CivilBay Concrete Anchorage Design v1.5.0

User Manual

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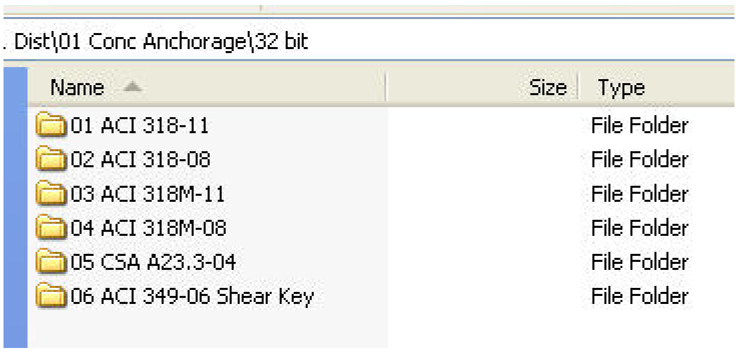
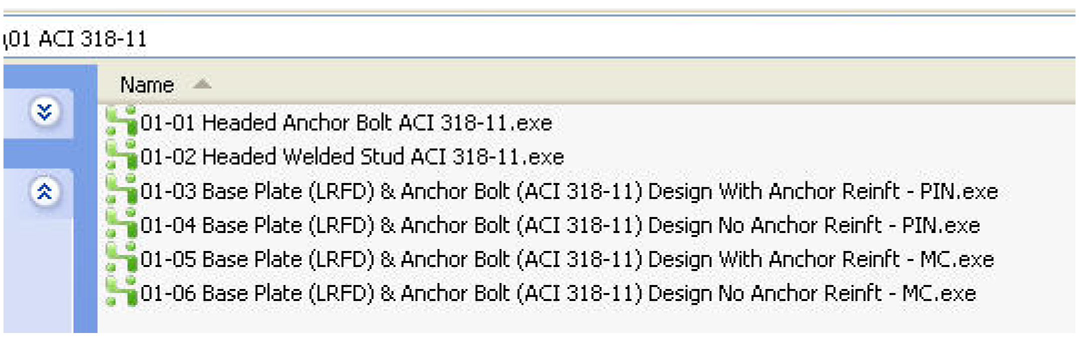
2.0 QUICK START

2.1 Software Installation

- After downloading the ZIP file the user can unzip the file and save it to user's computer.
- The extracted files are in 6 folders for the version of different codes as shown in the folder name. Each folder contains compiled Excel files in EXE format.

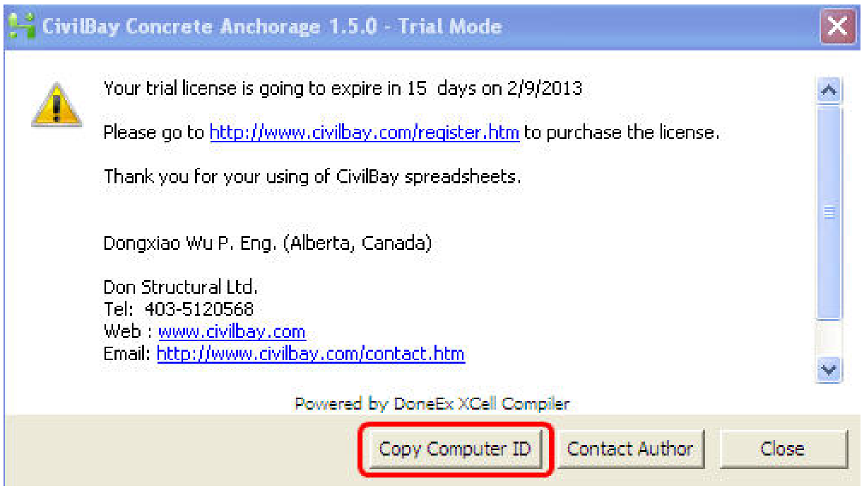


- User can go to the folder and double click on the EXE file and open it just as normal Excel file.



- The 15-day trial will start the same date when user tries any of these compiled Excel files.
- During trial period the software provides full functions except that the user can not save the file, but the user can print the file to printer and get a hard copy of the calculation for verification.
- The trial period will expire after 15 days. Any time during or after trial period the user can go to www.civilbay.com to purchase a license.

- After placing the order, the user shall send his/her Computer ID to author for licensing. The user can get his/her Computer ID by clicking on Copy Computer ID button on the pop-up dialog box.

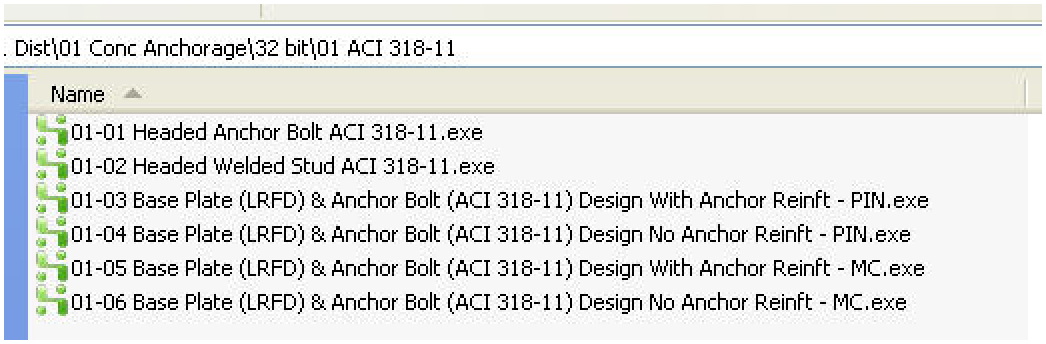


2.2 Software Licensing

- After receiving user's Computer ID, the author will send the user a license key to unlock the trial version.
- The user shall save the license key file at the same folder where the compiled Excel files locate.
- The user can copy, save and rename any of the compiled Excel files and use them same as the normal Excel files.
- All the compiled Excel files will fully function as long as they can find the license key in the same folder.
- The license key is created using the Computer ID sent by the user and it only works on that computer where the Computer ID is retrieved from.

2.3 Concrete Anchorage Design v1.5.0 Modules

- **01 ACI 318-11 Folder**



01-01 Headed Anchor Bolt ACI 318-11.exe

Headed anchor bolt design using ACI 318-11 code

This workbook contains 7 worksheets

Program Description Update Logo

This is a spreadsheet written to design Headed Anchor Bolt anchorage to concrete using ACI 318-11 code.

This workbook contains 7 worksheets, described as followings:

1. Doc	This worksheet.
2. Anchor Bolt TS Reinft	Group anchor bolt under tension + shear using anchor reinft to resist breakout
3. Anchor Bolt TSM Reinft	Group anchor bolt under tension + shear + moment using anchor reinft to resist breakout
4. Anchor Bolt TS Conc	Group anchor bolt under tension + shear using concrete to resist breakout
5. Anchor Bolt TSM Conc	Group anchor bolt under tension + shear + moment using concrete to resist breakout
6. Anchor Bolt Single Reinft	Single anchor bolt under tension + shear using anchor reinft to resist breakout
7. Anchor Bolt Single Conc	Single anchor bolt under tension + shear using concrete to resist breakout

01-02 Headed Welded Stud ACI 318-11.exe

Headed welded stud design using ACI 318-11 code

This workbook contains 7 worksheets

Program Description

Update Logo

This is a spreadsheet written to design Headed Anchor Stud anchorage to concrete using ACI 318-11 code.

This workbook contains 7 worksheets, described as followings:

1. Doc	This worksheet.
2. Anchor Stud TS Reinft	Group anchor stud under tension + shear using anchor reinft to resist breakout
3. Anchor Stud TSM Reinft	Group anchor stud under tension + shear + moment using anchor reinft to resist breakout
4. Anchor Stud TS Conc	Group anchor stud under tension + shear using concrete to resist breakout
5. Anchor Stud TSM Conc	Group anchor stud under tension + shear + moment using concrete to resist breakout
6. Anchor Stud Single Reinft	Single anchor stud under tension + shear using anchor reinft to resist breakout
7. Anchor Stud Single Conc	Single anchor stud under tension + shear using concrete to resist breakout

01-03 Base Plate (LRFD) & Anchor Bolt (ACI 318-11) Design With Anchor Reinft - PIN.exe

One input to design both base plate and anchor bolt using ACI 318-11 code

In anchor bolt design Anchor Reinforcement is used to replace concrete tension/shear breakout strength.

In base plate design the column base is assumed to be PIN connection and doesn't have moment.

01-04 Base Plate (LRFD) & Anchor Bolt (ACI 318-11) Design No Anchor Reinft - PIN.exe

One input to design both base plate and anchor bolt using ACI 318-11 code

In anchor bolt design NO Anchor Reinforcement is used.

In base plate design the column base is assumed to be PIN connection and doesn't have moment.

01-05 Base Plate (LRFD) & Anchor Bolt (ACI 318-11) Design With Anchor Reinft - MC.exe

One input to design both base plate and anchor bolt using ACI 318-11 code

In anchor bolt design Anchor Reinforcement is used to replace concrete tension/shear breakout strength.

In base plate design the column base is assumed to be Moment connection and carries moment.

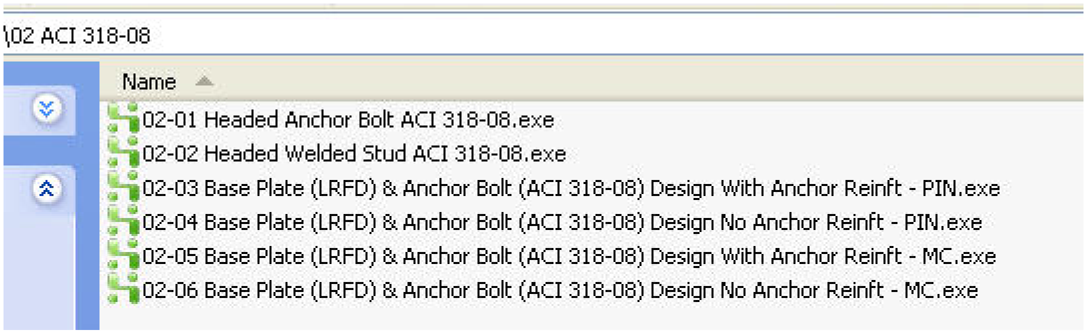
01-06 Base Plate (LRFD) & Anchor Bolt (ACI 318-11) Design No Anchor Reinft - MC.exe

One input to design both base plate and anchor bolt using ACI 318-11 code

In anchor bolt design NO Anchor Reinforcement is used.

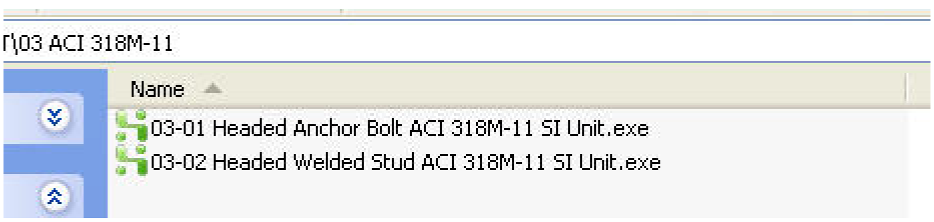
In base plate design the column base is assumed to be Moment connection and carries moment.

- **02 ACI 318-08 Folder**



Same as 01 ACI 318-11 folder but in ACI 318-08 code

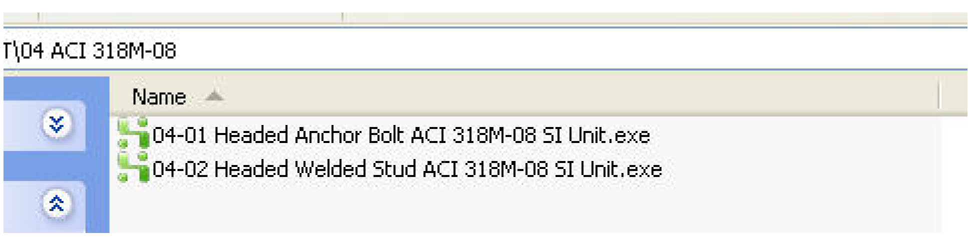
- **03 ACI 318M-11 Folder**



Same as 01 ACI 318-11 folder but in ACI 318M-11 code.

It only contains anchor bolt design spreadsheets and doesn't contain base plate design spreadsheets.

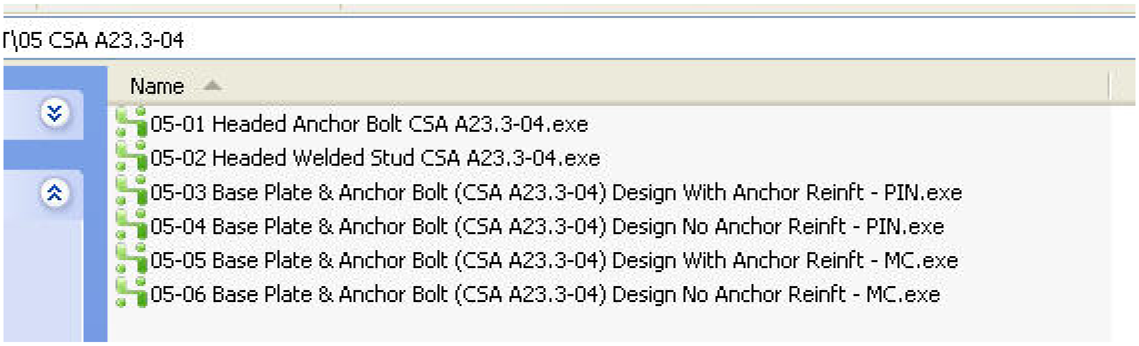
- **04 ACI 318M-08 Folder**



Same as 01 ACI 318-11 folder but in ACI 318M-08 code.

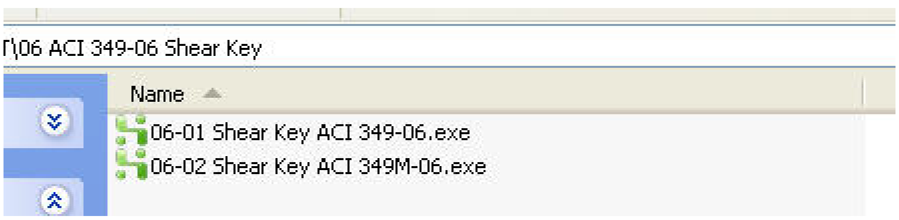
It only contains anchor bolt design spreadsheets and doesn't contain base plate design spreadsheets.

- **05 CSA A23.3-04 Folder**



Same as 01 ACI 318-11 folder but in CSA A23.3-04 (R2010) code.

- **06 ACI 349-06 Shear Key Folder**



06-01 Shear Key ACI 349-06.exe

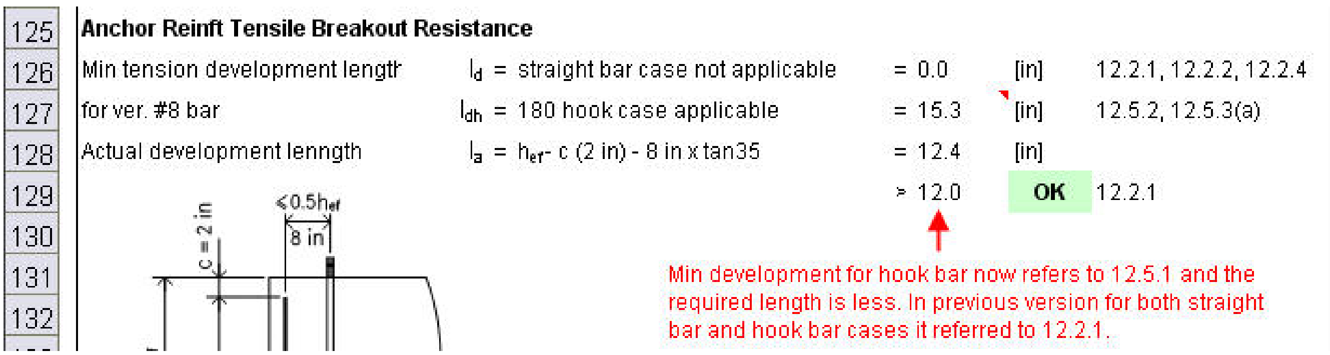
Shear lug design using ACI 349-06 code

06-02 Shear Key ACI 349M-06.exe

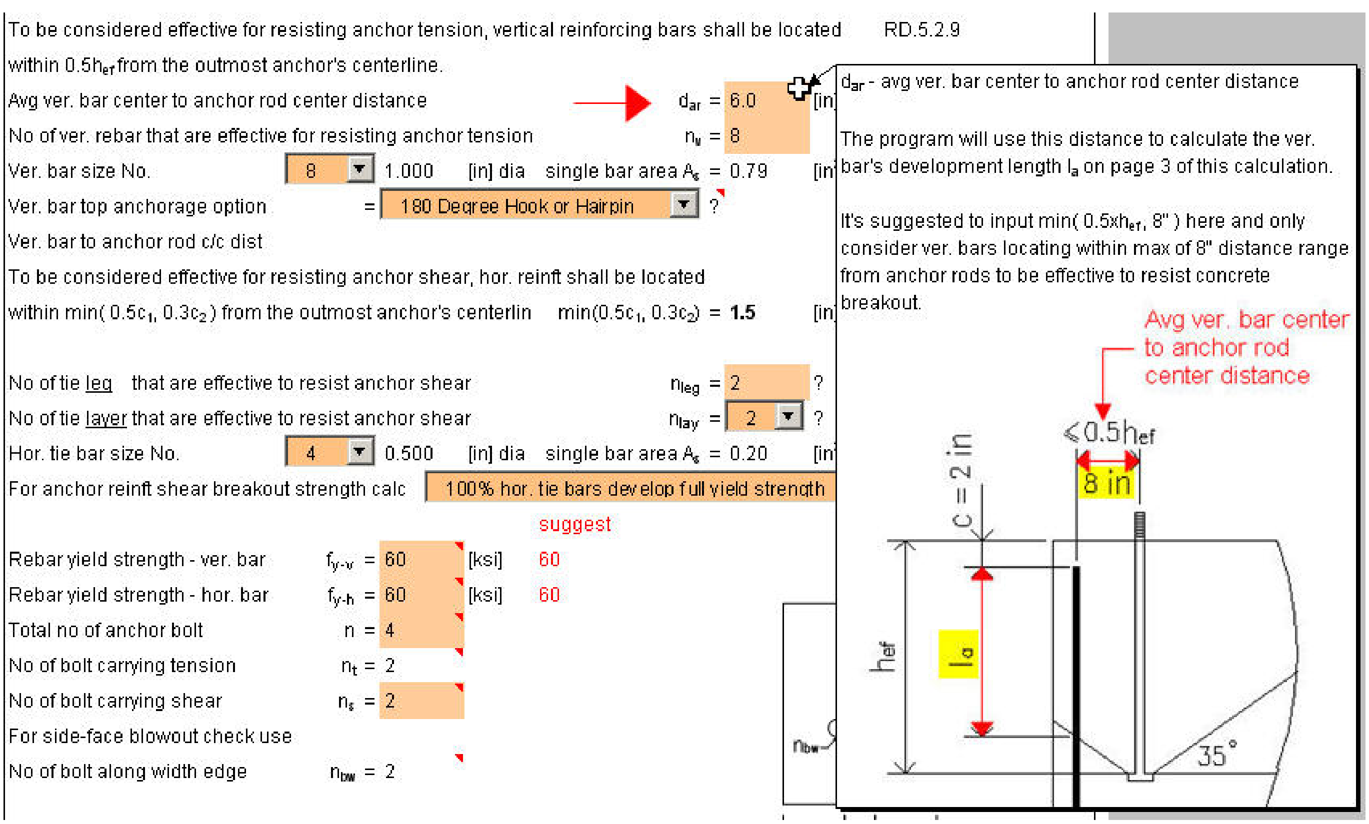
Shear lug design using ACI 349M-06 code (metric unit)

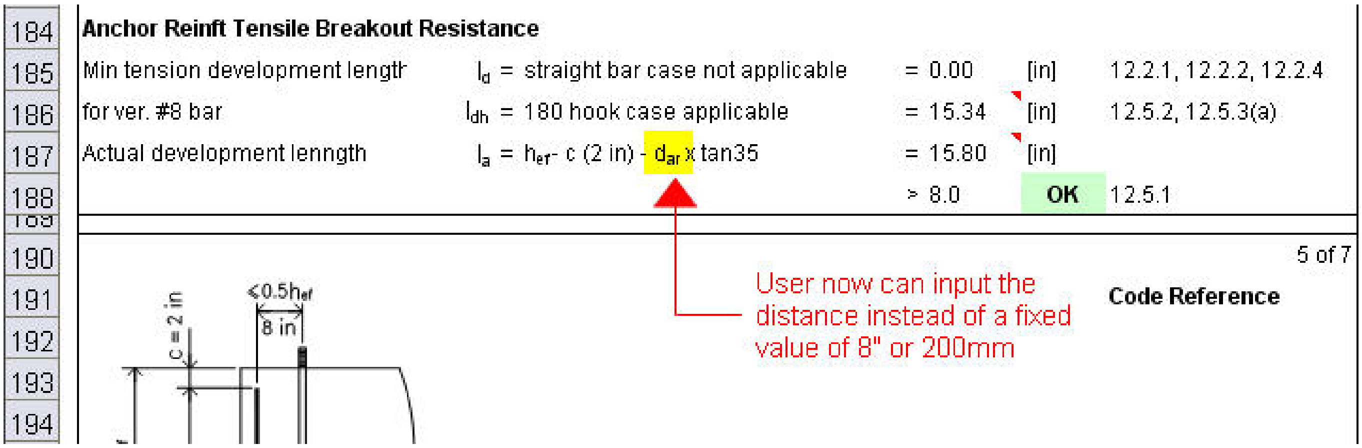
3.0 WHAT'S NEW IN v1.5.0

- ACI 318-11 and ACI 318M-11 code version are added
- Seismic design part is completely re-written to allow users to select specific options to meet seismic design requirements.
- Min development for hook bar now refers to 12.5.1 and the required length is less. In previous version for both straight bar and hook bar cases it all referred to 12.2.1.



- For case using vertical rebar to resist concrete tensile breakout, user now can input the average distance between vertical rebar and anchor rod. In previous version this distance is fixed at 8" or 200mm. Many users complain they can get a closer distance than 8" or 200mm and cannot take advantage of that. Now users have the option to input the distance instead of a fixed value.





Anchor Reinft Tensile Breakout Resistance

Min tension development length	l_d = straight bar case not applicable	= 0.00	[in]	12.2.1, 12.2.2, 12.2.4
for ver. #8 bar	l_{dh} = 180 hook case applicable	= 15.34	[in]	12.5.2, 12.5.3(a)
Actual development lenngth	l_a = h_{ef} - c (2 in) - d_{ar} x tan35	= 15.80	[in]	
		> 8.0	OK	12.5.1

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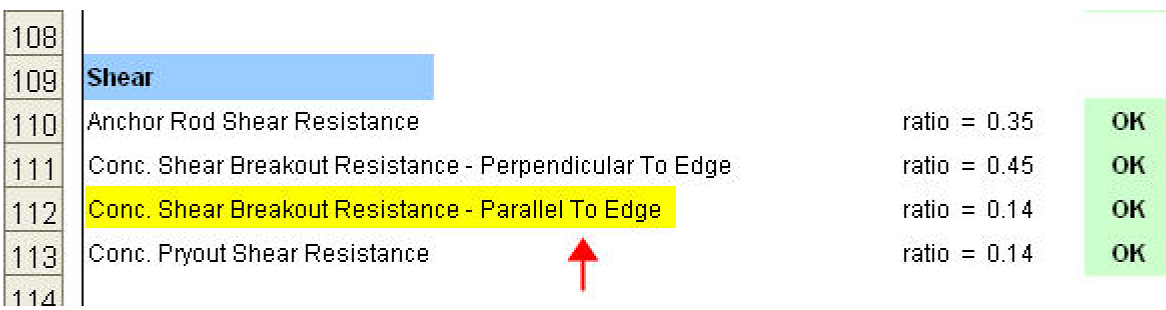
Code Reference

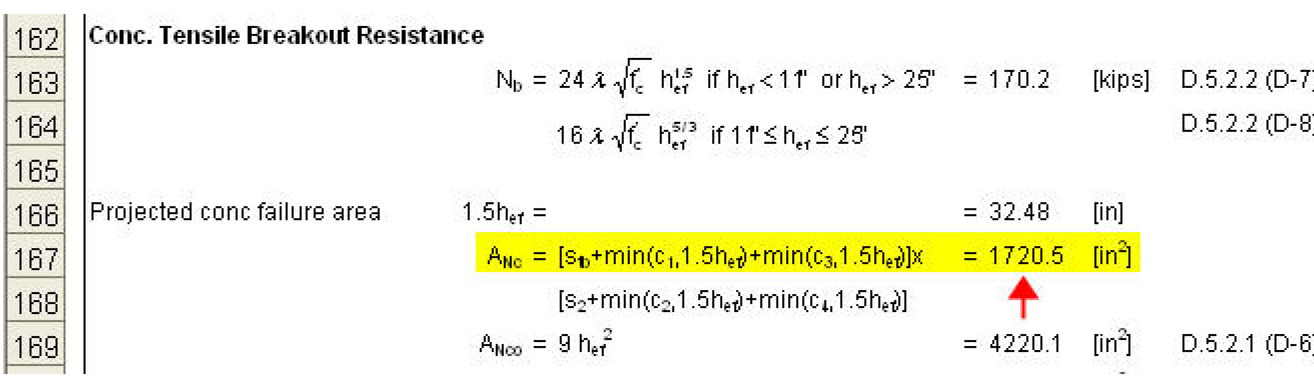
- For concrete shear breakout resistance check, in previous version the program only checked perpendicular to edge case. In the new version check on parallel to edge case as per ACI 318-08 D.6.2.1 (c), or A23.3-04 (R2010) D.7.2.1 (c) is added. User can refer to page 7 and 8 of calculation for the new added check.



Shear		
Anchor Rod Shear Resistance	ratio = 0.35	OK
Conc. Shear Breakout Resistance - Perpendicular To Edge	ratio = 0.45	OK
Conc. Shear Breakout Resistance - Parallel To Edge	ratio = 0.14	OK
Conc. Pryout Shear Resistance	ratio = 0.14	OK

- Bug fixed

  In concrete tensile breakout resistance check, the A_{NC} calculation in previous version didn't take advantage of enlarged edge distance when $s_{tb} < s_1$. In the new version, when only part of anchor bolts mobilize tensile force under moment, the A_{NC} calculation will re-calculate the bolt edge distance starting from the anchor bolts mobilizing tensile force to calculate A_{NC}.



Conc. Tensile Breakout Resistance

$N_b = 24\,\lambda\sqrt{f'_c}\ h_{ef}^{1.5}$ if $h_{ef} < 11"$ or $h_{ef} > 25"$ = 170.2 [kips] D.5.2.2 (D-7)

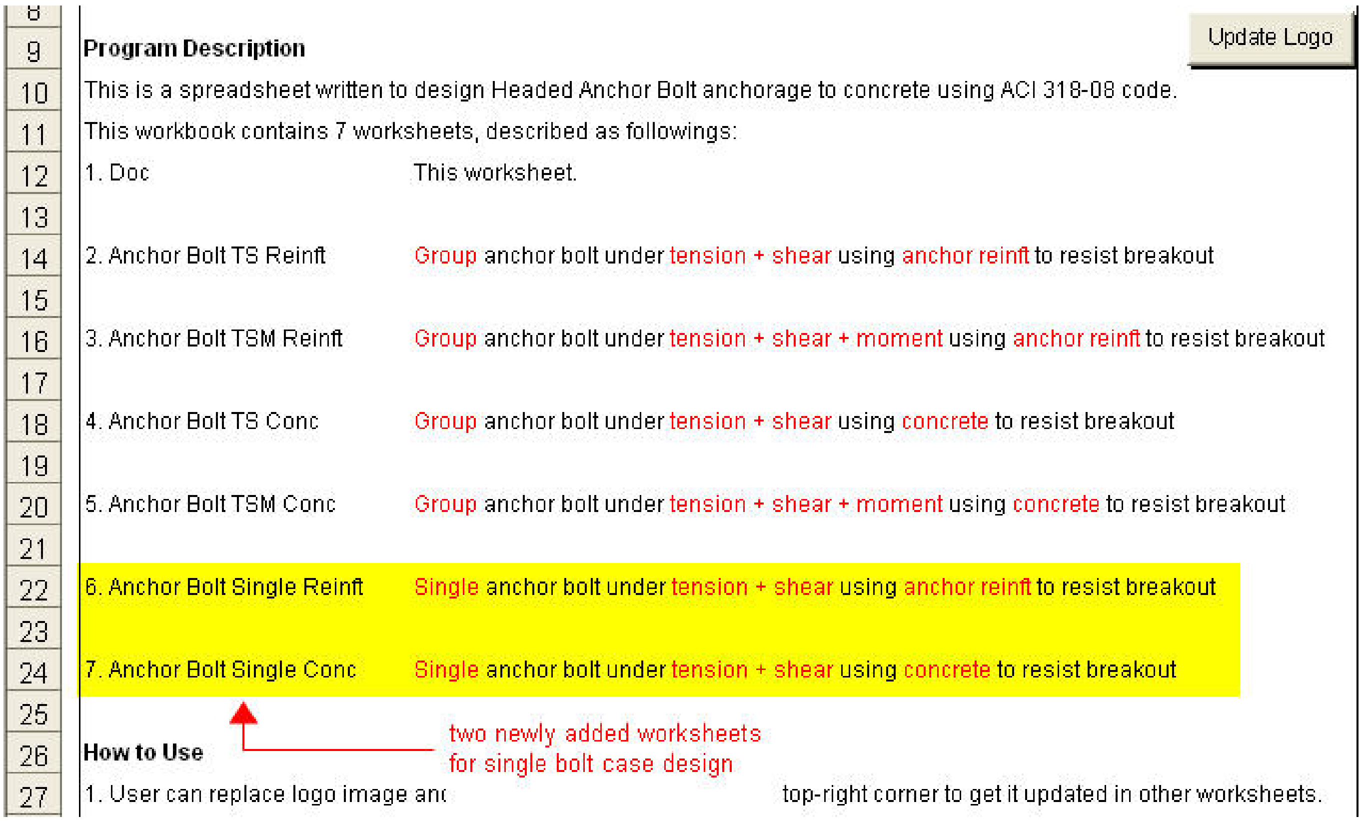
$16\,\lambda\sqrt{f'_c}\ h_{ef}^{5/3}$ if $11" \le h_{ef} \le 25"$ D.5.2.2 (D-8)

Projected conc failure area $1.5h_{ef}$ = = 32.48 [in]

$A_{Nc} = [s_{tb}+\min(c_1,1.5h_{ef})+\min(c_3,1.5h_{ef})]\times[s_2+\min(c_2,1.5h_{ef})+\min(c_4,1.5h_{ef})]$ = 1720.5 [in²]

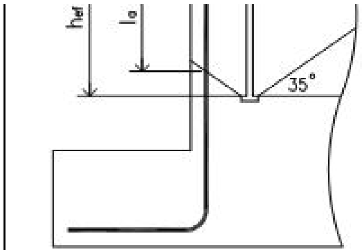
$A_{Nco} = 9\ h_{ef}^2$ = 4220.1 [in²] D.5.2.1 (D-6)

- Add two worksheets specifically for single anchor bolt/stud design with anchor reinforcement and without anchor reinforcement



- For ACI 318-08, ACI 318M-08 and CSA A23.3-04 version worksheets, when using anchor reinforcement to resist concrete tensile and shear breakout, the seismic 0.75 reduction factor has been taken out from vertical and horizontal anchor reinforcement breakout resistance strength calculation

Seismic 0.75 reduction factor is removed from vertical anchor reinforcement breakout resistance strength calculation



139						*ACI 318-08*
140		$N_{rb} = \phi_s \times f_{y\text{-}v} \times n_v \times A_s \times (l_a / l_d \text{, if } l_a < l_d)$	= 179.8	[kips]		12.2.5
141	Seismic design strength reduction	= x 0.75 applicable	= 134.9	[kips]		D.3.3.3
142		ratio = 0.15	> N_f		**OK**	
144						
145		0.75 seismic reduction for anchor reinforcement is taken out				**Code Referer**
146	**Anchor Pullout Resistance**					*ACI 318-08*
147	Single bolt pullout resistance	$N_p = 8\, A_{brg}\, f_c'$	= 37.2	[kips]		D.5.3.4 (D-15

Seismic 0.75 reduction factor is removed from horizontal anchor reinforcement breakout resistance strength calculation

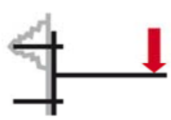
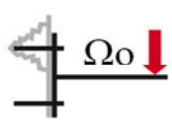
247						
248	Single tie bar tension resistanc	$T_r = \phi_s \times f_{y\text{-}t} \times A_s$	= 9.0	[kips]		
249						
250	Total tie bar tension resistance	V_{rb} = 1.0 x n x Tr	= 72.0	[kips]		
251	Seismic design strength reduction	= x 0.75 applicable	= 54.0	[kips]		D.3.3.3
252		ratio = 0.[illegible]6	> V_f		**OK**	
253		0.75 seismic reduction for anchor reinforcement is taken out				
254	**Conc. Pryout Shear Resistance**					
255	The pryout failure is only critical for short and stiff anchors. It is reasonable to assume that for general					
256	cast-in place headed anchors with h_{ef} > = 12d_a, the pryout failure will not govern					

4.0 SEISMIC DESIGN REQUIREMENTS

4.1 ACI 318-11 and ACI 318M-11 Code

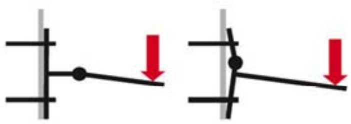
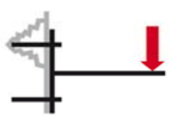
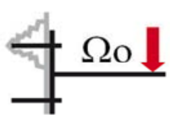
Seismic Design Requirements For Tension → D.3.3.4.3

This input is required when seismic SDC >= C (D.3.3.1) and Tensile E > 0.2U (D.3.3.4.2)
User can ignore this input when seismic SDC < C (D.3.3.1) or Tensile E <= 0.2U (D.3.3.4.1)

Options to Satisfy Additional Seismic Requirements	**Required Strength**
Option 1 D.3.3.4.3(a) Ductile anchor connection 	$U = 1.2D + 1.0E + 1.0L + 0.2S$ Eq. (9-5) $U = 0.9D + 1.0E$ Eq. (9-7) * When Option 1 is selected, user has to verify the conditions in D.3.3.4.3(a) subsections 3~6, as applicable, are met. * The program will flag OK if D.3.3.4.3(a) subsections 1 & 2 are met and the ductile anchor steel strength has the highest utilization ratio.
Option 2 D.3.3.4.3(b) Ductile attachment 	* The anchor bolt's steel attachments, such as steel base plate or column, will go for ductile yielding before or at the time when the anchor bolt reaching the tensile load N_u user input above. * User may re-input the tensile load N_u above to satisfy this option.
Option 3 D.3.3.4.3(c) Nonyielding attachment 	* The anchor bolt's non-yielding attachments, such as wood sill plate, will go for non-ductile failure, such as crushing, before or at the time when the anchor bolt reaching the tensile load N_u user input above. * User may re-input the tensile load N_u above to satisfy this option.
Option 4 D.3.3.4.3(d) Overstrength forces 	* The tensile load N_u user input above includes the seismic load E, with E increased by multiplying overstrength factor Ωo * User may re-input the tensile load N_u above to satisfy this option. $U = 1.2D + \Omega o\,(1.0E) + 1.0L + 0.2S$ Eq. (9-5) $U = 0.9D + \Omega o(1.0E)$ Eq. (9-7)

Seismic Design Requirements For Shear → D.3.3.5.3

This input is required when seismic SDC >= C (D.3.3.1) and Shear E > 0.2U (D.3.3.5.2)
User can ignore this input when seismic SDC < C (D.3.3.1) or Shear E <= 0.2U (D.3.3.5.1)

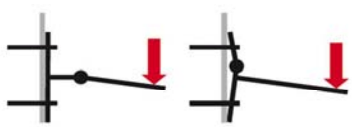
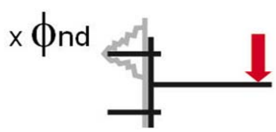
Options to Satisfy Additional Seismic Requirements	Required Strength
Option 1 D.3.3.5.3(a) Ductile attachment 	* The anchor bolt's steel attachments, such as steel base plate or column, will go for ductile yielding before or at the time when the anchor bolt reaching the shear load V_u user input above. * User may re-input the shear load V_u above to satisfy this option.
Option 2 D.3.3.5.3(b) Nonyielding attachment 	* The anchor bolt's non-yielding attachments, such as wood sill plate, will go for non-ductile failure, such as crushing, before or at the time when the anchor bolt reaching the shear load V_u user input above. * User may re-input the shear load V_u above to satisfy this option.
Option 3 D.3.3.5.3(c) Overstrength forces 	* The shear load V_u user input above includes the seismic load E, with E increased by multiplying overstrength factor Ωo * User may re-input the shear load V_u above to satisfy this option. U = 1.2D + Ωo (1.0E)+ 1.0L + 0.2S Eq. (9-5) U = 0.9D + Ωo(1.0E) Eq. (9-7)

4.2 ACI 318-08 and ACI 318M-08 Code

Seismic Design Requirements For Tension → D.3.3.4 ~ D.3.3.6

This input is required when seismic SDC >= C (D.3.3)

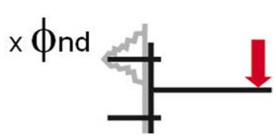
User can ignore this input when seismic SDC < C (D.3.3)

Options to Satisfy Additional Seismic Requirements	**Required Strength**
Option 1 D.3.3.4 Ductile anchor connection 	Option 1 is satisfied if $\phi N_{sa} < 0.75\ \phi\ (N_{cbg}, N_{pn}, N_{sbg})$ The design steel strength must be the governing design strength and having the highest utilization ratio. The program will flag NG if Option 1 is selected and this condition is not met.
Option 2 D.3.3.5 Ductile attachment 	The anchor bolt's steel attachments, such as steel base plate or column, will go for ductile yielding before or at the time when the anchor bolt reaching the tensile load N_u user input above. User may re-input the tensile load N_u above to satisfy this option.
Option 3 D.3.3.6 Non-ductile reduction factor ϕ_{nd} 	Non-ductile reduction factor ϕ_{nd} will be applied to the concrete failure modes. Option 3 is satisfied if $\phi_{nd}\ \phi\ N_n > N_u$ User shall input non-ductile reduction factor ϕ_{nd} next line if Option 3 is selected.

Seismic Design Requirements For Shear → D.3.3.4 ~ D.3.3.6

This input is required when seismic SDC >= C (D.3.3)

User can ignore this input when seismic SDC < C (D.3.3)

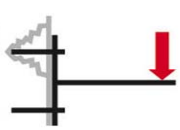
Options to Satisfy Additional Seismic Requirements	Required Strength
Option 1 D.3.3.4 Ductile anchor connection 	Option 1 is satisfied if $\phi V_{sa} < 0.75\ \phi\ (V_{cbg}\ , V_{cpg})$ The design steel strength must be the governing design strength and having the highest utilization ratio. The program will flag NG if Option 1 is selected and this condition is not met.
Option 2 D.3.3.5 Ductile attachment 	The anchor bolt's steel attachments, such as steel base plate or column, will go for ductile yielding before or at the time when the anchor bolt reaching the tensile load V_u user input above. User may re-input the tensile load V_u above to satisfy this option.
Option 3 D.3.3.6 Non-ductile reduction factor ϕ_{nd} 	Non-ductile reduction factor ϕ_{nd} will be applied to the concrete failure modes. Option 3 is satisfied if $\phi_{nd}\ \phi\ V_n > V_u$ User shall input non-ductile reduction factor ϕ_{nd} next line if Option 3 is selected.

4.3 CSA A23.3-04 R2010 Code

Seismic Design Requirements For Tension → D.4.3.6 ~ D.4.3.8

This input is required when seismic $I_E F_a S_a(0.2)$ >= 0.35 (D.4.3.3)

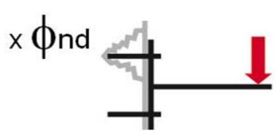
User can ignore this input when seismic $I_E F_a S_a(0.2)$ < 0.35 (D.4.3.3)

Options to Satisfy Additional Seismic Requirements	**Required Strength**
Option 1 D.4.3.6 Ductile anchor connection 	Option 1 is satisfied if $\phi N_{sa} < 0.75 \phi (N_{cbg} , N_{pn} , N_{sbg})$ The design steel strength must be the governing design strength and having the highest utilization ratio. The program will flag NG if Option 1 is selected and this condition is not met.
Option 2 D.4.3.7 Ductile attachment 	The anchor bolt's steel attachments, such as steel base plate or column, will go for ductile yielding before or at the time when the anchor bolt reaching the tensile load N_u user input above. User may re-input the tensile load N_u above to satisfy this option.
Option 3 D.4.3.8 Non-ductile reduction factor ϕ_{nd} x ϕnd 	Non-ductile reduction factor ϕ_{nd} will be applied to the concrete failure modes. Option 3 is satisfied if $\phi_{nd} \phi N_n > N_u$ User shall input non-ductile reduction factor ϕ_{nd} next line if Option 3 is selected.

Seismic Design Requirements For Shear → D.4.3.6 ~ D.4.3.8

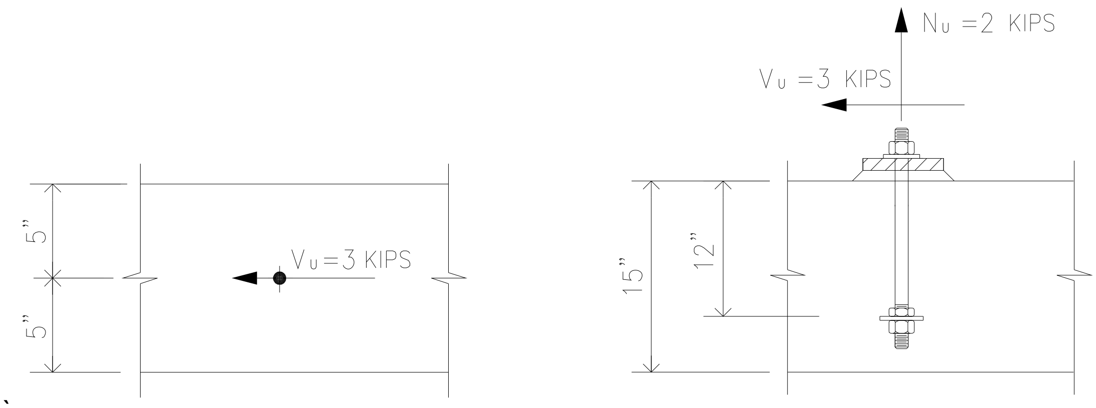
This input is required when seismic $I_E F_a S_a(0.2)$ >= 0.35 (D.4.3.3)

User can ignore this input when seismic $I_E F_a S_a(0.2)$ < 0.35 (D.4.3.3)

Options to Satisfy Additional Seismic Requirements	**Required Strength**
Option 1 D.4.3.6 Ductile anchor connection 	Option 1 is satisfied if $\phi V_{sa} < 0.75\, \phi\, (V_{cbg} , V_{cpg})$ The design steel strength must be the governing design strength and having the highest utilization ratio. The program will flag NG if Option 1 is selected and this condition is not met.
Option 2 D.4.3.7 Ductile attachment 	The anchor bolt's steel attachments, such as steel base plate or column, will go for ductile yielding before or at the time when the anchor bolt reaching the tensile load V_u user input above. User may re-input the tensile load V_u above to satisfy this option.
Option 3 D.4.3.8 Non-ductile reduction factor ϕ_{nd} 	Non-ductile reduction factor ϕ_{nd} will be applied to the concrete failure modes. Option 3 is satisfied if $\phi_{nd}\, \phi\, V_n > V_u$ User shall input non-ductile reduction factor ϕ_{nd} next line if Option 3 is selected.

5.0 DESIGN EXAMPLES

Example 01: Single Anchor Bolt + No Anchor Reinft + Tension & Shear + ACI 318-11 Code



N_u= 2 kips (Tension) V_u = 3 kips

Concrete f_c'= 4 ksi

Anchor bolt F1554 Grade 36 3/4” dia Hex Head h_{ef} = 12” h_a =15”

No supplementary reinforcement for tension and shear

Cracked concrete

Provide built-up grout pad

Seismic design category >= C Tension → Option 1 Shear → Option 2

ANCHOR BOLT DESIGN **Combined Tension and Shear**

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*

Anchor Bolt Data		set N_u = 0 if it's compression						**Code Reference**
Factored tension for design	N_u =	2.00	[kips]		= 8.9	[kN]		
Factored shear	V_u =	3.00	[kips]		= 13.3	[kN]		
Concrete strength	f'_c =	4.0	[ksi]		= 27.6	[MPa]		
Anchor bolt material		F1554 Grade 36						
Anchor tensile strength	f_{uta} =	58	[ksi]		= 400	[MPa]		*ACI 318-11*
		Anchor is ductile steel element						D.1
Anchor bolt diameter	d_a =	**0.75**	[in]		= 19.1	[mm]		*PIP STE05121*
Bolt sleeve diameter	d_s =	2.0	[in]					Page A -1 Table 1
Bolt sleeve height	h_s =	7.0	[in]					
				min required				
Anchor bolt embedment depth	h_{ef} =	12.0	[in]	9.0			**OK**	Page A -1 Table 1
Concrete thickness	h_a =	15.0	[in]	15.0			**OK**	
Bolt edge distance c_1	c_1 =	100.0	[in]	4.5			**OK**	Page A -1 Table 1
Bolt edge distance c_2	c_2 =	5.0	[in]	4.5			**OK**	
Bolt edge distance c_3	c_3 =	100.0	[in]	4.5			**OK**	
Bolt edge distance c_4	c_4 =	5.0	[in]	4.5			**OK**	*ACI 318-11*
$c_i > 1.5h_{ef}$ for at least two edges to avoid reducing of h_{ef} when $N_u > 0$							**Yes**	D.5.2.3
Adjusted h_{ef} for design	h_{ef} =	**12.00**	[in]	9.0			**OK**	D.5.2.3
Anchor head type	=	Hex			?			
Anchor effective cross sect area	A_{se} =	0.334	[in^2]					
Bearing area of head	A_{brg} =	**0.654**	[in^2]					
	A_{brg}		[in^2]	not applicable				
Bolt 1/8" (3mm) corrosion allowance	=	No	?					
Supplementary reinforcement								
For tension	=	No	Condition B					D.4.3 (c)
For shear	$\Psi_{c,V}$ =	1	Condition B		?			D.6.2.7
Provide built-up grout pad ?	=	Yes	?					D.6.1.3
Concrete cracking	=	cracked	?					D.5.2.6, D5.3.6, D.6.2.7
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 option	Tensile =	Option 1	?		Shear =	Option 3	?	D.3.3.4.3 & D.3.3.5.3

					Code Reference
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	$\phi_{t,c}$ = 0.70	Cdn-B	$\phi_{v,c}$ = 0.70	Cdn-B	D.4.3 (c)

Assumptions

1. Concrete is cracked	D.5.2.6, D5.3.6, D.6.2.7
2. Condition B - no supplementary reinforcement provided	D.4.3 (c)
3. Load combinations shall be per ACI 318-11 9.2	D.4.3
4. Tensile load acts through center of bolt group $\Psi_{ec,N}$ =1.0	D.5.2.4
5. Shear load acts through center of bolt group $\Psi_{ec,V}$ =1.0	D.6.2.5

CONCLUSION

Anchor Rod Embedment, Spacing and Edge Distance		**OK**	
Overall	ratio = **0.97**	**OK**	
Tension			
Anchor Rod Tensile Resistance	ratio = 0.14	**OK**	
Conc. Tensile Breakout Resistance	ratio = 0.28	**OK**	
Anchor Pullout Resistance	ratio = 0.18	**OK**	
Side Blowout Resistance	ratio = 0.00	**OK**	
Shear			
Anchor Rod Shear Resistance	ratio = 0.50	**OK**	
Conc. Shear Breakout Resistance - Perpendicular To Edge	ratio = 0.89	**OK**	
Conc. Shear Breakout Resistance - Parallel To Edge	ratio = 0.34	**OK**	
Conc. Pryout Shear Resistance	ratio = 0.21	**OK**	
Tension Shear Interaction			
Tension Shear Interaction	ratio = 0.97	**OK**	
Seismic Design			
Tension Applicable		**NG**	D.3.3.4

Option 1 is NOT satisfied

Seismic SDC>=C and E>0.2U , Option 1 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 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

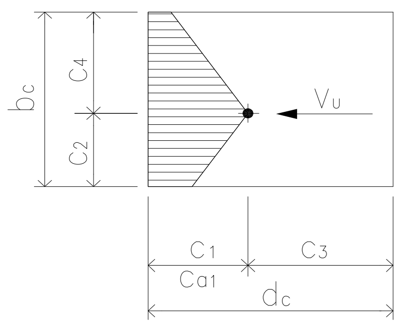
CALCULATION				Code Reference
				ACI 318-11
Anchor Rod Tensile	$\phi_{t,s} N_{sa} = \phi_{t,s} A_{se} f_{uta}$	= 14.53	[kips]	D.5.1.2 (D-2)
Resistance	ratio = 0.14	> N_u	**OK**	
Conc. Tensile Breakout Resistance				
	$N_b = 24\ \lambda \sqrt{f'_c}\ h_{ef}^{1.5}$ if $h_{ef} < 11"$ or $h_{ef} > 25"$	= 63.65	[kips]	D.5.2.2 (D-6)
	$16\ \lambda \sqrt{f'_c}\ h_{ef}^{5/3}$ if $11" \le h_{ef} \le 25"$			D.5.2.2 (D-7)
Projected conc failure area	$1.5h_{ef}$ =	= 18.0	[in]	
	A_{Nc} = [min(c_1,1.5h_{ef})+min(c_3,1.5h_{ef})] x [min(c_2,1.5h_{ef})+min(c_4,1.5h_{ef})]	= 360.0	[in^2]	
	$A_{Nco} = 9\ h_{ef}^2$	= 1296.0	[in^2]	D.5.2.1 (D-5)
	A_{Nc} = min (A_{Nc}, 1x A_{Nco})	= 360.0	[in^2]	D.5.2.1
Min edge distance	c_{min} = min(c_1, c_2, c_3, c_4)	= 5.0	[in]	
Eccentricity effects	$\Psi_{ec,N}$ = 1.0 for no eccentric load			D.5.2.4
Edge effects	$\Psi_{ed,N}$ = min[(0.7+0.3c_{min}/1.5h_{ef}), 1.0]	= 0.78		D.5.2.5
Concrete cracking	$\Psi_{c,N}$ = 1.00 for cracked concrete			D.5.2.6
Concrete splitting	$\Psi_{cp,N}$ = 1.0 for cast-in anchor			D.5.2.7
Concrete breakout resistance	$\phi_{t,c} N_{cb} = \phi_{t,c} \frac{A_{Nc}}{A_{Nco}} \Psi_{ec,N}\ \Psi_{ed,N}\ \Psi_{c,N}\ \Psi_{cp,N}\ N_b$	= 9.69	[kips]	D.5.2.1 (D-4)
Seismic design strength reduction	= x 0.75 applicable	= 7.27	[kips]	D.3.3.4.4
	ratio = 0.28	> N_u	**OK**	
Anchor Pullout Resistance				
Single bolt pullout resistance	$N_p = 8\ A_{brg}\ f_c'$	= 20.93	[kips]	D.5.3.4 (D-14)
	$\phi_{t,c} N_{pn} = \phi_{t,c}\ \Psi_{c,p}\ N_p$	= 14.65	[kips]	D.5.3.1 (D-13)
Seismic design strength reduction	= x 0.75 applicable	= 10.99	[kips]	D.3.3.4.4
	ratio = 0.18	> N_u	**OK**	
	$\Psi_{c,p}$ = 1.00 for cracked concrete			D.5.3.6
	$\phi_{t,c}$ = 0.70 pullout strength is always Condition B			D.4.3(c)
Side Blowout Resistance				
	c = min (c_1, c_2, c_3, c_4)	= 5.0	[in]	
Check if side blowout applicable	h_{ef} = 12.0 [in]			
	< 2.5c side bowout is NOT applicable			D.5.4.1
SB resistance	$\phi_{t,c} N_{sb} = \phi_{t,c} \left(160\ c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$	= 0.00	[kips]	D.5.4.1 (D-16)
Edge reduction factor	= (1+ c_{a2} / c_{a1}) / 4	= 1.00		D.5.4.1
SB resistance after edge reduction		= 0.00	[kips]	
Seismic design strength reduction	= x 0.75 applicable	= 0.00	[kips]	D.3.3.4.4
	ratio = 0.00	> N_u	**OK**	

					Code Reference
Govern Tensile Resistance	$\mathbf{N_r}$ =	min(ϕN_{sa}, ϕN_{cb}, ϕN_{pn}, ϕN_{sb})	= **7.27**	[kips]	*ACI 318-11*

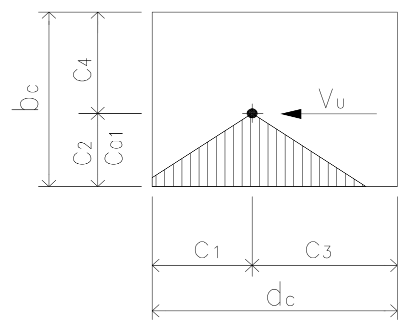
Note: Anchor bolt sleeve portion must be tape wrapped and grouted to resist shear

Anchor Rod Shear Resistance	$\phi_{v,s} V_{sa}$ =	$\phi_{v,s}$ 0.6 $A_{se} f_{uta}$	= 7.56	[kips]	D.6.1.2 (b) (D-29)
Reduction due to built-up grout pads		= x 0.8 , applicable	= 6.04	[kips]	D.6.1.3
	ratio =	0.50	> V_u	**OK**	

Conc. Shear Breakout Resistance - Perpendicular To Edge



Conc Shear Breakout
Perpendicular To Edge



Conc Shear Breakout
Parallel To Edge

Bolt edge distance	c_{a1} =	c_1	= 100.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges			= Yes		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ =	ca1 needs to be adjusted	= **10.0**	[in]	D.6.2.4
	$1.5c_{a1}$ =		= 15.0	[in]	
	A_{Vc} =	[min(c_2,1.5c_1) + min(c_4,1.5c_1)] x min(1.5c_1, h_a)	= 150.0	[in^2]	D.6.2.1
	A_{Vco} =	$4.5c_{a1}^2$	= 450.0	[in^2]	D.6.2.1 (D-32)
	A_{Vc} =	min (A_{Vc}, 1 x A_{Vco})	= 150.0	[in^2]	D.6.2.1
	l_e =	min(8d_a , h_{ef})	= 6.0	[in]	D.6.2.2
	V_{b1} =	$\left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 18.38	[kips]	D.6.2.2 (D-33)
	V_{b2} =	$9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 18.00	[kips]	D.6.2.2 (D-34)
	V_b =	min(V_{b1} , V_{b2})	= 18.00	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ =	1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	min[(0.7+0.3c_2/1.5c_1), 1.0]	= 0.80		D.6.2.6
Concrete cracking	$\Psi_{c,v}$ =	concrete is cracked	= 1.00		D.6.2.7
Member thickness	$\Psi_{h,v}$ =	max[(sqrt(1.5c_1 / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance - perpendicular to edge	$\phi_{v,c}V_{cb}$ =	$\phi_{v,c}\frac{A_{Vc}}{A_{Vco}}\Psi_{ec,V}\ \Psi_{ed,V}\ \Psi_{c,V}\ \Psi_{h,V}\ V_b$	= 3.36	[kips]	D.6.2.1 (D-31)
	ratio =	0.89	> V_u	**OK**	

					Code Reference
Conc. Shear Breakout Resistance - Parallel To Edge					*ACI 318-11*
Bolt edge distance	c_{a1} =	$\min(c_2 , c_4)$	= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges			= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ =	ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	$1.5c_{a1}$ =		= 7.5	[in]	
	A_{Vc} =	$[\min(c_1,1.5c_{a1}) + \min(c_3,1.5c_{a1})] \times \min(1.5c_{a1}, h_a)$	= 112.5	[in^2]	D.6.2.1
	A_{Vco} =	$4.5{c_{a1}}^2$	= 112.5	[in^2]	D.6.2.1 (D-32)
	A_{Vc} =	$\min (A_{Vc},\ 1x\, A_{Vco})$	= 112.5	[in^2]	D.6.2.1
	l_e =	$\min(8d_a , h_{ef})$	= 6.0	[in]	D.6.2.2
	V_{b1} =	$\left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 6.50	[kips]	D.6.2.2 (D-33)
	V_{b2} =	$9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b =	$\min(V_{b1} , V_{b2})$	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ =	1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =		= 1.00		D.6.2.1 (c)
Concrete cracking	$\Psi_{c,v}$ =	concrete is cracked	= 1.00		D.6.2.7
Member thickness	$\Psi_{h,v}$ =	max[(sqrt(1.5c_{a1} / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance - parallel to edge	$\phi_{v,c}V_{cb\text{-}p}$ =	$2 \times\ \phi_{v,c}\ \frac{A_{Vc}}{A_{Vco}}\Psi_{ec,V}\ \Psi_{ed,V}\ \Psi_{c,V}\ \Psi_{h,V}\ V_b$	= 8.91	[kips]	D.6.2.1 (D-31) D.6.2.1 (c)
	ratio =	0.34	> V_u	**OK**	
Conc. Pryout Shear Resistance					
	k_{cp} =	2.0			D.6.3.1
Factored shear pryout resistance	$\phi_{v,c}\ V_{cp}$ =	$\phi_{v,c}\ k_{cp}\ N_{cbg}$	= 19.39	[kips]	D.6.3.1 (D-41)
	$\phi_{\ v,c}$ =	0.70 pryout strength is always Condition B			D.4.3 (c)
Seismic design strength reduction	=	x 0.75 applicable	= 14.54	[kips]	D.3.3.4.4
	ratio =	0.21	> V_u	**OK**	
Govern Shear Resistance	$\mathbf{V_r}$ =	$\min (\phi V_{sa}, \phi V_{cb}, \phi V_{cb\text{-}p}, \phi V_{cp})$	= **3.36**	[kips]	
Tension Shear Interaction					
Check if $N_u > 0.2\phi\ N_n$ and $V_u > 0.2\phi\ V_n$		Yes			D.7.1 & D.7.2
		$N_u / \phi\ N_n + V_u / \phi\ V_n$	= 1.17		D.7.3 (D-42)
	ratio =	0.97	< 1.2	**OK**	

Seismic Design					**Code Reference**
Tension	Applicable			**NG**	*ACI 318-11*
Steel and concrete-governed	$1.2N_{sa}$ = 23.25	[kips]	N_{cb} = 13.85	[kips]	
nominal strength	N_{pn} = 20.93	[kips]	N_{sb} = 0.00	[kips]	
	N_u / min(N_{cb}, N_{pn}, N_{sb}) = 0.14		N_u / $1.2N_{sa}$ = 0.09		
			< 0.14	**NG**	

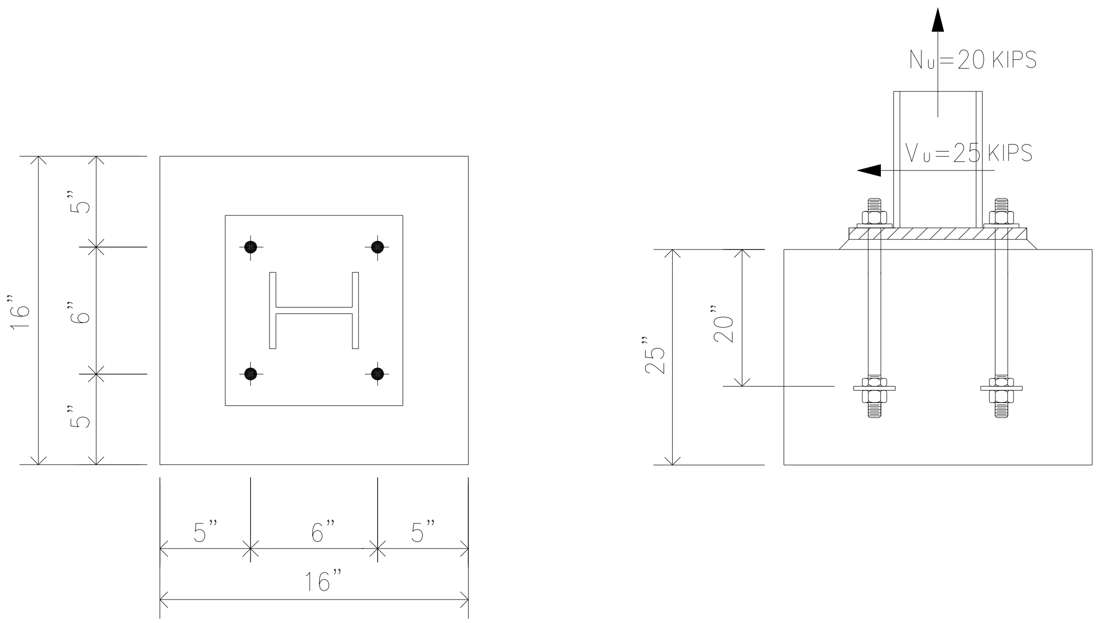
Option 1 is NOT satisfied

Seismic SDC>=C and E>0.2U , Option 1 is selected to satisfy additional seismic requirements as per D.3.3.4.3

Shear	Applicable	**OK**

Seismic SDC>=C and E>0.2U , Option 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

Example 02: Group Anchor Bolt + No Anchor Reinft + Tension & Shear + ACI 318-11 Code



N_u= 20 kips (Tension) V_u = 25 kips

Concrete f_c'= 4 ksi

Pedestal size 16” x 16”

Anchor bolt F1554 Grade 36 1.0” dia Hex Head h_{ef} = 20” h_a =25”

Supplementary Reinforcement

Tension → Yes Shear → $\Psi_{c,v}$ =1.2

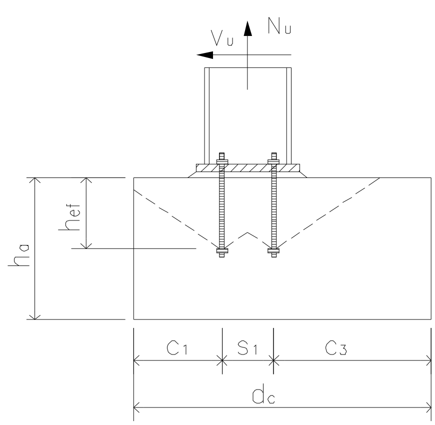
Cracked concrete

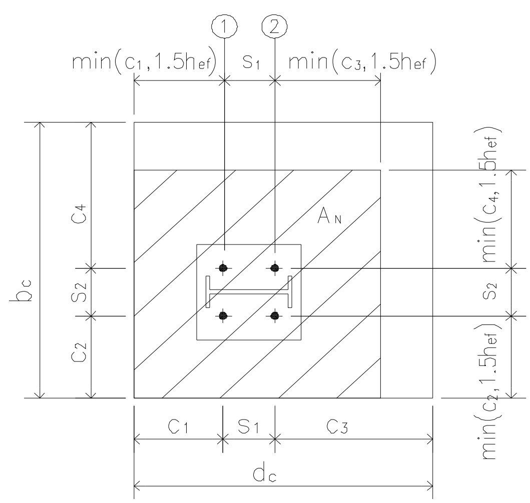
Provide built-up grout pad

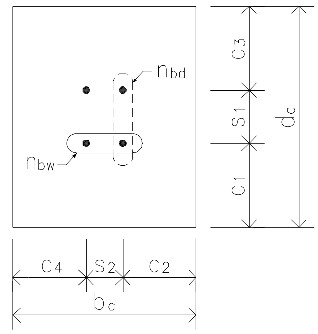
Seismic design category >= C Tension → Option 4 Shear → Option 3

ANCHOR BOLT DESIGN **Combined Tension and Shear**

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*
Anchor Bolt Data		set N_u = 0 if it's compression				**Code Reference**
Factored tension for design	$\mathbf{N_u}$ =	**20.00** [kips]		= 89.0 [kN]		
Factored shear	V_u =	25.00 [kips]		= 111.2 [kN]		
Factored shear for design	$\mathbf{V_u}$ =	**25.00** [kips]	V_u = 0 if shear key is provided			
Concrete strength	f'_c =	4.0 [ksi]		= 27.6 [MPa]		
Anchor bolt material		F1554 Grade 36				
Anchor tensile strength	f_{uta} =	58 [ksi]		= 400 [MPa]		*ACI 318-11*
		Anchor is ductile steel element				D.1
Anchor bolt diameter	$\mathbf{d_a}$ =	**1** [in]		= 25.4 [mm]		*PIP STE05121*
Bolt sleeve diameter	d_s =	3.0 [in]				Page A -1 Table 1
Bolt sleeve height	h_s =	10.0 [in]				
			min required			
Anchor bolt embedment depth	h_{ef} =	20.0 [in]	12.0		**OK**	Page A -1 Table 1
Concrete thickness	h_a =	25.0 [in]	23.0		**OK**	
Bolt edge distance c_1	c_1 =	5.0 [in]	4.5		**OK**	Page A -1 Table 1
Bolt edge distance c_2	c_2 =	5.0 [in]	4.5		**OK**	
Bolt edge distance c_3	c_3 =	5.0 [in]	4.5		**OK**	
Bolt edge distance c_4	c_4 =	5.0 [in]	4.5		**OK**	*ACI 318-11*
$c_i > 1.5h_{ef}$ for at least two edges to avoid reducing of h_{ef} when $N_u > 0$					**No**	D.5.2.3
Adjusted h_{ef} for design	h_{ef} =	**3.33** [in]	12.0		**Warn**	D.5.2.3
Outermost bolt line spacing s_1	s_1 =	6.0 [in]	4.0		**OK**	*PIP STE05121*
Outermost bolt line spacing s_2	s_2 =	6.0 [in]	4.0		**OK**	Page A -1 Table 1







Bolt No Input for Side-Face Blowout Check Use

Number of bolt at bolt line 1	n_1	= 2			
Number of bolt at bolt line 2	n_2	= 2			
Number of bolt carrying tension	n_t	= 4			
Oversized holes in base plate ?		= Yes	?		
Number of bolt carrying shear	n_s	= 4			
For side-face blowout check use					
No of bolt along width edge	n_{bw}	= 2			
No of bolt along depth edge	n_{bd}	= 2			
Anchor head type		= Hex	?		
Anchor effective cross sect area	A_{se}	= 0.606	[in^2]		
Bearing area of head	A_{brg}	= **1.163**	[in^2]		
	A_{brg}		[in^2]	not applicable	
Bolt 1/8" (3mm) corrosion allowance		= No	?		**Code Reference**
Provide shear key ?		= No	?		*ACI 318-11*
Supplementary reinforcement					
For tension		= Yes	Condition A		D.4.3 (c)
For shear	$\Psi_{c,V}$	= 1.2	Condition A	?	D.6.2.7
Provide built-up grout pad ?		= Yes	?		D.6.1.3
Concrete cracking		= cracked	?		D.5.2.6, D5.3.6, D.6.2.7
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 option	Tensile	= Option 4	?	Shear = Option 3 ?	D.3.3.4.3 & D.3.3.5.3

Strength reduction factors

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	$\phi_{t,c}$ = 0.75	Cdn-A	$\phi_{v,c}$ = 0.75	Cdn-A	D.4.3 (c)

Assumptions

1. Concrete is cracked	D.5.2.6, D5.3.6, D.6.2.7
2. Condition A - supplementary reinforcement provided	D.4.3 (c)
3. Load combinations shall be per ACI 318-11 9.2	D.4.3
4. Tensile load acts through center of bolt group $\Psi_{ec,N}$ =1.0	D.5.2.4
5. Shear load acts through center of bolt group $\Psi_{ec,V}$ =1.0	D.6.2.5
6. 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

CONCLUSION				**Code Reference**
				ACI 318-11
Anchor Rod Embedment, Spacing and Edge Distance			**Warn**	
Overall		ratio = **5.04**	**NG**	
Tension				
Anchor Rod Tensile Resistance		ratio = 0.19	**OK**	
Conc. Tensile Breakout Resistance		ratio = 1.50	**NG**	
Anchor Pullout Resistance		ratio = 0.26	**OK**	
Side Blowout Resistance		ratio = 0.27	**OK**	
Shear				
Anchor Rod Shear Resistance		ratio = 0.57	**OK**	
Conc. Shear Breakout Resistance - Perpendicular To Edge		ratio = 4.55	**NG**	
Conc. Shear Breakout Resistance - Parallel To Edge		ratio = 1.31	**NG**	
Conc. Pryout Shear Resistance		ratio = 1.01	**NG**	
Tension Shear Interaction				
Tension Shear Interaction		ratio = 5.04	**NG**	
Seismic Design				
Tension	Applicable		**OK**	D.3.3.4

Seismic SDC>=C and E>0.2U , Option 4 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 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

CALCULATION

Anchor Rod Tensile Resistance

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

ratio = 0.19 > N_u **OK**

Conc. Tensile Breakout Resistance

$N_b = 24\,\lambda \sqrt{f'_c}\; h_{ef}^{1.5}$ if $h_{ef} < 11"$ or $h_{ef} > 25"$ = 9.24 [kips] D.5.2.2 (D-6)

$16\,\lambda \sqrt{f'_c}\; h_{ef}^{5/3}$ if $11" \le h_{ef} \le 25"$ D.5.2.2 (D-7)

Projected conc failure area	$1.5h_{ef}$ =	= 5.00	[in]	
	$A_{Nc} = [s_1+\min(c_1,1.5h_{ef})+\min(c_3,1.5h_{ef})] \times [s_2+\min(c_2,1.5h_{ef})+\min(c_4,1.5h_{ef})]$	= 256.0	[in^2]	
	$A_{Nco} = 9\, h_{ef}^2$	= 100.0	[in^2]	D.5.2.1 (D-5)
	$A_{Nc} = \min(A_{Nc},\; n_t A_{Nco})$	= 256.0	[in^2]	D.5.2.1
Min edge distance	$c_{min} = \min(c_1, c_2, c_3, c_4)$	= 5.0	[in]	
Eccentricity effects	$\Psi_{ec,N}$ = 1.0 for no eccentric load			D.5.2.4

					Code Reference
					ACI 318-11
Edge effects	$\Psi_{ed,N}$	= min[$(0.7+0.3c_{min}/1.5h_{ef})$, 1.0]	= 1.00		D.5.2.5
Concrete cracking	$\Psi_{c,N}$	= 1.00 for cracked concrete			D.5.2.6
Concrete splitting	$\Psi_{cp,N}$	= 1.0 for cast-in anchor			D.5.2.7
Concrete breakout resistance	$\phi_{t,c} N_{cbg}$	= $\phi_{t,c} \frac{A_{Nc}}{A_{Nco}} \Psi_{ec,N} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$	= 17.74	[kips]	D.5.2.1 (D-4)
Seismic design strength reduction		= x 0.75 applicable	= 13.30	[kips]	D.3.3.4.4
	ratio	= 1.50	< N_u	**NG**	

Anchor Pullout Resistance

Single bolt pullout resistance	N_p	= $8 A_{brg} f_c'$	= 37.22	[kips]	D.5.3.4 (D-14)
	$\phi_{t,c} N_{pn}$	= $\phi_{t,c} n_t \Psi_{c,p} N_p$	= 104.20	[kips]	D.5.3.1 (D-13)
Seismic design strength reduction		= x 0.75 applicable	= 78.15	[kips]	D.3.3.4.4
	ratio	= 0.26	> N_u	**OK**	
	$\Psi_{c,p}$	= 1.00 for cracked concrete			D.5.3.6
	$\phi_{t,c}$	= 0.70 pullout strength is always Condition B			D.4.3(c)

Side Blowout Resistance

Failure Along Pedestal Width Edge

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)	= 5.0	[in]	
Check if side blowout applicable	h_{ef}	= 20.0 [in]			
		> 2.5c side bowout is applicable			D.5.4.1
Check if edge anchors work as a	s_{22}	= 6.0 [in] $s = s_2$	= 6.0	[in]	
a group or work individually		< 6c edge anchors work as a group			D.5.4.2
Single anchor SB resistance	$\phi_{t,c} N_{sb}$	= $\phi_{t,c} \left(160\, c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$	= 40.92	[kips]	D.5.4.1 (D-16)
Multiple anchors SB resistance	$\phi_{t,c} N_{sbg,w}$	=			
work as a group - applicable		= (1+s/ 6c) x $\phi_{t,c} N_{sb}$	= 49.11	[kips]	D.5.4.2 (D-17)
work individually - not applicable		= n_{bw} x $\phi_{t,c} N_{sb}$ x [1+(c_2 or c_4) / c] / 4	= 0.00	[kips]	D.5.4.1
Seismic design strength reduction		= x 0.75 applicable	= 36.83	[kips]	D.3.3.4.4
	ratio	= 0.27	> N_{buw}	**OK**	

Failure Along Pedestal Depth Edge

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

along pedestal depth edge	N_{bud}	= N_u x n_{bd} / n_t	= 10.00	[kips]	RD.5.4.2
	c	= min (c_2, c_4)	= 5.0	[in]	
Check if side blowout applicable	h_{ef}	= 20.0 [in]			
		> 2.5c side bowout is applicable			D.5.4.1
Check if edge anchors work as a	s_{11}	= 6.0 [in] $s = s_1$	= 6.0	[in]	
a group or work individually		< 6c edge anchors work as a group			D.5.4.2
Single anchor SB resistance	$\phi_{t,c} N_{sb}$	= $\phi_{t,c} \left(160\, c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$	= 40.92	[kips]	D.5.4.1 (D-16)

					Code Reference
Multiple anchors SB resistance	$\phi_{t,c} N_{sbg,d}$ =				*ACI 318-11*
work as a group - applicable		= $(1+s/6c) \times \phi_{t,c} N_{sb}$	= 49.11	[kips]	D.5.4.2 (D-17)
work individually - not applicable		= $n_{bd} \times \phi_{t,c} N_{sb} \times [1+(c_1 \text{ or } c_3)/c] / 4$	= 0.00	[kips]	D.5.4.1
Seismic design strength reduction		= x 0.75 applicable	= 36.83	[kips]	D.3.3.4.4
	ratio	= 0.27	> N_{bud}	**OK**	
Group side blowout resistance	$\phi_{t,c} N_{sbg}$	= $\phi_{t,c} \min\left(\frac{N_{sbg,w}}{n_{bw}} n_t, \frac{N_{sbg,d}}{n_{bd}} n_t\right)$	= 73.66	[kips]	
Govern Tensile Resistance	N_r	= $\min(\phi N_{sa}, \phi N_{cbg}, \phi N_{pn}, \phi N_{sbg})$	= **13.30**	[kips]	

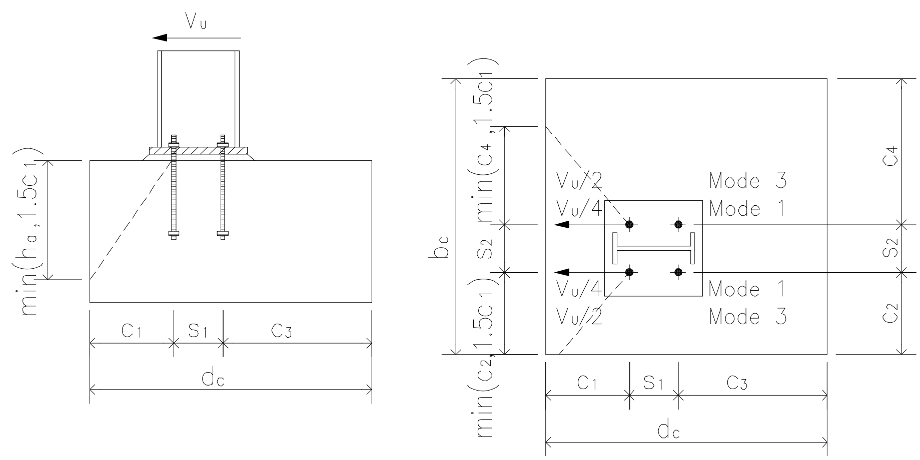
Note: Anchor bolt sleeve portion must be tape wrapped and grouted to resist shear

Anchor Rod Shear Resistance	$\phi_{v,s} V_{sa}$	= $\phi_{v,s} n_s 0.6 A_{se} f_{uta}$	= 54.83	[kips]	D.6.1.2 (b) (D-29)
Reduction due to built-up grout pads		= x 0.8 , applicable	= 43.86	[kips]	D.6.1.3
	ratio	= 0.57	> V_u	**OK**	

Conc. Shear Breakout Resistance - Perpendicular To Edge

Mode 1 Failure cone at front anchors, strength check against 0.5 x V_u

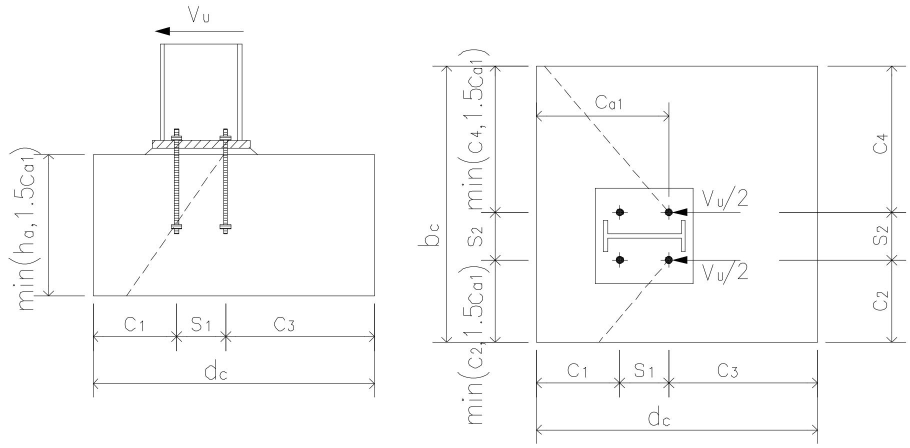
Mode 3 Failure cone at front anchors, strength check against 1.0 x V_u , applicable when oversized holes are used in base plate



Bolt edge distance	c_1 =		= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges			= No		D.6.2.4
Bolt edge distance - adjusted	c_1	= ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	c_2 =		= 5.0	[in]	
	$1.5c_1$ =		= 7.5	[in]	
	A_{Vc}	= $[\min(c_2,1.5c_1) + s_2 + \min(c_4,1.5c_1)] \times \min(1.5c_1, h_a)$	= 120.0	[in^2]	D.6.2.1
	A_{Vco}	= $4.5c_1^2$	= 112.5	[in^2]	D.6.2.1 (D-32)
	A_{Vc}	= $\min(A_{Vc}, n_1 A_{Vco})$	= 120.0	[in^2]	D.6.2.1
	l_e	= $\min(8d_a, h_{ef})$	= 8.0	[in]	D.6.2.2

				Code Reference
				ACI 318-11
	$V_{b1} = \left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\;c_1^{1.5}$	= 7.50	[kips]	D.6.2.2 (D-33)
	$V_{b2} = 9\lambda\sqrt{f'_c}\;c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b = min(V_{b1} , V_{b2})	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ = 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ = min[(0.7+0.3c_2/1.5c_1), 1.0]	= 0.90		D.6.2.6
Concrete cracking	$\Psi_{c,v}$ = concrete is cracked	= 1.20		D.6.2.7
Member thickness	$\Psi_{h,v}$ = max[(sqrt(1.5c_1 / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance	$V_{cbg1} = \phi_{v,c}\frac{A_{Vc}}{A_{Vco}}\Psi_{ec,V}\,\Psi_{ed,V}\,\Psi_{c,V}\,\Psi_{h,V}\,V_b$	= 5.50	[kips]	D.6.2.1 (D-31)
Mode 3 is used for checking	$\mathbf{V_{cbg1}}$ = V_{cbg1} x 1.0	= **5.50**	[kips]	

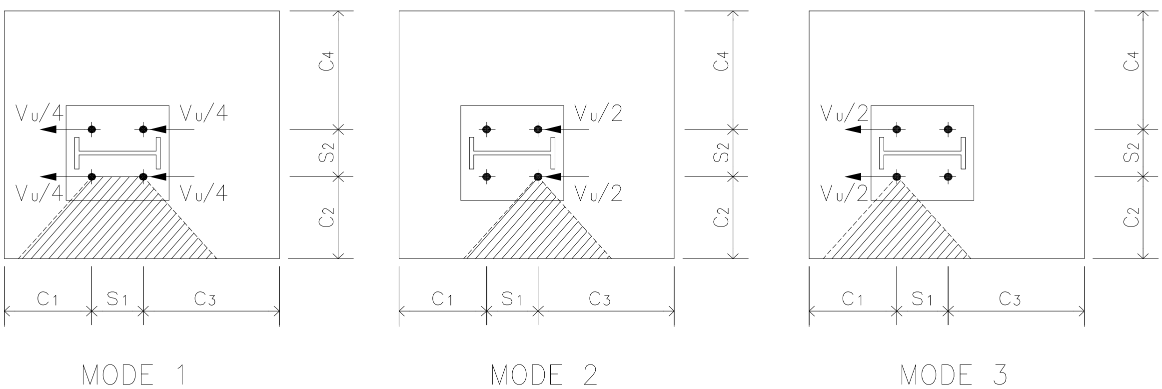
Mode 2 Failure cone at back anchors



				ACI 318-11
Bolt edge distance	c_{a1} = c_1 + s_1	= 11.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges		= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ = ca1 needs NOT to be adjusted	= **11.0**	[in]	D.6.2.4
	c_2 =	5.0	[in]	
	1.5c_{a1} =	16.5	[in]	
	A_{Vc} = [min(c_2,1.5c_{a1}) + s_2 + min(c_4,1.5c_{a1})] x min(1.5c_{a1}, h_a)	= 264.0	[in^2]	D.6.2.1
	A_{Vco} = 4.5c_{a1}^2	= 544.5	[in^2]	D.6.2.1 (D-32)
	A_{Vc} = min (A_{Vc}, n_2 A_{Vco})	= 264.0	[in^2]	D.6.2.1
	l_e = min(8d_a , h_{ef})	= 8.0	[in]	D.6.2.2
	$V_{b1} = \left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\;c_{a1}^{1.5}$	= 24.48	[kips]	D.6.2.2 (D-33)
	$V_{b2} = 9\lambda\sqrt{f'_c}\;c_{a1}^{1.5}$	= 20.77	[kips]	D.6.2.2 (D-34)
	V_b = min(V_{b1} , V_{b2})	= 20.77	[kips]	D.6.2.2

				Code Reference
				ACI 318-11
Eccentricity effects	$\Psi_{ec,v}$ = 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ = min[(0.7+0.3c$_2$/1.5c$_{a1}$), 1.0]	= 0.79		D.6.2.6
Concrete cracking	$\Psi_{c,v}$ = concrete is cracked	= 1.20		D.6.2.7
Member thickness	$\Psi_{h,v}$ = max[(sqrt(1.5c$_{a1}$ / h$_a$) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance	$V_{cbg2} = \phi_{v,c} \frac{A_{Vc}}{A_{Vco}} \Psi_{ec,V} \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_b$	= 7.17	[kips]	D.6.2.1 (D-31)
Min shear breakout resistance shear perpendicular to edge	$\phi_{v,c} V_{cbg}$ = min (V_{cbg1} , V_{cbg2})	= 5.50	[kips]	
	ratio = 4.55	< V_u	**NG**	

Conc. Shear Breakout Resistance - Parallel To Edge



Mode 1 Shear taken evenly by all anchor bolts, strength check against 0.5 x V_u

				ACI 318-11
Bolt edge distance	c_{a1} = min(c_2 , c_4)	= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges		= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ = ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	$1.5c_{a1}$ =	= 7.5	[in]	
	A_{Vc} = [min(c_1,1.5c_{a1}) + s_1 + min(c_3,1.5c_{a1})] x min(1.5c_{a1}, h_a)	= 120.0	[in^2]	D.6.2.1
	$A_{Vco} = 4.5c_{a1}^2$	= 112.5	[in^2]	D.6.2.1 (D-32)
	A_{Vc} = min (A_{Vc}, n_{bd} A_{Vco})	= 120.0	[in^2]	D.6.2.1
	l_e = min(8d_a , h_{ef})	= 8.0	[in]	D.6.2.2
	$V_{b1} = \left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 7.50	[kips]	D.6.2.2 (D-33)
	$V_{b2} = 9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b = min(V_{b1} , V_{b2})	= 6.36	[kips]	D.6.2.2

				Code Reference
				ACI 318-11
Eccentricity effects	$\Psi_{ec,v}$ = 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	= 1.00		D.6.2.1 (c)
Concrete cracking	$\Psi_{c,v}$ = concrete is cracked	= 1.20		D.6.2.7
Member thickness	$\Psi_{h,v}$ = max[(sqrt(1.5c_{a1} / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance - parallel to edge	$V_{cbg\text{-}p1} = 2 \times \phi_{v,c} \dfrac{A_{Vc}}{A_{Vco}} \Psi_{ec,V}\, \Psi_{ed,V}\, \Psi_{c,V}\, \Psi_{h,V}\, V_b$	= 12.22	[kips]	D.6.2.1 (D-31) D.6.2.1 (c)

Mode 2 Shear taken evenly by back anchor bolts, strength check against 0.5 x V_u

Bolt edge distance	c_{a1} = min(c_2 , c_4)	= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges		= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ = ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	1.5c_{a1} =	= 7.5	[in]	
	A_{Vc} = [min((s_1+c_1,1.5c_{a1}) + min(c_3,1.5c_{a1})] x min(1.5c_{a1}, h_a)	= 93.8	[in^2]	D.6.2.1
	A_{Vco} = 4.5c_{a1}^2	= 112.5	[in^2]	D.6.2.1 (D-32)
	A_{Vc} = min (A_{Vc}, n_{bd} A_{Vco})	= 93.8	[in^2]	D.6.2.1
	l_e = min(8d_a , h_{ef})	= 8.0	[in]	D.6.2.2
	$V_{b1} = \left[7\left(\dfrac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\; c_{a1}^{1.5}$	= 7.50	[kips]	D.6.2.2 (D-33)
	$V_{b2} = 9\lambda\sqrt{f'_c}\; c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b = min(V_{b1} , V_{b2})	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ = 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	= 1.00		D.6.2.1 (c)
Concrete cracking	$\Psi_{c,v}$ = concrete is cracked	= 1.20		D.6.2.7
Member thickness	$\Psi_{h,v}$ = max[(sqrt(1.5c_{a1} / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance - parallel to edge	$V_{cbg\text{-}p2} = 2 \times \phi_{v,c} \dfrac{A_{Vc}}{A_{Vco}} \Psi_{ec,V}\, \Psi_{ed,V}\, \Psi_{c,V}\, \Psi_{h,V}\, V_b$	= 9.55	[kips]	D.6.2.1 (D-31) D.6.2.1 (c)

Mode 3 Shear taken evenly by front anchor bolts, strength check against 0.5 x V_u

Bolt edge distance	c_{a1} = min(c_2 , c_4)	= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges		= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ = ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	1.5c_{a1} =	= 7.5	[in]	
	A_{Vc} = [min(c_1,1.5c_{a1}) + min(s_1+c_3,1.5c_{a1})] x min(1.5c_{a1}, h_a)	= 93.8	[in^2]	D.6.2.1

				Code Reference
				ACI 318-11
	$A_{Vco} = 4.5c_{a1}^{2}$	= 112.5	[in^2]	D.6.2.1 (D-32)
	$A_{Vc} = \min(A_{Vc}, n_{bd} A_{Vco})$	= 93.8	[in^2]	D.6.2.1
	$l_e = \min(8d_a, h_{ef})$	= 8.0	[in]	D.6.2.2
	$V_{b1} = \left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f_c'}\ c_{a1}^{1.5}$	= 7.50	[kips]	D.6.2.2 (D-33)
	$V_{b2} = 9\lambda\sqrt{f_c'}\ c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	$V_b = \min(V_{b1}, V_{b2})$	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ = 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	= 1.00		D.6.2.1 (c)
Concrete cracking	$\Psi_{c,v}$ = concrete is cracked	= 1.20		D.6.2.7
Member thickness	$\Psi_{h,v}$ = max[(sqrt(1.5c_{a1} / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance - parallel to edge	$V_{cbg-p3} = 2 \times \phi_{v,c} \frac{A_{Vc}}{A_{Vco}} \Psi_{ec,V}\ \Psi_{ed,V}\ \Psi_{c,V}\ \Psi_{h,V}\ V_b$	= 9.55	[kips]	D.6.2.1 (D-31) D.6.2.1 (c)
Min shear breakout resistance shear parallel to edge	$\phi_{v,c}V_{cbg-p} = \min(V_{cbg-p1}, V_{cbg-p2}, V_{cbg-p3}) \times 2$ side	= 19.09	[kips]	
	ratio = 1.31	< V_u	**NG**	

Conc. Pryout Shear Resistance

	$k_{cp} = 2.0$			D.6.3.1
Factored shear pryout resistance	$\phi_{v,c} V_{cpg} = \phi_{v,c} k_{cp} N_{cbg}$	= 33.11	[kips]	D.6.3.1 (D-41)
	$\phi_{v,c}$ = 0.70 pryout strength is always Condition B			D.4.3(c)
Seismic design strength reduction	= x 0.75 applicable	= 24.83	[kips]	D.3.3.4.4
	ratio = 1.01	< V_u	**NG**	
Govern Shear Resistance	$\mathbf{V_r} = \min(\phi V_{sa}, \phi V_{cbg}, \phi V_{cbg-p}, \phi V_{cpg})$	= **5.50**	[kips]	

Tension Shear Interaction

Check if $N_u > 0.2\phi\ N_n$ and $V_u > 0.2\phi\ V_n$	Yes			D.7.1 & D.7.2
	$N_u / \phi\ N_n + V_u / \phi\ V_n$	= 6.05		D.7.3 (D-42)
	ratio = 5.04	> 1.2	**NG**	

Code Reference

ACI 318-11

Seismic Design

Tension	Applicable					**OK**
Steel and concrete-governed	$1.2N_{sa}$ = 0.00	[kips]		N_{cbg} = 0.00	[kips]	
nominal strength	N_{pn} = 0.00	[kips]		N_{sbg} = 0.00	[kips]	
	N_u / min(N_{cbg}, N_{pn}, N_{sbg}) = 0.00			N_u / $1.2N_{sa}$ = 0.00		
				> 0.00		**NA**

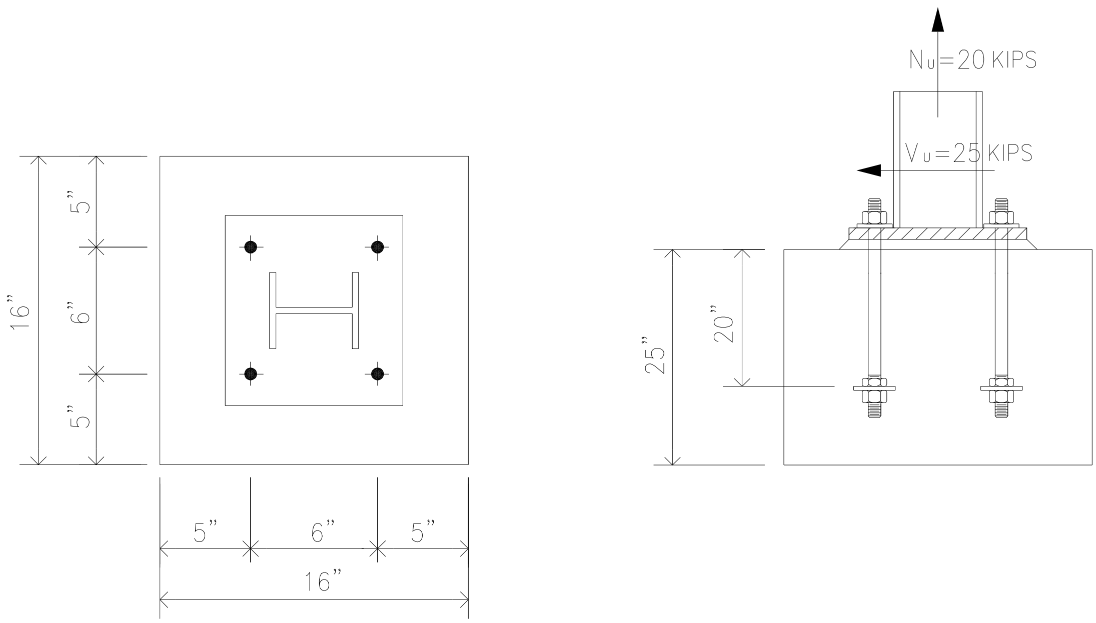
Not Applicable - Check Option 1 D.3.3.4.3 (a) subsections 1~2

Seismic SDC>=C and E>0.2U , Option 4 is selected to satisfy additional seismic requirements as per D.3.3.4.3

Shear	Applicable	**OK**

Seismic SDC>=C and E>0.2U , Option 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

Example 03: Group Anchor Bolt + Anchor Reinft + Tension & Shear + ACI 318-11 Code



N_u= 20 kips (Tension) V_u = 25 kips

Concrete f_c’= 4 ksi Rebar f_y = 60 ksi

Pedestal size 16” x 16”

Anchor bolt F1554 Grade 36 1.0” dia Hex Head h_{ef} = 20” h_a =25”

Anchor reinforcement Tension → 2-No 8 ver. bar

Shear → 2-layer, 2-leg No 4 hor. bar

Provide built-up grout pad

Seismic design category >= C Tension → Option 4 Shear → Option 3

ANCHOR BOLT DESIGN **Combined Tension and Shear**

Anchor bolt design based on — **Code Abbreviation**

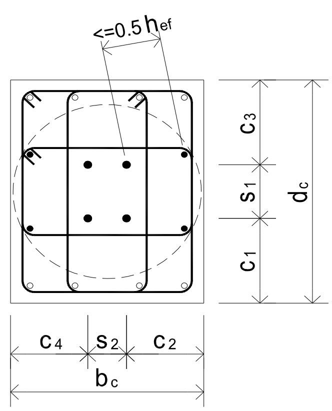
ACI 318-11 Building Code Requirements for Structural Concrete and Commentary Appendix D — *ACI 318-11*

PIP STE05121 Anchor Bolt Design Guide-2006 — *PIP STE05121*

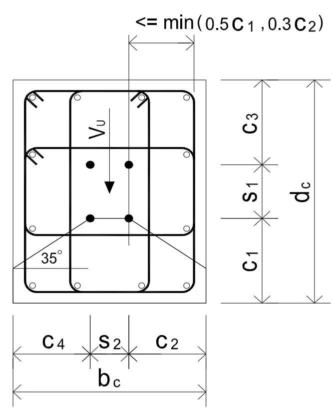
	Code Reference
Assumptions	*ACI 318-11*
1. Concrete is cracked	D.5.2.6, D5.3.6, D.6.2.7
2. Condition A - supplementary reinforcement is provided	D.4.3 (c)
3. Load combinations shall be per ACI 318-11 9.2	D.4.3
4. Anchor reinft strength is used to replace concrete tension / shear breakout strength as 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

Anchor Bolt Data set N_u = 0 if it's compression

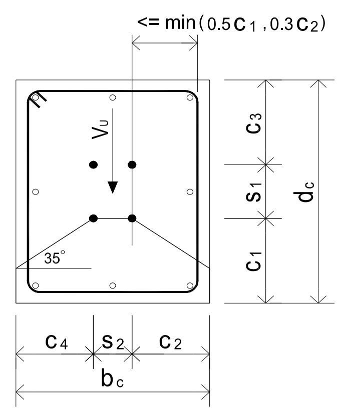
Factored <u>tension</u> for design	$\mathbf{N_u}$ =	**20.00**	[kips]		= 89.0	[kN]	
Factored shear	V_u =	25.00	[kips]		= 111.2	[kN]	
Factored shear for design	$\mathbf{V_u}$ =	**25.00**	[kips]	V_u = 0 if shear key is provided			
Concrete strength	f'_c =	4.0	[ksi]		= 27.6	[MPa]	
Anchor bolt material	=	F1554 Grade 36					
Anchor tensile strength	f_{uta} =	58	[ksi]		= 400	[MPa]	*ACI 318-11*
		Anchor is ductile steel element					D.1
Anchor bolt diameter	$\mathbf{d_a}$ =	**1**	[in]		= 25.4	[mm]	*PIP STE05121*
Bolt sleeve diameter	d_s =	3.0	[in]				Page A -1 Table 1
Bolt sleeve height	h_s =	10.0	[in]				
				min required			
Anchor bolt embedment depth	h_{ef} =	20.0	[in]	12.0	OK		Page A -1 Table 1
Pedestal height	h =	25.0	[in]	23.0	OK		
Pedestal width	b_c =	16.0	[in]				
Pedestal depth	d_c =	16.0	[in]				



Ver. Reinft For Tension



Hor. Ties For Shear - 4 Legs



Hor. Ties For Shear - 2 Legs

				min required		
Bolt edge distance c_1	c_1 =	5.0	[in]	4.5	OK	**Code Reference**
Bolt edge distance c_2	c_2 =	5.0	[in]	4.5	OK	*PIP STE05121*
Bolt edge distance c_3	c_3 =	5.0	[in]	4.5	OK	Page A -1 Table 1
Bolt edge distance c_4	c_4 =	5.0	[in]	4.5	OK	
Outermost bolt line spacing s_1	s_1 =	6.0	[in]	4.0	OK	Page A -1 Table 1
Outermost bolt line spacing s_2	s_2 =	6.0	[in]	4.0	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} = 4.0 [in]

No of ver. rebar that are effective for resisting anchor tension n_v = 2

Ver. bar size No. 8 : 1.000 [in] dia single bar area A_s = 0.79 [in^2]

Ver. bar top anchorage option = 180 Degree Hook or Hairpin ?

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 min($0.5c_1$, $0.3c_2$) = **1.5** [in] RD.6.2.9

No of tie <u>leg</u> that are effective to resist anchor shear n_{leg} = 2 ?

No of tie <u>layer</u> that are effective to resist anchor shear n_{lay} = 2 ?

Hor. tie bar size No. 4 : 0.500 [in] dia single bar area A_s = 0.20 [in^2]

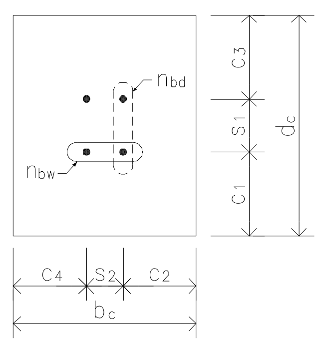
For anchor reinft shear breakout strength calc 100% hor. tie bars develop full yield strength ?

				suggest
Rebar yield strength - ver. bar	f_{y-v} =	60	[ksi]	60
Rebar yield strength - hor. bar	f_{y-h} =	60	[ksi]	60
No of bolt carrying tension	n_t =	4		
No of bolt carrying shear	n_s =	4		

For side-face blowout check use

No of bolt along width edge n_{bw} = 2

No of bolt along depth edge n_{bd} = 2



Bolt No Input for Side-Face Blowout Check Use

Anchor head type = Hex ?

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

Bearing area of head A_{brg} = **1.163** [in^2]

A_{brg} [in^2] not applicable

Bolt 1/8" (3mm) corrosion allowance = No ?

Provide shear key ? = 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 option Tensile = Option 4 ? Shear = Option 3 ? D.3.3.4.3 & D.3.3.5.3

				Code Reference
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**	
Min Rquired Anchor Reinft. Development Length	ratio = 0.53	**OK**	12.5.1
Overall	ratio = **0.81**	**OK**	
Tension			
Anchor Rod Tensile Resistance	ratio = 0.19	**OK**	
Anchor Reinft Tensile Breakout Resistance	ratio = 0.28	**OK**	
Anchor Pullout Resistance	ratio = 0.26	**OK**	
Side Blowout Resistance	ratio = 0.27	**OK**	
Shear			
Anchor Rod Shear Resistance	ratio = 0.57	**OK**	
Anchor Reinft Shear Breakout Resistance			
Strut Bearing Strength	ratio = 0.59	**OK**	
Tie Reinforcement	ratio = 0.69	**OK**	
Conc. Pryout Not Govern When h_{ef} >= $12d_a$		**OK**	
Tension Shear Interaction			
Tension Shear Interaction	ratio = 0.81	**OK**	

Seismic Design

Tension	Applicable	**OK**	D.3.3.4

Seismic SDC>=C and E>0.2U , Option 4 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 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

CACULATION

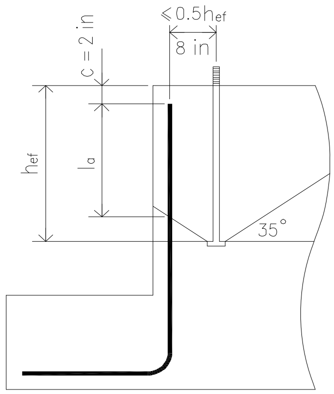
Anchor Rod Tensile	$\phi_{t,s} N_{sa} = \phi_{t,s} n_t A_{se} f_{uta}$	= 105.44	[kips]		D.5.1.2 (D-2)
Resistance	ratio = 0.19	> N_u		**OK**	

Anchor Reinft Tensile Breakout Resistance

Min tension development length	l_d = straight bar case not applicable	= 0.00	[in]		12.2.1, 12.2.2, 12.2.4
for ver. #8 bar	l_{dh} = 180 hook case applicable	= 13.28	[in]		12.5.2, 12.5.3(a)
Actual development lenngth	$l_a = h_{ef}$ - c (2 in) - d_{ar} x tan35	= 15.20	[in]		
		> 8.00		**OK**	12.5.1

Code Reference

ACI 318-11



$\phi_s N_n = \phi_s \times f_{y\text{-}v} \times n_v \times A_s \times (l_a / l_d \text{, if } l_a < l_d)$ = 71.10 [kips] D.3.3.4.5 & D.5.2.9

12.2.5

ratio = 0.28 > N_u **OK**

Anchor Pullout Resistance

Single bolt pullout resistance $N_p = 8\, A_{brg}\, f_c'$ = 37.22 [kips] D.5.3.4 (D-14)

$\phi_{t,c} N_{pn} = \phi_{t,c}\, n_t\, \Psi_{c,p}\, N_p$ = 104.20 [kips] D.5.3.1 (D-13)

Seismic design strength reduction = x 0.75 applicable = 78.15 [kips] D.3.3.4.4

ratio = 0.26 > N_u **OK**

$\Psi_{c,p}$ = 1 for cracked conc D.5.3.6

$\phi_{t,c}$ = 0.70 pullout strength is always Condition B D.4.3(c)

Side Blowout Resistance

Failure Along Pedestal Width Edge

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

along pedestal width edge $N_{buw} = N_u \times n_{bw} / n_t$ = 10.00 [kips] RD.5.4.2

$c = \min(c_1, c_3)$ = 5.0 [in]

Check if side blowout applicable h_{ef} = 20.0 [in]

> 2.5c side bowout is applicable D.5.4.1

Check if edge anchors work as a s_{22} = 6.0 [in] $s = s_2$ = 6.0 [in]

a group or work individually < 6c edge anchors work as a group D.5.4.2

Single anchor SB resistance $\phi_{t,c} N_{sb} = \phi_{t,c} \left(160\, c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$ = 40.92 [kips] D.5.4.1 (D-16)

Multiple anchors SB resistance $\phi_{t,c} N_{sbg,w}$ =

work as a group - applicable = $(1+s/6c) \times \phi_{t,c} N_{sb}$ = 49.11 [kips] D.5.4.2 (D-17)

work individually - not applicable = $n_{bw} \times \phi_{t,c} N_{sb} \times [1+(c_2 \text{ or } c_4)/c] / 4$ = 0.00 [kips] D.5.4.1

Seismic design strength reduction = x 0.75 applicable = 36.83 [kips] D.3.3.4.4

ratio = 0.27 > N_{buw} **OK**

Failure Along Pedestal Depth Edge

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

$c = \min(c_2, c_4)$ = 5.0 [in]

Check if side blowout applicable h_{ef} = 20.0 [in]

> 2.5c side bowout is applicable D.5.4.1

Code Reference

ACI 318-11

Check if edge anchors work as a s_{11} = 6.0 [in] $s = s_1$ = 6.0 [in]

a group or work individually < 6c edge anchors work as a group D.5.4.2

Single anchor SB resistance $\phi_{t,c}\, N_{sb} = \phi_{t,c} \left(160\, c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$ = 40.92 [kips] D.5.4.1 (D-16)

Multiple anchors SB resistance $\phi_{t,c} N_{sbg,d}$ =

work as a group - applicable = $(1+s/\,6c) \times \phi_{t,c}\, N_{sb}$ = 49.11 [kips] D.5.4.2 (D-17)

work individually - not applicable = $n_{bd} \times \phi_{t,c}\, N_{sb} \times [1+(c_1 \text{ or } c_3)\,/\,c]\,/\,4$ = 0.00 [kips] D.5.4.1

Seismic design strength reduction = x 0.75 applicable = 36.83 [kips] D.3.3.4.4

ratio = 0.27 > N_{bud} **OK**

Group side blowout resistance $\phi_{t,c}\, N_{sbg} = \phi_{t,c}\, \min\left(\frac{N_{sbg,w}}{n_{bw}} n_t\,,\ \frac{N_{sbg,d}}{n_{bd}} n_t\right)$ = 73.66 [kips]

Govern Tensile Resistance $\mathbf{N_r} = \min(\phi\, N_{sa}, \phi\, N_n, \phi\, N_{pn}, \phi\, N_{sbg})$ = **71.10** [kips]

Note: Anchor bolt sleeve portion must be tape wrapped and grouted to resist shear

Anchor Rod Shear Resistance $\phi_{v,s} V_{sa} = \phi_{v,s}\, n_s\, 0.6\, A_{se}\, f_{uta}$ = 54.83 [kips] D.6.1.2 (b) (D-29)

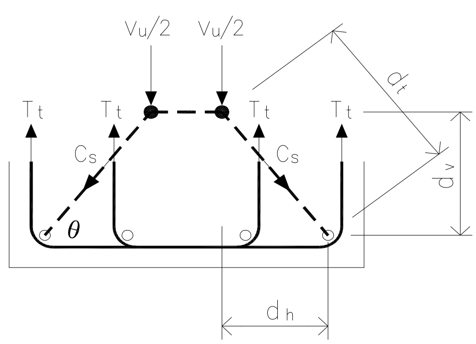
Reduction due to built-up grout pads = x 0.8 , applicable = 43.86 [kips] D.6.1.3

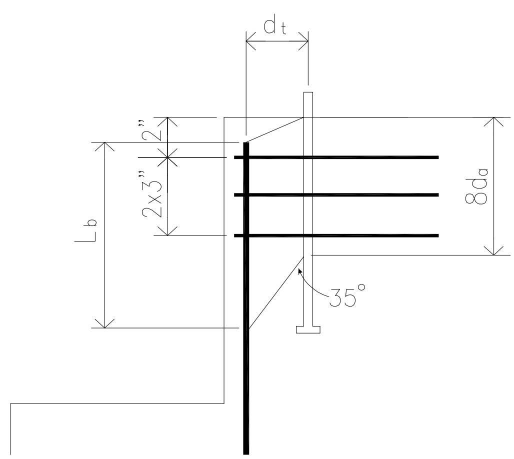
ratio = 0.57 > V_u **OK**

Anchor Reinft Shear Breakout Resistance

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





					Code Reference
Strut-and-Tie model geometry	d_v = 2.250 [in]	d_h = 2.250	[in]		*ACI 318-11*
	θ = 45	d_t = 3.182	[in]		
Strut compression force	C_s = 0.5 V_u / sinθ	= 17.68	[kips]		
Strut Bearing Strength					
Strut compressive strength	f_{ce} = 0.85 f'_c	= 3.4	[ksi]		A.3.2 (A-3)
* Bearing of anchor bolt					
Anchor bearing length	l_e = min($8d_a$, h_{ef})	= 8.0	[in]		D.6.2.2
Anchor bearing area	A_{brg} = l_e x d_a	= 8.0	[in^2]		
Anchor bearing resistance	C_r = n_s x ϕ_{st} x f_{ce} x A_{brg}	= 81.60	[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	= 11.8	[in^2]		
Ver bar bearing resistance	C_r = ϕ_{st} x f_{ce} x A_{brg}	= 30.02	[kips]		
	ratio = 0.59	> 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	= 3.04	[kips]		D.5.3.5 (D-15)
	e_h = 4.5 d_b	= 2.250	[in]		
Single tie bar tension resistance	T_r = ϕ_s x $f_{y\text{-}h}$ x A_s	= 9.00	[kips]		
Total tie bar tension resistance	$\phi_s V_n$ = 1.0 x n x Tr	= 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

	$12d_a$ = 12.0 [in]	h_{ef} = 20.0	[in]	
		> $12d_a$	**OK**	
Govern Shear Resistance	$\mathbf{V_r}$ = min ($\phi_{v,s}V_{sa}$, $\phi_s V_n$)	= **36.00**	[kips]	

Code Reference
ACI 318-11

Tension Shear Interaction

Check if $N_u > 0.2\phi\ N_n$ and $V_u > 0.2\phi\ V_n$	Yes			D.7.1 & D.7.2
	$N_u / \phi\ N_n + V_u / \phi\ V_n$	= 0.98		D.7.3 (D-42)
ratio = 0.81		< 1.2	**OK**	

Seismic Design

Tension	Applicable			**OK**
Steel nominal strength x 1.2	$1.2N_{sa}$ = 0.00 [kips]			
Concrete-governed nominal strength	N_{pn} = 0.00 [kips]	N_{sbg} = 0.00	[kips]	
	N_u / min(N_{pn}, N_{sbg}) = 0.00	$N_u / 1.2N_{sa}$ = 0.00		
		> 0.00		**NA**

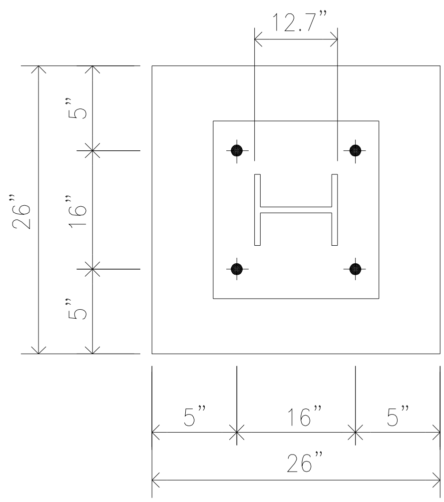
Not Applicable - Check Option 1 D.3.3.4.3 (a) subsections 1~2

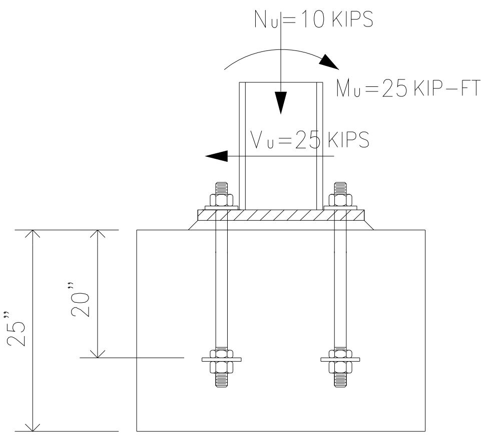
Seismic SDC>=C and E>0.2U , Option 4 is selected to satisfy additional seismic requirements as per D.3.3.4.3

Shear	Applicable	**OK**

Seismic SDC>=C and E>0.2U , Option 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

Example 04: Group Anchor Bolt + No Anchor Reinft + Tension Shear & Moment + ACI 318-11 Code





N_u= 10 kips (Compression) V_u = 25 kips M_u= 25 kip-ft

Concrete f_c’= 4 ksi

Pedestal size   26” x 26”

Anchor bolt   F1554 Grade 36   1.25” dia   Hex Head h_{ef} = 20” h_a =25”

Supplementary Reinforcement

Tension → Yes   Shear → $\Psi_{c,v}$ =1.4

Cracked concrete

Provide built-up grout pad

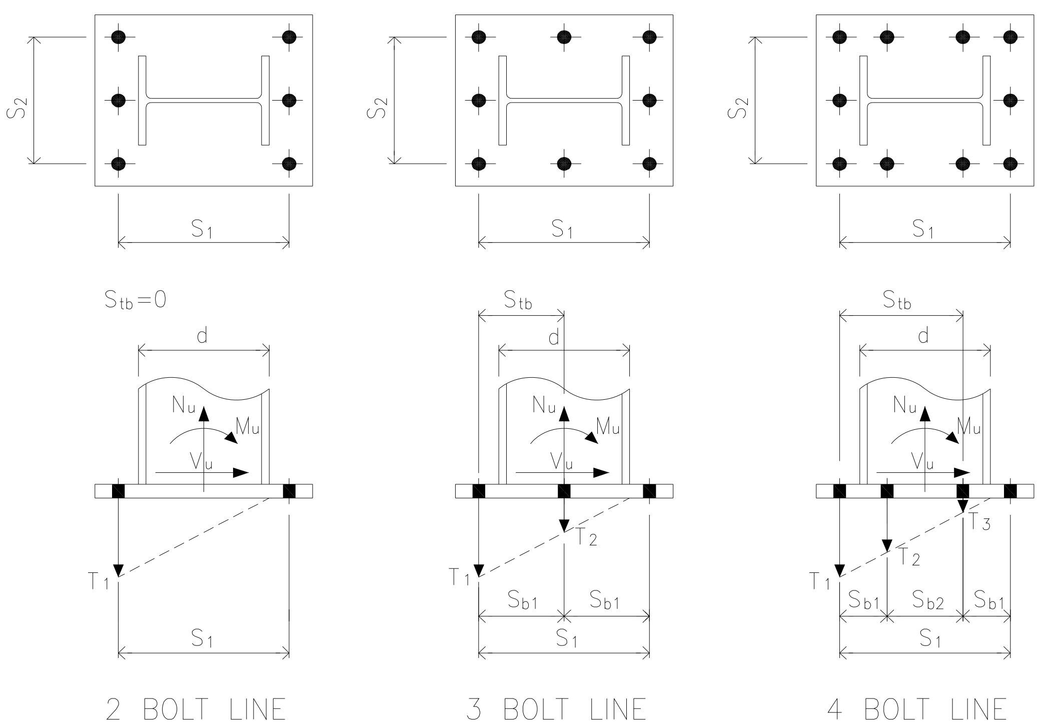
Seismic design category >= C   Tension → Option 1   Shear → Option 3

ANCHOR BOLT DESIGN **Combined Tension, Shear and Moment**

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*
		Code Reference
Assumptions		*ACI 318-11*
1. Concrete is cracked		D.5.2.6, D5.3.6, D.6.2.7
2. Condition A - supplementary reinforcement provided		D.4.3 (c)
3. Load combinations shall be per ACI 318-11 9.2		D.4.3
4. Shear load acts through center of bolt group $\Psi_{ec,V}$ =1.0		D.6.2.5
5. For anchor group subject to moment, the anchor tensile load is designed using elastic analysis and there is no redistribution of the forces between highly stressed and less stressed anchors		D.3.1
6. For anchor tensile force calc in anchor group subject to moment, assume the compression resultant is at the outside edge of the compression flange and base plate exhibits rigid-body rotation. This simplified approach yields conservative output		
7. 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

Anchor Bolt Data

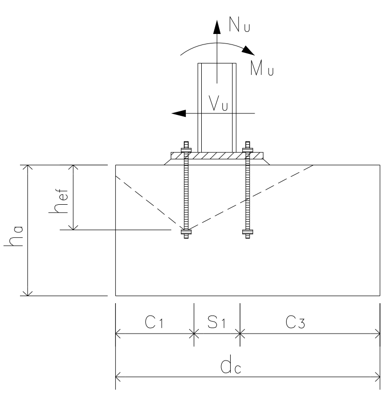
Factored moment	M_u	= 25.00	[kip-ft]		= 33.9	[kNm]
Factored tension /compression	N_u	= -10.00	[kips]	in compression	= -44.5	[kN]
Factored shear	V_u	= 25.00	[kips]		= 111.2	[kN]
Factored shear for bolt design	$\mathbf{V_u}$	= **25.00**	[kips]	V_u = 0 if shear key is provided		

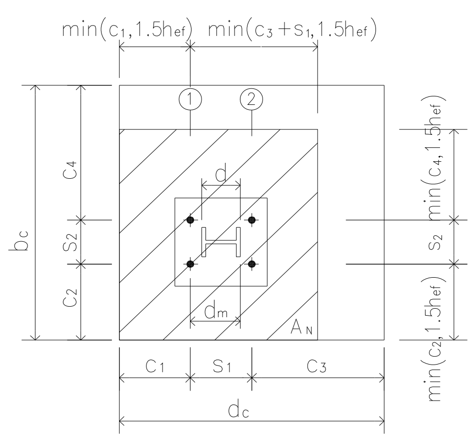


No of bolt line for resisting moment = 2 Bolt Line

No of bolt along outermost bolt line = 2

Item	Symbol	Value	Unit	Min required	Check	Converted	Code Reference
No of bolt along side edge	n_{bd} =	2					
				min required			*PIP STE05121*
Outermost bolt line spacing s_1	s_1 =	16.0	[in]	5.0	**OK**		Page A -1 Table 1
Outermost bolt line spacing s_2	s_2 =	16.0	[in]	5.0	**OK**		
Internal bolt line spacing s_{b1}	s_{b1} =	6.0	[in]	5.0	**OK**		
Internal bolt line spacing s_{b2}	s_{b2} =	0.0	[in]	5.0	**OK**		
Max spacing between anchors in tension	=	16.0	[in]				
Column depth	d =	12.7	[in]				
Concrete strength	f'_c =	4.0	[ksi]			= 27.6 [MPa]	
Anchor bolt material	=	F1554 Grade 36					
Anchor tensile strength	f_{uta} =	58	[ksi]			= 400 [MPa]	*ACI 318-11*
		Anchor is ductile steel element					D.1
Anchor bolt diameter	d_a =	**1.25**	[in]			= 31.8 [mm]	*PIP STE05121*
Bolt sleeve diameter	d_s =	3.0	[in]				Page A -1 Table 1
Bolt sleeve height	h_s =	10.0	[in]				
				min required			
Anchor bolt embedment depth	h_{ef} =	20.0	[in]	15.0	**OK**		Page A -1 Table 1
Concrete thickness	h_a =	25.0	[in]	23.0	**OK**		
Bolt edge distance c_1	c_1 =	5.0	[in]	5.0	**OK**		Page A -1 Table 1
Bolt edge distance c_2	c_2 =	5.0	[in]	5.0	**OK**		
Bolt edge distance c_3	c_3 =	5.0	[in]	5.0	**OK**		
Bolt edge distance c_4	c_4 =	5.0	[in]	5.0	**OK**		*ACI 318-11*
$c_i > 1.5h_{ef}$ for at least two edges to avoid reducing of h_{ef} when $N_u > 0$					**No**		D.5.2.3
Adjusted h_{ef} for design	h_{ef} =	**5.33**	[in]	15.0	**Warn**		D.5.2.3





Number of bolt at bolt line 1	n_1 =	2			**Code Reference**
Number of bolt at bolt line 2	n_2 =	2			*ACI 318-11*
Number of bolt carrying tension	n_t =	2			
Oversized holes in base plate ?	=	No	?		
Total no of anchor bolt	n =	4			
Number of bolt carrying shear	n_s =	4			
Anchor head type	=	Hex	?		
Anchor effective cross sect area	A_{se} =	0.969	[in^2]		
Bearing area of head	A_{brg} =	**1.817**	[in^2]		
	A_{brg}		[in^2]	not applicable	
Bolt 1/8" (3mm) corrosion allowance		No	?		
Provide shear key ?		No	?		
Supplementary reinforcement					
For tension		Yes	Condition A		D.4.3 (c)
For shear	$\Psi_{c,V}$ =	1.4	Condition A	?	D.6.2.7
Provide built-up grout pad ?		Yes	?		D.6.1.3
Concrete cracking	=	cracked	?		D.5.2.6, D5.3.6, D.6.2.7
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 option	Tensile =	Option 1	?	Shear = Option 3 ?	D.3.3.4.3 & D.3.3.5.3
Strength reduction factors					
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	$\phi_{t,c}$ =	0.75	Cdn-A	$\phi_{v,c}$ = 0.75 Cdn-A	D.4.3 (c)

CONCLUSION

Anchor Rod Embedment, Spacing and Edge Distance		**Warn**
Overall	ratio = **2.41**	**NG**
Tension		
Anchor Rod Tensile Resistance	ratio = 0.20	**OK**
Conc. Tensile Breakout Resistance	ratio = 1.34	**NG**
Anchor Pullout Resistance	ratio = 0.27	**OK**
Side Blowout Resistance	ratio = 0.28	**OK**
Shear		
Anchor Rod Shear Resistance	ratio = 0.36	**OK**
Conc. Shear Breakout Resistance - Perpendicular To Edge	ratio = 1.56	**NG**
Conc. Shear Breakout Resistance - Parallel To Edge	ratio = 1.12	**NG**
Conc. Pryout Shear Resistance	ratio = 1.09	**NG**

					Code Reference
Tension Shear Interaction					
Tension Shear Interaction		ratio = 2.41		**NG**	*ACI 318-11*

Seismic Design			
Tension	Applicable	**NG**	D.3.3.4

Option 1 is NOT satisfied

Seismic SDC>=C and E>0.2U , Option 1 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 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

CALCULATION

Anchor Tensile Force

Single bolt tensile force	T_1 = 8.24	[kips]	No of bolt for T_1 n_{T1} = 2			
	T_2 = 0.00	[kips]	No of bolt for T_2 n_{T2} = 0			
	T_3 = 0.00	[kips]	No of bolt for T_3 n_{T3} = 0			
Sum of bolt tensile force	$\mathbf{N_u} = \Sigma\, n_i\, T_i$			= **16.48**	[kips]	

Tensile bolts outer distance s_{tb} s_{tb} = 0.0 [in]

Eccentricity e'_N -- distance between resultant of tensile load and centroid of anchors loaded in tension e'_N = 0.00 [in] Fig. RD.5.2.4 (b)

Eccentricity modification factor $\Psi_{ec,N} = \dfrac{1}{\left(1+\dfrac{2e'_N}{3h_{ef}}\right)}$ = 1.00 D.5.2.4 (D-8)

Anchor Rod Tensile Resistance	$\phi_{t,s} N_{sa} = \phi_{t,s} A_{se} f_{uta}$	= 42.15	[kips]	D.5.1.2 (D-2)
	ratio = 0.20	> T_1	**OK**	

Conc. Tensile Breakout Resistance

	$N_b = 24\,\lambda\sqrt{f'_c}\;h_{ef}^{1.5}$ if $h_{ef} < 11"$ or $h_{ef} > 25"$	= 18.70	[kips]	D.5.2.2 (D-6)
	$16\,\lambda\sqrt{f'_c}\;h_{ef}^{5/3}$ if $11" \le h_{ef} \le 25"$			D.5.2.2 (D-7)
Projected conc failure area	$1.5h_{ef}$ =	= 8.00	[in]	
	A_{Nc} = [s_{tb}+min(c_1,1.5h_{ef})+min(c_3,1.5h_{ef})]x [s_2+min(c_2,1.5h_{ef})+min(c_4,1.5h_{ef})]	= 338.0	[in^2]	
	$A_{Nco} = 9\,h_{ef}^2$	= 256.0	[in^2]	D.5.2.1 (D-5)
	A_{Nc} = min (A_{Nc}, $n_t\,A_{Nco}$)	= 338.0	[in^2]	D.5.2.1
Min edge distance	c_{min} = min(c_1, c_2, c_3, c_4)	= 5.0	[in]	
Eccentricity effects	$\Psi_{ec,N}$ =	= 1.00		D.5.2.4 (D-8)
Edge effects	$\Psi_{ed,N}$ = min[(0.7+0.3c_{min}/1.5h_{ef}), 1.0]	= 0.89		D.5.2.5
Concrete cracking	$\Psi_{c,N}$ = 1.00 for cracked concrete			D.5.2.6
Concrete splitting	$\Psi_{cp,N}$ = 1.0 for cast-in anchor			D.5.2.7

					Code Reference
					ACI 318-11
Concrete breakout resistance	$\phi_{t,c} N_{cbg}$	$= \phi_{t,c} \frac{A_{Nc}}{A_{Nco}} \Psi_{ec,N} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$	= 16.43	[kips]	D.5.2.1 (D-4)
Seismic design strength reduction		= x 0.75 applicable	= 12.32	[kips]	D.3.3.4.4
	ratio	= 1.34	< N_u	**NG**	
Anchor Pullout Resistance					
Single bolt pullout resistance	N_p	$= 8 A_{brg} f_c'$	= 58.14	[kips]	D.5.3.4 (D-14)
	$\phi_{t,c} N_{pn}$	$= \phi_{t,c} \Psi_{c,p} N_p$	= 40.70	[kips]	D.5.3.1 (D-13)
Seismic design strength reduction		= x 0.75 applicable	= 30.53	[kips]	D.3.3.4.4
	ratio	= 0.27	> T_1	**OK**	
	$\Psi_{c,p}$	= 1.00 for cracked concrete			D.5.3.6
	$\phi_{t,c}$	= 0.70 pullout strength is always Condition B			D.4.3(c)
Side Blowout Resistance					
<u>Failure Along Pedestal Width Edge</u>					
Tensile load carried by anchors close to edge which may cause side-face blowout					
along pedestal width edge	N_{buw}	$= n_{T1} T_1$	= 16.48	[kips]	RD.5.4.2
	c	= min (c_1, c_3)	= 5.0	[in]	
Check if side blowout applicable	h_{ef}	= 20.0 [in]			
		> 2.5c side bowout is applicable			D.5.4.1
Check if edge anchors work as a	s_{22}	= 16.0 [in] $s = s_2$	= 16.0	[in]	
a group or work individually		< 6c edge anchors work as a group			D.5.4.2
Single anchor SB resistance	$\phi_{t,c} N_{sb}$	$= \phi_{t,c} \left(160 c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$	= 51.15	[kips]	D.5.4.1 (D-16)
Multiple anchors SB resistance	$\phi_{t,c} N_{sbg,w}$	=			
work as a group - applicable		= (1+s/ 6c) x $\phi_{t,c} N_{sb}$	= 78.43	[kips]	D.5.4.2 (D-17)
work individually - not applicable		= n_{bw} x $\phi_{t,c} N_{sb}$ x [1+(c_2 or c_4) / c] / 4	= 0.00	[kips]	D.5.4.1
Seismic design strength reduction		= x 0.75 applicable	= 58.82	[kips]	D.3.3.4.4
	ratio	= 0.28	> N_{buw}	**OK**	
Group side blowout resistance	$\phi_{t,c} N_{sbg}$	$= \phi_{t,c} \frac{N_{sbgr,w}}{n_{T1}} n_t$	= 58.82	[kips]	
Govern Tensile Resistance	$\mathbf{N_r}$	= min ($\phi n_t N_{sa}$, ϕN_{cbg}, $\phi n_t N_{pn}$, ϕN_{sbg})	= **12.32**	[kips]	

Note: Anchor bolt sleeve portion must be tape wrapped and grouted to resist shear

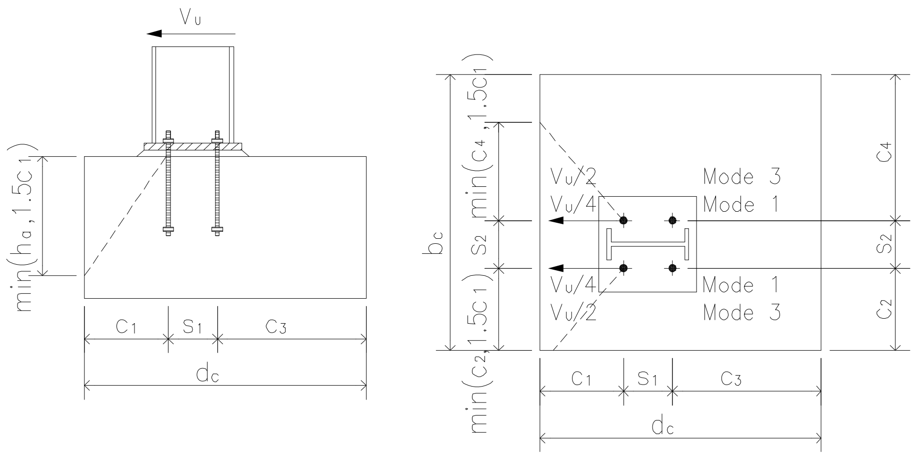
Anchor Rod Shear Resistance	$\phi_{v,s} V_{sa}$	$= \phi_{v,s} n_s 0.6 A_{se} f_{uta}$	= 87.68	[kips]	D.6.1.2 (b) (D-29)
Reduction due to built-up grout pads		= x 0.8 , applicable	= 70.14	[kips]	D.6.1.3
	ratio	= 0.36	> V_u	**OK**	

Code Reference

Conc. Shear Breakout Resistance - Perpendicular To Edge

Mode 1 Failure cone at front anchors, strength check against 0.5 x V_u

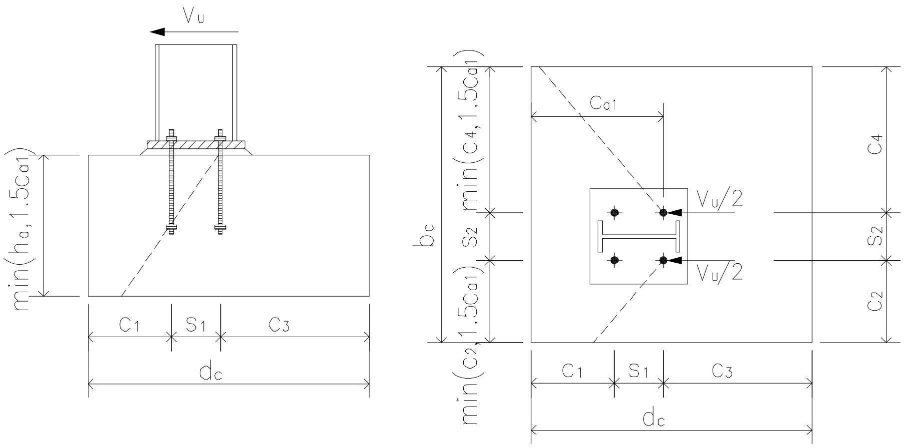
Mode 3 Failure cone at front anchors, strength check against 1.0 x V_u , applicable when oversized holes are used in base plate



ACI 318-11

Bolt edge distance	c_{a1} =		= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges			= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ =	ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	c_2 =		= 5.0	[in]	
	$1.5c_{a1}$ =		= 7.5	[in]	
	A_{Vc} =	$[\min(c_2,1.5c_{a1}) + s_2 + \min(c_4,1.5c_{a1})] \times \min(1.5c_{a1}, h_a)$	= 195.0	[in²]	D.6.2.1
	A_{Vco} =	$4.5c_{a1}^{\ 2}$	= 112.5	[in²]	D.6.2.1 (D-32)
	A_{Vc} =	$\min(A_{Vc},\ n_1 A_{Vco})$	= 195.0	[in²]	D.6.2.1
	l_e =	$\min(8d_a, h_{ef})$	= 10.0	[in]	D.6.2.2
	V_{b1} =	$\left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 8.39	[kips]	D.6.2.2 (D-33)
	V_{b2} =	$9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b =	$\min(V_{b1}, V_{b2})$	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ =	1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	$\min[(0.7+0.3c_2/1.5c_1), 1.0]$	= 0.90		D.6.2.6
Concrete cracking	$\Psi_{c,v}$ =	concrete is cracked	= 1.40		D.6.2.7
Member thickness	$\Psi_{h,v}$ =	$\max[(\mathrm{sqrt}(1.5c_1 / h_a), 1.0]$	= 1.00		D.6.2.8
Conc shear breakout resistance	V_{cbg1} =	$\phi_{v,c}\frac{A_{Vc}}{A_{Vco}}\Psi_{ec,V}\Psi_{ed,V}\Psi_{c,V}\Psi_{h,V}V_b$	= 10.42	[kips]	D.6.2.1 (D-31) Fig. RD.6.2.1 (b)
Mode 1 is used for checking	$\mathbf{V_{cbg1}}$ =	V_{cbg1} x 2.0	= **20.85**	[kips]	note

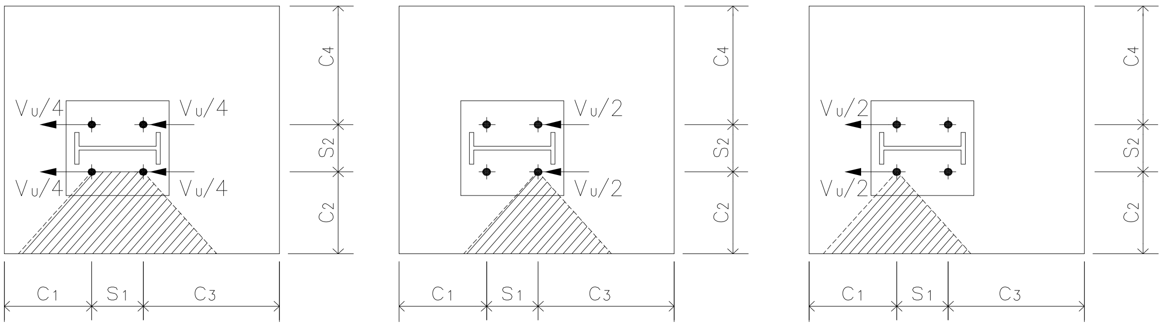
Mode 2 Failure cone at back anchors **Code Reference**



ACI 318-11

Bolt edge distance	c_{a1} =		= 21.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges			= Yes		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ =	ca1 needs to be adjusted	= **16.7**	[in]	D.6.2.4
	c_2 =		5.0	[in]	
	$1.5c_{a1}$ =		25.0	[in]	
	A_{Vc} =	$[\min(c_2,1.5c_{a1}) + s_2 + \min(c_4,1.5c_{a1})] \times \min(1.5c_{a1}, h_a)$	= 650.0	[in^2]	D.6.2.1
	A_{Vco} =	$4.5c_{a1}^2$	= 1250.0	[in^2]	D.6.2.1 (D-32)
	A_{Vc} =	$\min(A_{Vc},\ n_2 A_{Vco})$	= 650.0	[in^2]	D.6.2.1
	l_e =	$\min(8d_a, h_{ef})$	= 10.0	[in]	D.6.2.2
	V_{b1} =	$\left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 51.05	[kips]	D.6.2.2 (D-33)
	V_{b2} =	$9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 38.73	[kips]	D.6.2.2 (D-34)
	V_b =	$\min(V_{b1}, V_{b2})$	= 38.73	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ =	1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	$\min[(0.7+0.3c_2/1.5c_{a1}), 1.0]$	= 0.76		D.6.2.6
Concrete cracking	$\Psi_{c,v}$ =	concrete is cracked	= 1.40		D.6.2.7
Member thickness	$\Psi_{h,v}$ =	$\max[(\mathrm{sqrt}(1.5c_{a1} / h_a)), 1.0]$	= 1.00		D.6.2.8
Conc shear breakout resistance	V_{cbg2} =	$\phi_{v,c}\frac{A_{Vc}}{A_{Vco}}\Psi_{ec,V}\Psi_{ed,V}\Psi_{c,V}\Psi_{h,V}\ V_b$	= 16.07	[kips]	D.6.2.1 (D-31)
Min shear breakout resistance	$\phi_{v,c}V_{cbg}$ =	$\min(V_{cbg1}, V_{cbg2})$	= 16.07	[kips]	
	ratio =	1.56	< V_u	NG	

Conc. Shear Breakout Resistance - Parallel To Edge



MODE 1 MODE 2 MODE 3

Mode 1 Shear taken evenly by all anchor bolts, strength check against $0.5 \times V_u$					**Code Reference**
					ACI 318-11
Bolt edge distance	c_{a1}	$= \min(c_2 , c_4)$	= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges			= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$	= ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	$1.5c_{a1}$	=	= 7.5	[in]	
	A_{Vc}	$= [\min(c_1,1.5c_{a1}) + s_1 + \min(c_3,1.5c_{a1})] \times \min(1.5c_{a1}, h_a)$	= 195.0	[in^2]	D.6.2.1
	A_{Vco}	$= 4.5c_{a1}^2$	= 112.5	[in^2]	D.6.2.1 (D-32)
	A_{Vc}	$= \min (A_{Vc},\ n_{bd} A_{Vco})$	= 195.0	[in^2]	D.6.2.1
	l_e	$= \min(8d_a , h_{ef})$	= 10.0	[in]	D.6.2.2
	V_{b1}	$= \left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 8.39	[kips]	D.6.2.2 (D-33)
	V_{b2}	$= 9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b	$= \min(V_{b1} , V_{b2})$	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$	= 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$	=	= 1.00		D.6.2.1 (c)
Concrete cracking	$\Psi_{c,v}$	= concrete is cracked	= 1.40		D.6.2.7
Member thickness	$\Psi_{h,v}$	$= \max[(\mathrm{sqrt}(1.5c_{a1} / h_a) , 1.0]$	= 1.00		D.6.2.8
Conc shear breakout resistance - parallel to edge	$V_{cbg\text{-}p1}$	$= 2 \times \phi_{v,c} \frac{A_{Vc}}{A_{Vco}} \Psi_{ec,V}\ \Psi_{ed,V}\ \Psi_{c,V}\ \Psi_{h,V}\ V_b$	= 23.16	[kips]	D.6.2.1 (D-31) D.6.2.1 (c)
Mode 2 Shear taken evenly by back anchor bolts, strength check against $0.5 \times V_u$					
Bolt edge distance	c_{a1}	$= \min(c_2 , c_4)$	= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges			= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$	= ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	$1.5c_{a1}$	=	= 7.5	[in]	
	A_{Vc}	$= [\min((s_1+c_1,1.5c_{a1}) + \min(c_3,1.5c_{a1})] \times \min(1.5c_{a1}, h_a)$	= 93.8	[in^2]	D.6.2.1
	A_{Vco}	$= 4.5c_{a1}^2$	= 112.5	[in^2]	D.6.2.1 (D-32)

				Code Reference
				ACI 318-11
	A_{Vc} = min (A_{Vc}, n_{bd} A_{Vco})	= 93.8	[in^2]	D.6.2.1
	l_e = min($8d_a$, h_{ef})	= 10.0	[in]	D.6.2.2
	$V_{b1} = \left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 8.39	[kips]	D.6.2.2 (D-33)
	$V_{b2} = 9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b = min(V_{b1} , V_{b2})	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ = 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	= 1.00		D.6.2.1 (c)
Concrete cracking	$\Psi_{c,v}$ = concrete is cracked	= 1.40		D.6.2.7
Member thickness	$\Psi_{h,v}$ = max[(sqrt(1.5c_{a1} / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance - parallel to edge	$V_{cbg\text{-}p2} = 2 \times \phi_{v,c} \frac{A_{Vc}}{A_{Vco}} \Psi_{ec,V}\ \Psi_{ed,V}\ \Psi_{c,V}\ \Psi_{h,V}\ V_b$	= 11.14	[kips]	D.6.2.1 (D-31)
				D.6.2.1 (c)

Mode 3 Shear taken evenly by front anchor bolts, strength check against 0.5 x V_u

Bolt edge distance	c_{a1} = min(c_2 , c_4)	= 5.0	[in]	
Limiting c_{a1} when anchors are influenced by 3 or more edges		= No		D.6.2.4
Bolt edge distance - adjusted	$\mathbf{c_{a1}}$ = ca1 needs NOT to be adjusted	= **5.0**	[in]	D.6.2.4
	$1.5c_{a1}$ =	= 7.5	[in]	
	A_{Vc} = [min(c_1,1.5c_{a1}) + min(s_1+c_3,1.5c_{a1})] x min(1.5c_{a1}, h_a)	= 93.8	[in^2]	D.6.2.1
	A_{Vco} = 4.5$c_{a1}{}^2$	= 112.5	[in^2]	D.6.2.1 (D-32)
	A_{Vc} = min (A_{Vc}, n_{bd} A_{Vco})	= 93.8	[in^2]	D.6.2.1
	l_e = min($8d_a$, h_{ef})	= 10.0	[in]	D.6.2.2
	$V_{b1} = \left[7\left(\frac{l_e}{d_a}\right)^{0.2}\sqrt{d_a}\right]\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 8.39	[kips]	D.6.2.2 (D-33)
	$V_{b2} = 9\lambda\sqrt{f'_c}\ c_{a1}^{1.5}$	= 6.36	[kips]	D.6.2.2 (D-34)
	V_b = min(V_{b1} , V_{b2})	= 6.36	[kips]	D.6.2.2
Eccentricity effects	$\Psi_{ec,v}$ = 1.0 shear acts through center of group			D.6.2.5
Edge effects	$\Psi_{ed,v}$ =	= 1.00		D.6.2.1 (c)
Concrete cracking	$\Psi_{c,v}$ = concrete is cracked	= 1.40		D.6.2.7
Member thickness	$\Psi_{h,v}$ = max[(sqrt(1.5c_{a1} / h_a) , 1.0]	= 1.00		D.6.2.8
Conc shear breakout resistance - parallel to edge	$V_{cbg\text{-}p3} = 2 \times \phi_{v,c} \frac{A_{Vc}}{A_{Vco}} \Psi_{ec,V}\ \Psi_{ed,V}\ \Psi_{c,V}\ \Psi_{h,V}\ V_b$	= 11.14	[kips]	D.6.2.1 (D-31)
				D.6.2.1 (c)
Min shear breakout resistance shear parallel to edge	$\phi_{v,c}V_{cbg\text{-}p}$ = min ($V_{cbg\text{-}p1}$, $V_{cbg\text{-}p2}$, $V_{cbg\text{-}p3}$) x 2 side	= 22.27	[kips]	
	ratio = 1.12	< V_u	**NG**	

					Code Reference
					ACI 318-11
Conc. Pryout Shear Resistance					
	k_{cp}	= 2.0			D.6.3.1
Factored shear pryout resistance	$\phi_{v,c} V_{cpg}$	= $\phi_{v,c}\, k_{cp}\, N_{cbg}$	= 30.67	[kips]	D.6.3.1 (D-41)
	$\phi_{v,c}$	= 0.70 pryout strength is always Condition B			D.4.3(c)
Seismic design strength reduction		= x 0.75 applicable	= 23.00	[kips]	D.3.3.4.4
	ratio	= 1.09	< V_u	**NG**	
Govern Shear Resistance	$\mathbf{V_r}$	= min (ϕV_{sa}, ϕV_{cbg}, $\phi V_{cbg\text{-}p}$, ϕV_{cpg})	= **16.07**	[kips]	
Tension Shear Interaction					
Check if $N_u > 0.2\phi\, N_n$ and $V_u > 0.2\phi\, V_n$		Yes			D.7.1 & D.7.2
		$N_u / \phi\, N_n + V_u / \phi\, V_n$	= 2.89		D.7.3 (D-42)
	ratio	= 2.41	> 1.2	**NG**	

Seismic Design

Tension	Applicable					**NG**
Steel nominal strength x 1.2	$1.2 n_t N_{sa}$	= 134.88	[kips]	N_{cbg}	= 21.91	[kips]
Concrete-governed nominal strength	$n_t N_{pn}$	= 116.29	[kips]	N_{sbg}	= 104.58	[kips]
	N_u / min(N_{cbg}, N_{pn}, N_{sbg})	= 0.75		$N_u / 1.2 N_{sa}$	= 0.12	
					< 0.75	**NG**

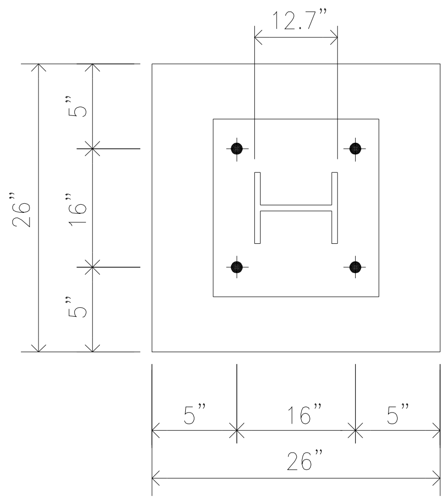
Option 1 is NOT satisfied

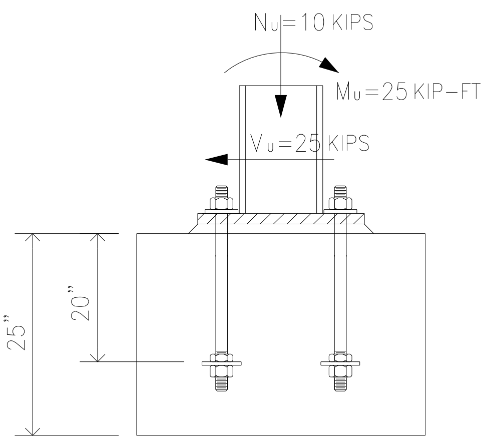
Seismic SDC>=C and E>0.2U , Option 1 is selected to satisfy additional seismic requirements as per D.3.3.4.3

Shear	Applicable	**OK**

Seismic SDC>=C and E>0.2U , Option 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

Example 05: Group Anchor Bolt + Anchor Reinft + Tension Shear & Moment + ACI 318-11 Code





N_u= 10 kips (Compression)			V_u = 25 kips	M_u= 25 kip-ft		
Concrete	f_c'= 4 ksi	Rebar	f_y = 60 ksi			
Pedestal size	26” x 26”					
Anchor bolt	F1554 Grade 36		1.25” dia	Hex Head	h_{ef} = 20”	h_a =25”
Anchor reinforcement		Tension → 4-No 8 ver. bar				
		Shear → 2-layer, 2-leg No 4 hor. bar				

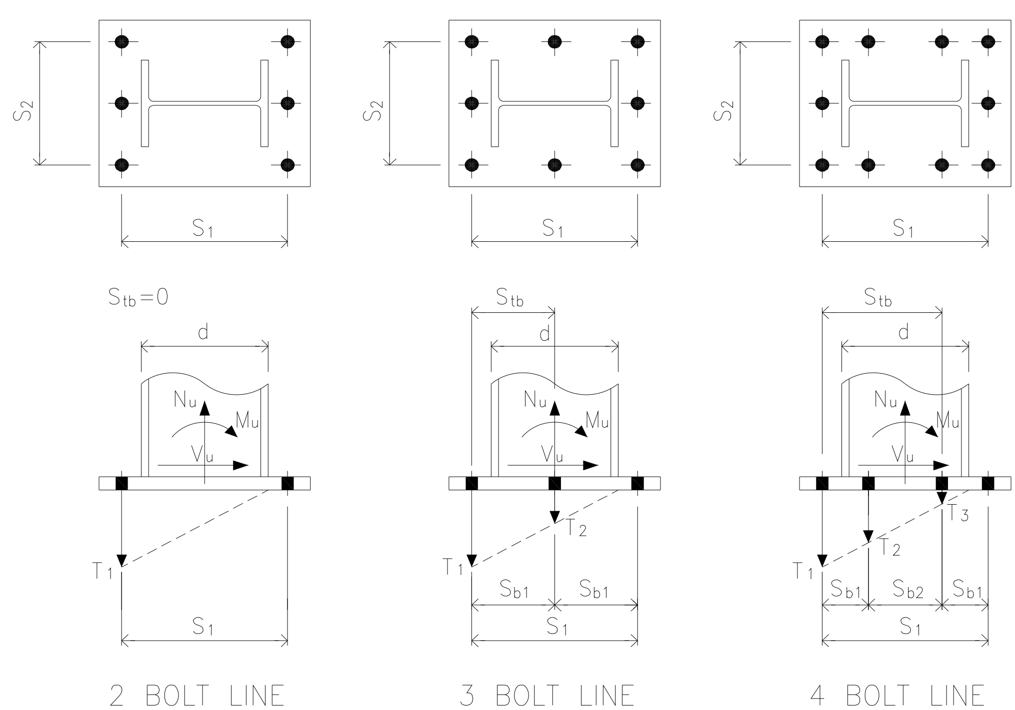
Provide built-up grout pad

Seismic design category >= C | Tension → Option 1 | Shear → Option 3

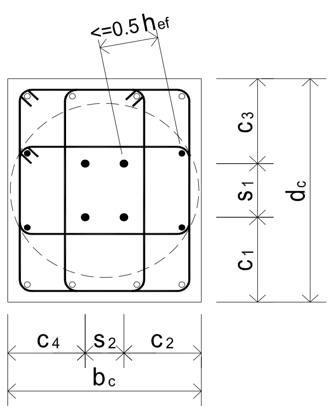
ANCHOR BOLT DESIGN **Combined Tension, Shear and Moment**

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*
	Code Reference
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. For anchor group subject to moment, the anchor tensile load is designed using elastic analysis and there is no redistribution of the forces between highly stressed and less stressed anchors	D.3.1
8. For anchor tensile force calc in anchor group subject to moment, assume the compression resultant is at the outside edge of the compression flange and base plate exhibits rigid-body rotation. This simplified approach yields conservative output	
9. Anchor reinft used in structures with SDC>=C shall meet requirements specified in D.3.3.7	D.3.3.7
10. Anchor bolt washer shall be tack welded to base plate for all anchor bolts to transfer shear	*AISC Design Guide 1*
Anchor Bolt Data	section 3.5.3

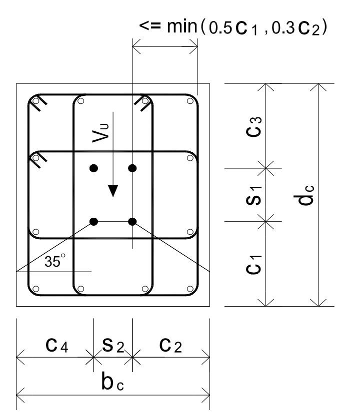
Factored moment	M_u	= 25.00	[kip-ft]		= 33.9	[kNm]
Factored tension /compression	N_u	= -10.00	[kips]	in compression	= -44.5	[kN]
Factored shear	V_u	= 25.00	[kips]		= 111.2	[kN]
Factored shear for design	$\mathbf{V_u}$	= **25.00**	[kips]	V_u = 0 if shear key is provided		



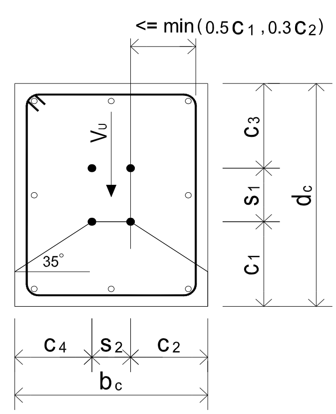
								Code Reference
No of bolt line for resisting moment	=	2 Bolt Line						
No of bolt along outermost bolt line	=	2						
				min required				*PIP STE05121*
Outermost bolt line spacing s_1	s_1 =	16.0	[in]	5.0	**OK**			Page A -1 Table 1
Outermost bolt line spacing s_2	s_2 =	16.0	[in]	5.0	**OK**			
Internal bolt line spacing s_{b1}	s_{b1} =	5.0	[in]	5.0	**OK**			
Internal bolt line spacing s_{b2}	s_{b2} =	0.0	[in]	5.0	**OK**			
Column depth	d =	12.7	[in]					
Concrete strength	f'_c =	4.0	[ksi]			= 27.6	[MPa]	
Anchor bolt material	=	F1554 Grade 36						
Anchor tensile strength	f_{uta} =	58	[ksi]			= 400	[MPa]	*ACI 318-11*
		Anchor is ductile steel element						D.1
Anchor bolt diameter	d_a =	**1.25**	[in]			= 31.8	[mm]	*PIP STE05121*
Bolt sleeve diameter	d_s =	3.0	[in]					Page A -1 Table 1
Bolt sleeve height	h_s =	10.0	[in]					
				min required				
Anchor bolt embedment depth	h_{ef} =	20.0	[in]	15.0	**OK**			Page A -1 Table 1
Pedestal height	h =	25.0	[in]	23.0	**OK**			
Pedestal width	b_c =	26.0	[in]					
Pedestal depth	d_c =	26.0	[in]					
Bolt edge distance c_1	c_1 =	5.0	[in]	5.0	**OK**			Page A -1 Table 1
Bolt edge distance c_2	c_2 =	5.0	[in]	5.0	**OK**			
Bolt edge distance c_3	c_3 =	5.0	[in]	5.0	**OK**			
Bolt edge distance c_4	c_4 =	5.0	[in]	5.0	**OK**			



Ver. Reinft For Tension

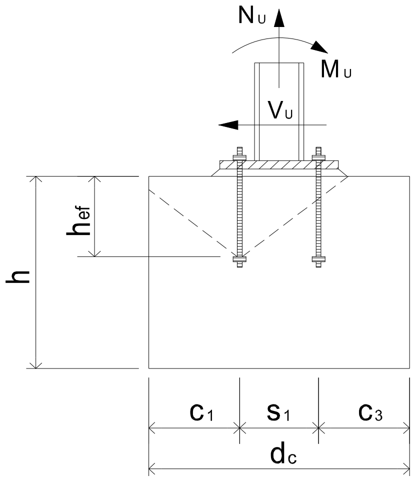


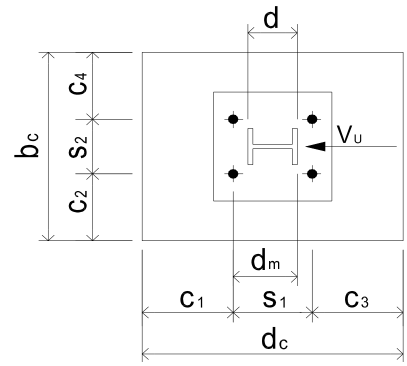
Hor. Ties For Shear - 4 Legs



Hor. Ties For Shear - 2 Legs

Code Reference





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} = 5.0 [in]

No of ver. rebar that are effective for resisting anchor tension n_v = 4

Ver. bar size No. 8 : 1.000 [in] dia single bar area A_s = 0.79 [in^2]

Ver. bar top anchorage option = 180 Degree Hook or Hairpin ?

Ver. bar to anchor rod c/c dist

To be considered effective for resisting anchor shear, hor. reinft shall be located RD.6.2.9

within min($0.5c_1$, $0.3c_2$) from the outmost anchor's centerline min($0.5c_1$, $0.3c_2$) = **1.5** [in]

No of tie leg that are effective to resist anchor shear n_{leg} = 2 ?

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

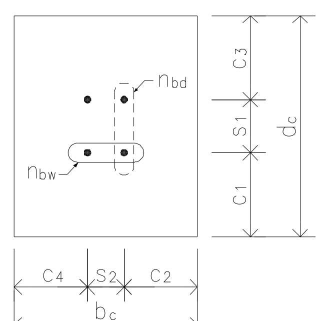
Hor. tie bar size No. 4 : 0.500 [in] dia single bar area A_s = 0.20 [in^2]

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

				suggest
Rebar yield strength - ver. bar	f_{y-v}	= 60	[ksi]	60
Rebar yield strength - hor. bar	f_{y-h}	= 60	[ksi]	60
Total no of anchor bolt	n	= 4		
No of bolt carrying tension	n_t	= 2		
No of bolt carrying shear	n_s	= 4		

For side-face blowout check use

No of bolt along width edge n_{bw} = 2



Bolt No Input for Side-Face Blowout Check Use

Anchor head type = Hex ?

Anchor effective cross sect area A_{se} = 0.969 [in^2]

Bearing area of head A_{brg} = **1.817** [in^2]

A_{brg} [in^2] not applicable

Bolt 1/8" (3mm) corrosion allowance = No ?

Provide shear key ? = No ? *ACI 318-11*

Provide built-up grout pad ? = Yes ? D.6.1.3

						Code Reference
						ACI 318-11
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 option	Tensile	= Option 1	?	Shear	= Option 3	? D.3.3.4.3 & D.3.3.5.3

Strength reduction factors

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**	
Min Rquired Anchor Reinft. Development Length	ratio = 0.55	**OK**	12.5.1
Overall	ratio = **0.81**	**OK**	
Tension			
Anchor Rod Tensile Resistance	ratio = 0.20	**OK**	
Anchor Reinft Tensile Breakout Resistance	ratio = 0.12	**OK**	
Anchor Pullout Resistance	ratio = 0.27	**OK**	
Side Blowout Resistance	ratio = 0.28	**OK**	
Shear			
Anchor Rod Shear Resistance	ratio = 0.36	**OK**	
Anchor Reinft Shear Breakout Resistance			
Strut Bearing Strength	ratio = 0.51	**OK**	
Tie Reinforcement	ratio = 0.69	**OK**	
Conc. Pryout Not Govern When h_{ef} >= $12d_a$		**OK**	
Tension Shear Interaction			
Tension Shear Interaction	ratio = 0.81	**OK**	

Seismic Design

Tension Applicable **NG** D.3.3.4

Option 1 is NOT satisfied

Seismic SDC>=C and E>0.2U , Option 1 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 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

Code Reference

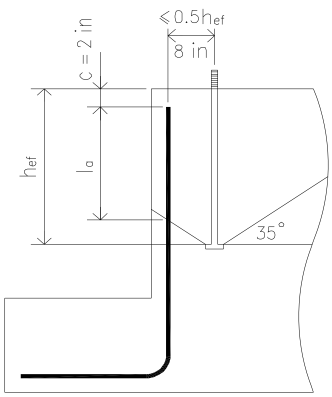
CACULATION *ACI 318-11*

Anchor Tensile Force

Single bolt tensile force	T_1 = 8.24	[kips]	No of bolt for T_1 n_{T1} = 2				
	T_2 = 0.00	[kips]	No of bolt for T_2 n_{T2} = 0				
	T_3 = 0.00	[kips]	No of bolt for T_3 n_{T3} = 0				
Sum of bolt tensile force	$\mathbf{N_u} = \Sigma\, n_i\, T_i$			= **16.48**	[kips]		
Anchor Rod Tensile	$\phi_{t,s}\, N_{sa} = \phi_{t,s}\, A_{se}\, f_{uta}$			= 42.15	[kips]		D.5.1.2 (D-2)
Resistance	ratio = 0.20			> T_1	**OK**		

Anchor Reinft Tensile Breakout Resistance

Min tension development length	l_d = straight bar case not applicable	= 0.00	[in]		12.2.1, 12.2.2, 12.2.4
for ver. #8 bar	l_{dh} = 180 hook case applicable	= 13.28	[in]		12.5.2, 12.5.3(a)
Actual development lenngth	$l_a = h_{ef}$ - c (2 in) - d_{ar} x tan35	= 14.50	[in]		
		> 8.00	**OK**		12.5.1



ACI 318-11

$\phi_s\, N_n = \phi_s$ x $f_{y\text{-}v}$ x n_v x A_s x (l_a / l_d , if $l_a < l_d$)	= 142.20	[kips]		D.3.3.4.5 & D.5.2.9
				12.2.5
ratio = 0.12	> N_u	**OK**		

Anchor Pullout Resistance

Single bolt pullout resistance	N_p = 8 A_{brg} f_c'	= 58.14	[kips]	D.5.3.4 (D-14)
	$N_{cpr} = \phi_{t,c}\, N_{pn} = \phi_{t,c}\, \Psi_{c,p}\, N_p$	= 40.70	[kips]	D.5.3.1 (D-13)
Seismic design strength reduction	= x 0.75 applicable	= 30.53	[kips]	D.3.3.4.4
	ratio = 0.27	> T_1	**OK**	
	$\Psi_{c,p}$ = 1 for cracked conc			D.5.3.6
	$\phi_{t,c}$ = 0.70 pullout strength is always Condition B			D.4.3 (c)

Side Blowout Resistance

<u>Failure Along Pedestal Width Edge</u>

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

along pedestal width edge $N_{buw} = n_{T1}\, T_1$ = 16.48 [kips] RD.5.4.2

					Code Reference
	c	$= \min(c_1, c_3)$	$= 5.0$	[in]	*ACI 318-11*
Check if side blowout applicable	h_{ef}	$= 20.0$ [in]			
		$> 2.5c$ side bowout is applicable			D.5.4.1
Check if edge anchors work as a	s_{22}	$= 16.0$ [in]	$s = s_2 = 16.0$	[in]	
a group or work individually		$< 6c$ edge anchors work as a group			D.5.4.2
Single anchor SB resistance	$\phi_{t,c} N_{sb}$	$= \phi_{t,c} \left(160\, c \sqrt{A_{brg}}\right) \lambda \sqrt{f'_c}$	$= 51.15$	[kips]	D.5.4.1 (D-16)
Multiple anchors SB resistance	$\phi_{t,c} N_{sbg,w}$	=			
work as a group - applicable		$= (1+s/\ 6c) \times \phi_{t,c} N_{sb}$	$= 78.43$	[kips]	D.5.4.2 (D-17)
work individually - not applicable		$= n_{bw} \times \phi_{t,c} N_{sb} \times [1+(c_2 \text{ or } c_4)/\ c] / 4$	$= 0.00$	[kips]	D.5.4.1
Seismic design strength reduction		$= \times 0.75$ applicable	$= 58.82$	[kips]	D.3.3.4.4
	ratio	$= 0.28$	$> N_{buw}$	**OK**	
Group side blowout resistance	$\phi_{t,c} N_{sbg}$	$= \phi_{t,c} \dfrac{N_{sbgr,w}}{n_{T1}} n_t$	$= 58.82$	[kips]	
Govern Tensile Resistance	$\mathbf{N_r}$	$= \min(\phi\, n_t N_{sa}, \phi N_n, \phi\, n_t N_{pn}, \phi N_{sbg})$	$=$ **58.82**	[kips]	

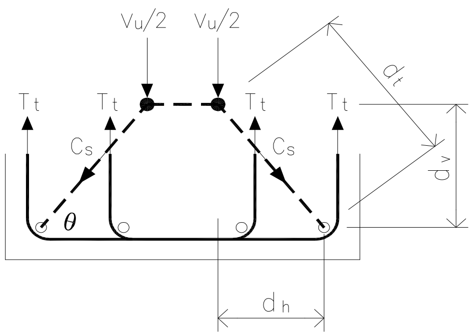
Note: Anchor bolt sleeve portion must be tape wrapped and grouted to resist shear

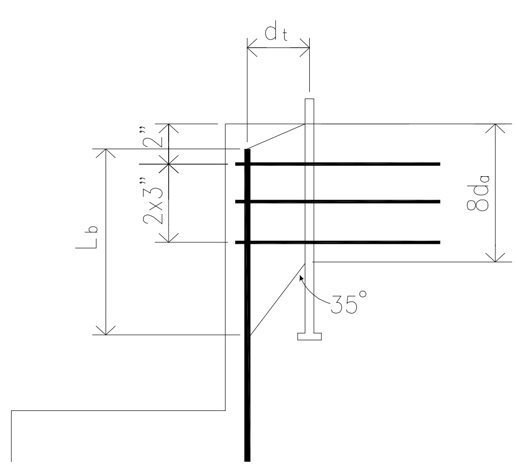
Anchor Rod Shear Resistance	$\phi_{v,s} V_{sa}$	$= \phi_{v,s} n_s 0.6 A_{se} f_{uta}$	$= 87.68$	[kips]	D.6.1.2 (b) (D-29)
Reduction due to built-up grout pads		$= \times 0.8$, applicable	$= 70.14$	[kips]	D.6.1.3
	ratio	$= 0.36$	$> V_u$	**OK**	

Anchor Reinft Shear Breakout Resistance

Strut-and-Tie model is used to anlyze the shear transfer and to design the required tie reinft

STM strength reduction factor $\phi_{st} = 0.75$ 9.3.2.6





					Code Reference
					ACI 318-11
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					
Strut compressive strength	f_{ce} = 0.85 f'_c		= 3.4	[ksi]	A.3.2 (A-3)
* Bearing of anchor bolt					
Anchor bearing length	l_e = min($8d_a$, h_{ef})		= 10.0	[in]	D.6.2.2
Anchor bearing area	A_{brg} = l_e x d_a		= 12.5	[in^2]	
Anchor bearing resistance	C_r = n_s x ϕ_{st} x f_{ce} x A_{brg}		= 127.50	[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		= 13.6	[in^2]	
Ver bar bearing resistance	C_r = ϕ_{st} x f_{ce} x A_{brg}		= 34.80	[kips]	
	ratio = 0.51		> 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.

					ACI 318-11
Total number of hor tie bar	n = n_{leg} (leg) x n_{lay} (layer)		= 4		
Pull out resistance at hook	T_h = $\phi_{t,c}$ 0.9 f_c' e_h d_a		= 3.04	[kips]	D.5.3.5 (D-15)
	e_h = 4.5 d_b		= 2.250	[in]	
Single tie bar tension resistance	T_r = ϕ_s x $f_{y\text{-}h}$ x A_s		= 9.00	[kips]	
Total tie bar tension resistance	$\phi_s V_n$ = 1.0 x n x Tr		= 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

	$12d_a$ = 15.0 [in]	h_{ef}	= 20.0	[in]	
			> $12d_a$	**OK**	
Govern Shear Resistance	$\mathbf{V_r}$ = min ($\phi_{v,s}V_{sa}$, $\phi_s V_n$)		= **36.00**	[kips]	

					Code Reference
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
	$N_u / \phi\ N_n + V_u / \phi\ V_n$		= 0.97		D.7.3 (D-42)
	ratio = 0.81		< 1.2	**OK**	

Seismic Design

Tension	Applicable				**NG**
Steel nominal strength x 1.2	$1.2n_t\ N_{sa}$ = 134.88	[kips]			
Concrete-governed nominal strength	$n_t\ N_{pn}$ = 116.29	[kips]	N_{sbg} = 104.58	[kips]	
	N_u / min(N_{pn}, N_{sbg}) = 0.16		$N_u / 1.2N_{sa}$ = 0.12		
			< 0.16		**NG**

Option 1 is NOT satisfied

Seismic SDC>=C and E>0.2U , Option 1 is selected to satisfy additional seismic requirements as per D.3.3.4.3

Shear	Applicable	**OK**

Seismic SDC>=C and E>0.2U , Option 3 is selected to satisfy additional seismic requirements as per D.3.3.5.3

6.0 REFERENCES

1. ACI 318-11 Building Code Requirements for Structural Concrete and Commentary

2. ACI 318M-11 Metric Building Code Requirements for Structural Concrete and Commentary

3. ACI 349-06 Code Requirements for Nuclear Safety-Related Concrete Structures & Commentary

4. ACI 349.2R-07 Guide to the Concrete Capacity Design (CCD) Method - Embedment Design Examples

5. ACI 355.3R-11 Guide for Design of Anchorage to Concrete: Examples Using ACI 318 Appendix D

6. Design of Anchor Reinforcement in Concrete Pedestals by Widianto, Chandu Patel, and Jerry Owen

7. CSA A23.3-04 (R2010) - Design of Concrete Structures

8. AISC Design Guide 1: Base Plate and Anchor Rod Design 2nd Edition

9. PIP STE05121 Anchor Bolt Design Guide-2006