpin

ACI 318-11

To be considered effective for resisting anchor shear, hor. reinft shall be located within min($0.5c_1$, $0.3c_2$) from the outmost anchor's centerline — RD.6.2.9

min ($0.5c_1$, $0.3c_2$)=1.50 [in]

No of tie leg that are effective to resist anchor shear n_{leg}= 2.0

No of tie layer that are effective to resist anchor shear n_{lay}= 2

Hor. tie rebar size No. 4 =0.500 [in] dia single rebar area A_s=0.200 [in^2]

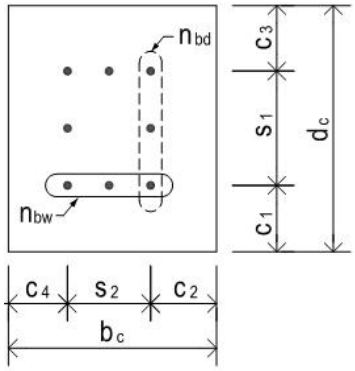
For anchor reinft shear breakout strength calc: 100% hor. tie bars develop full yield strength

Rebar yield strength - ver. rebar $f_{y\text{-}v}$= 60.0 [ksi]

Rebar yield strength - hor. rebar $f_{y\text{-}h}$= 60.0 [ksi]

No of anchor bolt carrying tension n_t= 4.0

No of anchor bolt carrying shear n_s= 4.0



Bolt No Input for Side Face Blowout Check

For side-face blowout check use

No of anchor bolt along width edge n_{bw}= 2.0

No of anchor bolt along depth edge n_{bd}= 2.0

Anchor bolt head type: Heavy Hex

Anchor effective cross section area A_{se}=0.606 [in^2]

Anchor bolt head bearing area A_{brg}=1.501 [in^2]

Anchor bolt 1/8" (3mm) corrosion allowance =	No		ACI 318-11
Provide built-up grout pad ?	= Yes		D.6.1.3
Seismic design category SDC >= C	= Yes		D.3.3.1
Anchor bolt load E <= 0.2U	Tensile= No	Shear= No	D.3.3.4.1 & D.3.3.5.1
Anchor bolt satisfies opion	Tensile= Option D	Shear= Option C	D.3.3.4.3 & D.3.3.5.3

Strength reduction factors			ACI 318-11
Anchor reinforcement	ϕ_s=0.75		D.5.2.9 & D.6.2.9
Anchor rod - ductile steel	$\phi_{t,s}$=0.75	$\phi_{v,s}$=0.65	D.4.3 (a)
Concrete - condition A	$\phi_{t,c}$=0.75	$\phi_{v,c}$=0.75	D.4.3 (c)

CONCLUSION

Anchor Rod Embedment, Spacing and Edge Distance		OK	ACI 318-11
Min Rquired Anchor Reinft. Development Length	ratio=0.87	OK	12.5.1
Overall	ratio=**0.75**	OK	
Tension			
Anchor Rod Tensile Resistance	ratio=0.19	OK	

Anchor Reinft Tensile Breakout Resistance	ratio=0.18	OK	
Anchor Pullout Resistance	ratio=0.15	OK	
Side Blowout Resistance	ratio=0.21	OK	
Shear			
Anchor Rod Shear Resistance	ratio=0.57	OK	
Anchor Reinft Shear Breakout Resistance			
Strut Bearing Strength	ratio=0.45	OK	
Tie Reinforcement	ratio=0.69	OK	
Conc. Pryout Not Govern When h_{ef} >= $12d_a$		OK	
Tension Shear Interaction			
Tension Shear Interaction	ratio=0.75	OK	

Seismic Design ACI 318-11

Tension	Applicable	OK	D.3.3.4

Seismic SDC>=C and E>0.2U , Option D is selected to satisfy additional seismic requirements as per D.3.3.4.3

Shear	Applicable	OK	D.3.3.5

Seismic SDC>=C and E>0.2U , Option C is selected to satisfy additional seismic requirements as per D.3.3.5.3

Assumptions ACI 318-11

1. Concrete is cracked	D.5.2.6, D5.3.6, D.6.2.7
2. Condition A - supplementary reinforcement is provided	D.4.3 (c)
3. Load combinations shall be per ACI 318-11 9.2	D.4.3
4. Anchor reinft strength is used to replace concrete tension / shear breakout strength as per ACI 318-11 Appendix D clause D.5.2.9 and D.6.2.9	D.5.2.9 & D.6.2.9
5. For tie reinft, only the top most 2 or 3 layers of ties (2" from TOC and 2x3" after) are effective	
6. Strut-and-Tie model is used to anlyze the shear transfer and to design the required tie reinft	
7. Anchor reinft used in structures with SDC>=C shall meet requirements specified in D.3.3.7	D.3.3.7
8. Anchor bolt washer shall be tack welded to base plate for all anchor bolts to transfer shear	AISC Design Guide 1 Section 3.5.3

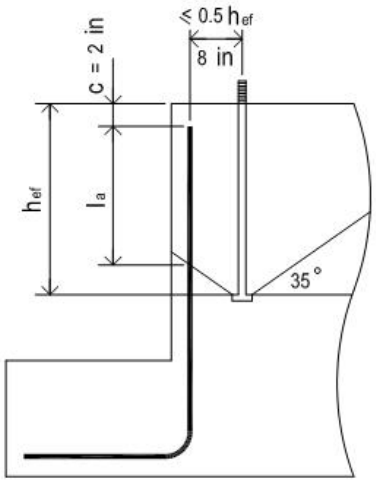
CACULATION

Anchor Rod Tensile Resistance ACI 318-11

$\phi_{t,s} N_{sa} = \phi_{t,s} n_t A_{se} f_{uta}$	=105.44 [kips]		D.5.1.2 (D-2)
ratio=0.19	>N_u	OK	

Anchor Reinft Tensile Breakout Resistance ACI 318-11

Min required full yield tension l_{dh}	l_{dh}=180 degree hook case	=11.65	[in]	12.5.2, 12.5.3(a)
Actual development lenngth	$l_a=h_{ef}$ - c (2 in) - d_{ar} x tan35	=9.20	[in]	
		>8.00	OK	12.5.1



ACI 318-11

Anchor reinft breakout resistance	$\phi_s N_n=\phi_s$ x f_{y-v} x n_v x A_s x (l_a / l_d , if l_a < l_d)	=112.30	[kips]	D.3.3.4.5, D.5.2.9, 12.2.5
	ratio=0.18	>N_u	OK	

Anchor Pullout Resistance

ACI 318-11

Single bolt pullout resistance	$N_p=8\ A_{brg}\ f_c'$	=62.44	[kips]	D.5.3.4 (D-14)
	$\phi_{t,c}\ N_{pn}=\phi_{t,c}\ n_t\ \Psi_{c,p}\ N_p$	=174.84	[kips]	D.5.3.1 (D-13)
	$\Psi_{c,p}$=1 for cracked conc			D.5.3.6
	$\phi_{t,c}$=0.70 pullout strength is always Condition B			D.4.3(c)
Seismic design strength reduction	=x 0.75 applicable	=131.13	[kips]	D.3.3.4.4
	ratio=0.15	>N_u	OK	

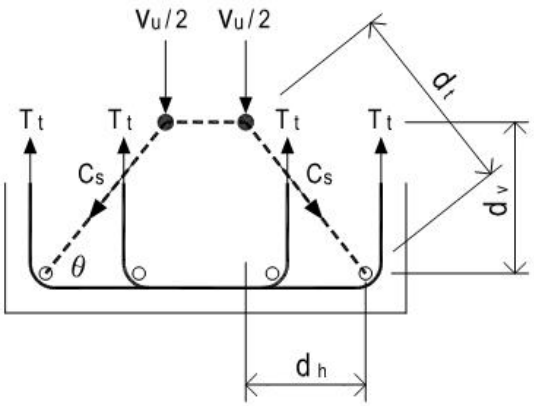
Side Blowout Resistance

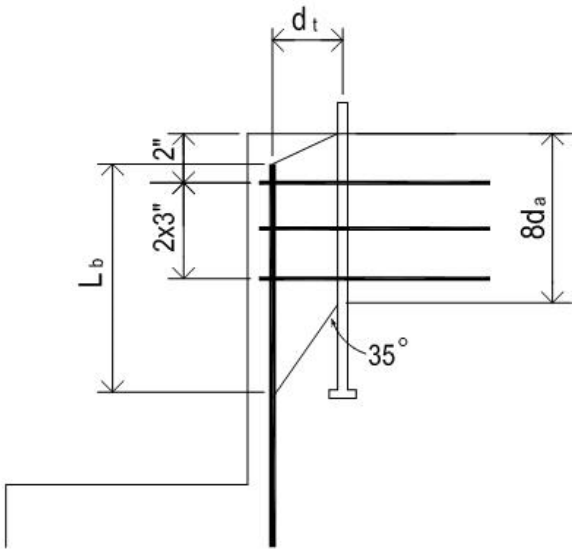
Failure Along Pedestal Width Edge — ACI 318-11

Tensile load carried by anchors close to edge which may cause side-face blowout

along pedestal width edge	$N_{buw}=N_u$ x n_{bw} / n_t	=10.00	[kips]	RD.5.4.2
	c=min (c_1, c_3)	=5.00	[in]	
	s=s_2	=6.00	[in]	
Check if side blowout applicable	h_{ef}=14.00 [in]			
	>2.5c side bowout is applicable			D.5.4.1
Single anchor SB resistance	$\phi_{t,c}\ N_{sb}=\phi_{t,c}\left(160\ c\sqrt{A_{brg}}\right)\lambda\sqrt{f'_c}$	=53.01	[kips]	D.5.4.1 (D-16)
Multiple anchors side blowout work as group	$\phi_{tc}N_{sbgw}$=(1+s/ 6c) x $\phi_{t,c}\ N_{sb}$	=63.61	[kips]	D.5.4.2 (D-17)
Seismic design strength reduction	=x 0.75 applicable	=47.71	[kips]	D.3.3.4.4
	ratio=0.21	>N_{buw}	OK	

Failure Along Pedestal Depth Edge					ACI 318-11
Tensile load carried by anchors close to edge which may cause side-face blowout					
along pedestal depth edge	$N_{bud}=N_u \times n_{bd} / n_t$		=10.00	[kips]	RD.5.4.2
	$c=\min (c_2, c_4)$		=5.00	[in]	
	$s=s_1$		=6.00	[in]	
Check if side blowout applicable	h_{ef}=14.00	[in]			
	>2.5c	side bowout is applicable			D.5.4.1
Single anchor SB resistance	$\phi_{t,c} N_{sb}= \phi_{t,c} \left(160\, c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$		=53.01	[kips]	D.5.4.1 (D-16)
Multiple anchors side blowout					
work as group	$\phi_{tc}N_{sbgd}=(1+s/ 6c) \times \phi_{t,c} N_{sb}$		=63.61	[kips]	D.5.4.2 (D-17)
Seismic design strength reduction	=x 0.75 applicable		=47.71	[kips]	D.3.3.4.4
	ratio=0.21		>N_{bud}	OK	
Group side blowout resistance	$\phi_{tc} N_{sbg}= \phi_{t,c} \min\left(\frac{N_{sbg,w}}{n_{bw}} n_t , \frac{N_{sbg,d}}{n_{bd}} n_t \right)$		=95.41	[kips]	
Govern Tensile Resistance	$N_r=\min (\phi N_{sa}, \phi N_n, \phi N_{pn}, \phi N_{sbg})$		**=95.41**	[kips]	
Anchor Rod Shear Resistance					ACI 318-11
	$\phi_{v,s}V_{sa}=\phi_{v,s} n_s 0.6 A_{se} f_{uta}$		=54.83	[kips]	D.6.1.2 (b) (D-29)
Reduction due to built-up grout pad	=x 0.8 , applicable		=43.86	[kips]	D.6.1.3
	ratio=0.57		>V_u	OK	
Anchor Reinft Shear Breakout Resistance					ACI 318-11
Strut-and-Tie model is used to anlyze the shear transfer and to design the required tie reinft					
STM strength reduction factor	ϕ_{st}=0.75				9.3.2.6





Strut-and-Tie model geometry	d_v=2.250 [in]	d_h=2.250	[in]	
	θ=45	d_t=3.182	[in]	
Strut compression force	C_s=0.5 V_u / sinθ	=17.68	[kips]	

Strut Bearing Strength

ACI 318-11

Strut compressive strength	f_{ce}=0.85 f'_c	=4.4	[ksi]	A.3.2 (A-3)

* Bearing of anchor bolt

Anchor bearing length	l_e=min(8d_a , h_{ef})	=8.00	[in]	D.6.2.2
Anchor bearing area	A_{brg} =l_e x d_a	=8.00	[in^2]	
Anchor bearing resistance	C_r=n_s x ϕ_{st} x f_{ce} x A_{brg}	=106.08	[kips]	
		>V_u	OK	

* Bearing of ver reinft bar

Ver bar bearing area	A_{brg} =(l_e +1.5 x d_t - d_a/2 -d_b/2) x d_b	=11.77	[in^2]	
Ver bar bearing resistance	C_r=ϕ_{st} x f_{ce} x A_{brg}	=39.03	[kips]	
	ratio=0.45	>C_s	OK	

Tie Reinforcement

* For tie reinft, only the top most 2 or 3 layers of ties (2" from TOC and 2x3" after) are effective

* For enclosed tie, at hook location the tie cannot develop full yield strength f_y . Use the pullout resistance in tension of a single hooked bolt as per ACI 318-11 Eq. (D-15) as the max force can be developed at hook T_h

* Assume 100% of hor. tie bars can develop full yield strength

Total number of hor tie bar	n=n_{leg} (leg) x n_{lay} (layer)	=4	

ACI 318-11

Pull out resistance at hook	$T_h=\phi_{t,c}\ 0.9\ f_c'\ e_h\ d_a$	=3.95	[kips]	D.5.3.5 (D-15)
	$e_h=4.5\ d_b$	=2.250	[in]	
Single tie bar tension resistance	$T_r=\phi_s \times f_{y\text{-}h} \times A_s$	=9.00	[kips]	
Total tie bar tension resistance	$\phi_s V_n=1.0 \times n \times T_r$	=36.00	[kips]	D.3.3.5.4 & D.6.2.9
	ratio=0.69	>V_u	OK	

Conc. Pryout Shear Resistance

The pryout failure is only critical for short and stiff anchors. It is reasonable to assume that for general cast-in place headed anchors with $h_{ef} >= 12d_a$, the pryout failure will not govern

	$12d_a$=12.00 [in]	h_{ef}=14.00	[in]	
		>$12d_a$	OK	
Govern Shear Resistance	$\mathbf{V_r}$=min ($\phi_{v,s}V_{sa}$, $\phi_s V_n$)	=**36.00**	[kips]	

Tension Shear Interaction ACI 318-11

Check if $N_u >0.2\phi\ N_n$ and $V_u >0.2\phi\ V_n$	=Yes			D.7.1 & D.7.2
	$N_u / \phi\ N_n + V_u / \phi\ V_n$	=0.90		D.7.3 (D-42)
	ratio=0.75	<1.2	OK	

Seismic Design

Tension	Applicable		OK

Option D is selected. ACI 318-11

User has to ensure that the tensile load N_u user input above includes the seismic load E, with E increased by multiplying overstrength factor Ω_o D.3.3.4.3(d)

Seismic SDC>=C and E>0.2U , Option D is selected to satisfy additional seismic requirements as per D.3.3.4.3

Shear	Applicable		OK

Option C is selected. ACI 318-11

User has to ensure that the shear load V_u user input above includes the seismic load E, with E increased by multiplying overstrength factor Ω_o D.3.3.5.3(c)

Seismic SDC>=C and E>0.2U , Option C is selected to satisfy additional seismic requirements as per D.3.3.5.3