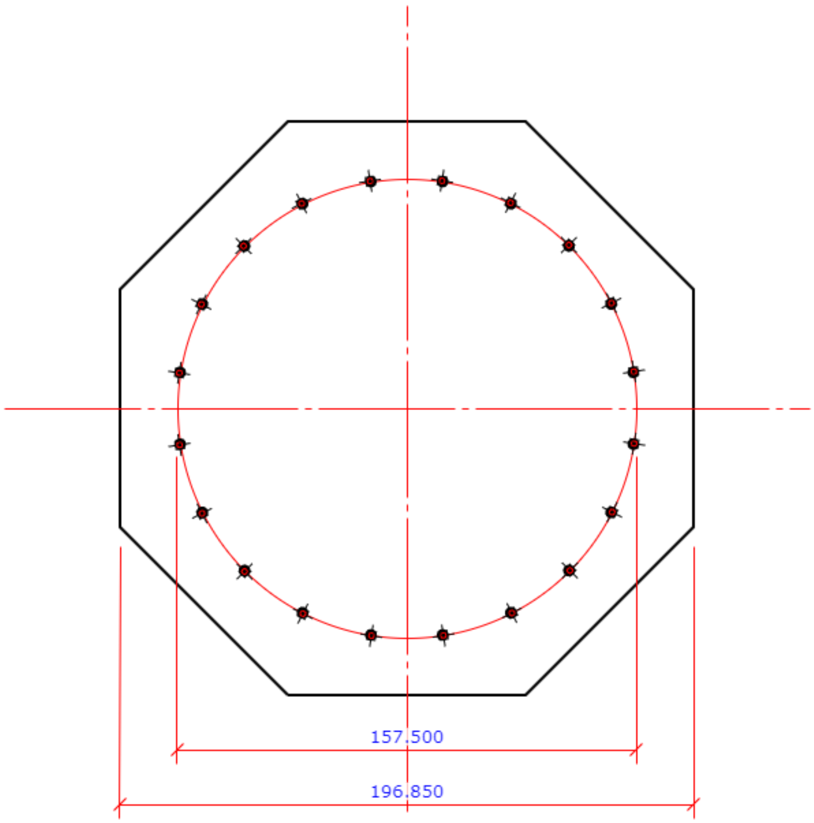
Result Summary - Overall	Anchorage Design	Code=ACI 318-19

Result Summary - Overall	geometries & weld limitations = **PASS**	limit states max ratio = **0.50**	**PASS**
Vertical Vessel Leg Anchor	geometries & weld limitations = **PASS**	limit states max ratio = **0.50**	**PASS**

Sketch	Anchorage Design	Code=ACI 318-19



Vertical Vessel Anchor Forces Calculation

Design Basis and Assumptions

The design of circular pattern anchor bolt group uses the Method 2 Sawcut with h_{ef}' and Neutral Axis at Center as stated in the following references

1. ASCE Anchorage Design for Petrochemical Facilities - 2013 Example 2 Step 5(c) on Page 145
2. ASCE 2010 Structural Congress - Concrete Breakout Strength in Tension for Vertical Vessel Anchorage in Octagon Pedestals

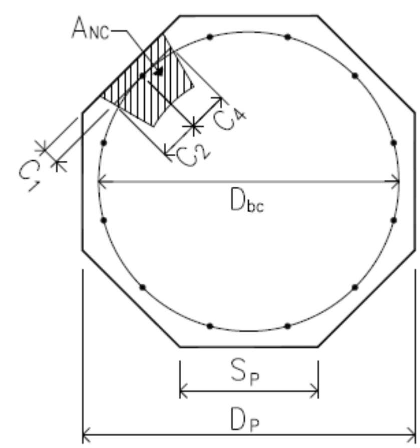
The design of circular pattern anchor bolt group is simplified as design of a single anchor bolt with 3 side free edges sawcut at midway between adjacent anchors. The simplified design method uses the following assumptions

1. The moment is resisted only by the anchor bolt group and it does not take into account the contribution of concrete compression force against base plate in the moment equilibrium
2. The neutral axis is not shifted and is located at center of vessel
3. It does not consider strain compatibility between the concrete and steel elements which comprise the anchorage.
4. In the assumed 3 side free edges sawcut model, when anchor is located less than 1.5hef from three or more edges, the reduced h_{ef}' is used to calculate concrete projected failure area A_{NC}

The utilization ratio of simplified method used in this calculation is conservative compared to the accurate but more complex approach. The detail comparison and analysis of this simplified method is addressed in reference 2 above.

Octagon Concrete Mat Geometrics

Octagon mat face-to-face distance	D_p = from user input	= 196.85	[in]
Anchor bolt bolt circle diameter	D_{bc} = from user input	= 157.50	[in]
No of anchor bolt	N_a = from user input	= 20	
Anchor bolt edge distance	$c_1 = (D_p - D_{bc}) / 2$	= 19.68	[in]
	$c_3 = D_p - c_1$	= 177.18	[in]
	$c_2 = \frac{D_{bc}}{2} \tan \frac{360}{2 N_a}$	= 12.47	[in]
	$c_4 = c_2$	= 12.47	[in]
		ACI 318-19 17.6.2.1.2	
Effective embedment depth	$h_{ef}' =$	= 13.12	[in]
Octagon side edge length	$S_p = \frac{D_p}{(1 + \sqrt{2})}$	= 81.54	[in]



Octagon shape conc mat area	$A_p =$	= 32101.5	[in^2]
Projected conc failure area	$A_{NC} = \frac{A_p - (\pi/4)\,[D_{bc} - \min(3h_{ef}', D_{bc})]^2}{N_a}$	= **1056.9**	[in^2]

Single Anchor Bolt Tensile and Shear Load

				PIP STE03350 -2008
Factored compression at top of concrete pedestal	$P_u = \frac{M_u}{0.667\, D_{bc}} + 0.9 \frac{D_e}{2}$	= 135.54	[kips]	Section 4.6.1 Eq 5
Factored shear at base of vessel	V_u = from user input	= **29.90**	[kips]	
Vessel base to concrete support surface friction factor	μ = from user input	= 0.55		Section 4.6.2
Strength reduction factor	ϕ =	= 0.75		Section 4.6.2
Factored frictional resistance	$\phi V_f = \phi \mu P_u$	= **55.91**	[kips]	Section 4.6.1 Eq 6
	$> V_u$ shear load taken by the friction			Section 4.6.2 Eq 7
Factored single anchor shear load	V_{ua} = shear load taken by the friction	= **0.00**	[kips]	

Anchor Tensile - Uplift LCB by Wind

Factored base moment - wind	M_{uw} = from user input	= 1000.9	[kip-ft]	
Vessel empty weight	D_e = from user input	= 47.00	[kips]	
Factored single anchor tensile load	$N_{uaw} = \frac{4 M_{uw}}{N_a D_{bc}} - 0.9 \frac{D_e}{N_a}$	= 13.14	[kips]	Section 4.6.1 Eq 4

Anchor Tensile - Uplift LCB by Seismic

Factored base moment - seismic	M_{us} = from user input	= 434.20	[kip-ft]	
Vessel operating weight	D_o = from user input	= 280.80	[kips]	

When $\frac{4 M_{us}}{N_a D_{bc}} < 0.9 \frac{D_o}{N_a}$, there is no tensile load mobilized on anchor

Factored <u>single</u> anchor tensile load	$N_{uas} = \frac{4 M_{us}}{N_a D_{bc}} - 0.9 \frac{D_o}{N_a}$	= 0.00	[kips]	Section 4.6.1 Eq 4
Factored <u>single</u> anchor tensile load - max	N_{ua} = max (N_{uaw} , N_{uas})	= **13.14**	[kips]	

Vertical Vessel Anchor Bolt P_t =13.1 kip V =0.0 kip Code=ACI 318-19

Result Summary geometries & weld limitations = **PASS** limit states max ratio = **0.50** **PASS**

Min Anchor Dimensions Check Per PIP STE05121 - Optional **PASS**

Min Anchor Dimensions Check

Check min anchor dimensions as per PIP STE05121 Application of ASCE Anchorage Design for Petrochemical Facilities - 2018 Table 1 as shown below.

This check is NOT a code requirement. User can turn this check On/Off by changing setting at Anchor Bolt --> Anchor Bolt - Config & Setting --> Check min anchor spacing and edge distance as per PIP STE05121 Table 1

Anchor Rod Inputs

Anchor rod grade and dia	grade = F1554 Gr36	d_a = 1.000	[in]
Anchor sleeve dia and height	d_s = 3.000 [in]	h_s = 10.000	[in]

Min Anchor Edge Distance

Anchor edge distance	c_1 = 19.675 [in]	c_2 = 12.473	[in]	
	c_3 = 177.175 [in]	c_4 = 12.473	[in]	
Min anchor edge distance required	c_{min} = from PIP STE05121 Table 1 below	= **5.500**	[in]	PIP STE05121 Table 1
Min anchor edge distance	c = min(c_1 , c_2 , c_3 , c_4)	= **19.675**	[in]	
		≥ c_{min}	OK	

Min Anchor Embedment Depth

Min anchor embedment required	h_{min} = from PIP STE05121 Table 1 below	= **16.000**	[in]	PIP STE05121 Table 1
Min anchor embedment depth	h_{ef} = from user input	= **18.000**	[in]	
		≥ h_{min}	OK	

Table 1 from PIP STE05121 Application of ASCE Anchorage Design for Petrochemical Facilities - 2018

PIP STE05121
Application of ASCE Anchorage Design for Petrochemical Facilities

EDITORIAL REVISION
January 2018

Table 1 - Minimum Anchor Dimensions – U.S. Customary Units

(See Figure 1 for dimension locations)

ASCE ANCHORAGE DESIGN REPORT
MINIMUM DIMENSIONS (Note 1)

ANCHOR ROD DIAMETE	EFFECTIVE CROSS-SECTIO AREA OF ANCHOR ROD TENSION (Note 3)	HEAVY HEX HEAD/ NUT WIDTH	ANCHOR TY THREAD LENGTH A BOTTOM O ANCHOR		h_{ef}	EDGE DISTANCE c_a (Note 2)		SPAC -ING	SLEEVES (See Note 1 (d))		
			WITH NO AP	WITH AP (Note 4)	$12d_a$	A307/ A36 F1554 GRADE 36	HIGH-STRENGTH (> 36 ksi) OR TORQUED ANCHORS	$4d_a$	SHELL SIZE		h'e
d_a	$A_{se,N}$	W_h	TB1	TB2		$4d_a \geq 4.5"$	$6d_a \geq 4.5"$		Diam d_s	Height h_s	$6d_a \geq 6"$
in.	in²	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
5/8	0.226	1.25	1.25	--	7.5	4.5	4.5	2.5	2	7	6
3/4	0.334	1.44	1.25	2.25	9.0	4.5	4.5	3.0	2	7	6
7/8	0.462	1.69	1.50	2.50	10.5	4.5	5.3	3.5	2	7	6
1	0.606	1.88	1.75	3.00	12.0	4.5	6.0	4.0	3	10	6
1-1/4	0.969	2.31	2.00	3.50	15.0	5.0	7.5	5.0	---	---	---
1-1/2	1.405	2.75	2.25	4.00	18.0	6.0	9.0	6.0	---	---	---
1-3/4	1.900	3.19	2.50	4.75	21.0	7.0	10.5	7.0	---	---	---
2	2.500	3.63	2.75	5.25	24.0	8.0	12.0	8.0	---	---	---
2-1/4	3.250	4.06	3.00	5.75	27.0	9.0	13.5	9.0	---	---	---
2-1/2	4.000	4.50	3.50	6.50	30.0	10.0	15.0	10.0	---	---	---
2-3/4	4.930	4.94	3.75	7.00	33.0	11.0	16.5	11.0	---	---	---
3	5.970	5.31	4.00	7.75	36.0	12.0	18.0	12.0	---	---	---

NOTES:

1. If sleeves are used, the following dimensional modifications apply:
   (a) Embedment should be the greater of $12d_a$ or (h_s + h'_e)
   (b) Edge distance should be increased by $0.5(d_s - d_a)$
   (c) Spacing should be increased by $(d_s - d_a)$
   (d) Partial length sleeves are not recommended for anchors greater than 1 in. See *ASCE Anchorage Design Report*, Section 3.2.3.1.

Anchor Rod Tensile Resistance ratio = 13.1 / 26.4 = **0.50** **PASS**

Anchor rod effective section area	A_{se} = 0.61 [in²]	f_{uta} = 58.0 [ksi]	
Anchor rod steel strength in tension	$N_{sa} = A_{se} f_{uta}$	= 35.15 [kips]	ACI 318-19 17.6.1.2

Max Single Anchor Tensile Force

Anchor group axial tensile force	P = from user load input	= -13.14 [kips]	in tension
No of anchors in the group	n_t =	= 1	
Single anchor tensile force	$T = P / n_t$	= **13.14** [kips]	
Strength reduction factor	ϕ_{ts} = 0.75		ACI 318-19 17.5.3(a)
	$\phi_{ts} N_{sa}$ = 0.75 x 35.15	= **26.36** [kips]	
	ratio = **0.50**	> T	OK

Anchor Concrete Tensile Breakout Resistance ratio = 13.1 / 35.1 = **0.37** **PASS**

Anchor embedment depth-adjusted h_{ef} = from Anchor Forces Calculation above = 13.117 [in]

Conc strength & lightweight conc factor $f_c = 4.4$ [ksi] $\lambda = 1.0$ ACI 318-19 17.2.4.1

Single anchor concrete breakout strength $N_b = 24\lambda \sqrt{f_c}\, h_{ef}^{1.5}$ If $h_{ef} < 11"$ or $h_{ef} > 25"$ = 76.98 [kips] ACI 318-19 17.6.2.2.1

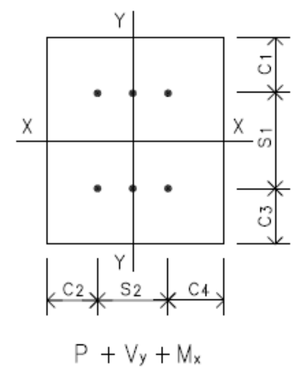
$16\lambda \sqrt{f_c}\, h_{ef}^{5/3}$ If $11" \le h_{ef} \le 25"$ ACI 318-19 17.6.2.2.3

Refer to Vertical Vessel Anchor Forces Calculation above for vertical vessel $c_1 \sim c_4$ calculation and design assumptions

Anchor edge distance $c_1 = 19.675$ [in] $c_2 = 12.473$ [in]

$c_3 = 177.175$ [in] $c_4 = 12.473$ [in]

Anchor out-out spacing $s_1 = 0.000$ [in] $s_2 = 0.000$ [in]



Refer to Vertical Vessel Anchor Forces Calculation above for the details of vertical vessel circular anchor group and single anchor of that group projected failure area A_{NC1} calculation as shown below

A_{NC1} = = 1056.9 [in^2]

$A_{Nco} = 9\, h_{ef}^2$ = 1548.4 [in^2] ACI 318-19 17.6.2.1.4

No of anchors in the group resisting tension n_t = from Anchor Forces Calculation above = 1

$A_{Nc} = \min(A_{Nc1}, n_t A_{Nco})$ = 1056.9 [in^2] ACI 318-19 17.6.2.1.1

Eccentricity modification factor $\Psi_{ec,N}$ = from Anchor Forces Calculation above = 1.000 ACI 318-19 17.6.2.3.1

Min edge distance $c_{min} = \min(c_1, c_2, c_3, c_4)$ = 12.473 [in]

Edge modification factor $\Psi_{ed,N} = \min[0.7 + \frac{0.3c_{min}}{1.5h_{ef}}, 1.0]$ = 0.890 ACI 318-19 17.6.2.4.1

Conc cracking modification factor $\Psi_{c,N}$ = = 1.00 ACI 318-19 17.6.2.5.1

Conc splitting modification factor $\Psi_{cp,N}$ = = 1.00 ACI 318-19 17.6.2.6.1

Concrete breakout resistance $N_{cbg} = \frac{A_{Nc}}{A_{Nco}} \Psi_{ec,N} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_b$ = 46.78 [kips] ACI 318-19 17.6.2.1b

Sum of anchors tensile force in anchor group N_u = from Anchor Forces Calculation above = **13.14** [kips]

Strength reduction factor $\phi_{tc} = 0.75$ supplementary reinft present ACI 318-19 17.5.3(b)

$\phi_{tc} N_{cbg} = 0.75 \times 46.78$ = 35.08 [kips]

Seismic design strength reduction = x 1.0 not applicable = **35.08** [kips] ACI 318-19 17.10.5.4(b)

ratio = **0.37** $> N_u$ OK

Anchor Pullout Resistance ratio = 13.1 / 36.6 = **0.36** **PASS**

Anchor head net bearing area & conc strength	A_{brg} = 1.50 [in^2]	f_c = 4.4	[ksi]	
Single bolt pullout resistance	$N_p = 8\ A_{brg}\ f_c$	= 52.23	[kips]	ACI 318-19 17.6.3.2.2a
Pullout cracking factor	Ψ_{cP} = for cracked concrete	= 1.00		ACI 318-19 17.6.3.3.1(b)

Max Single Anchor Tensile Force

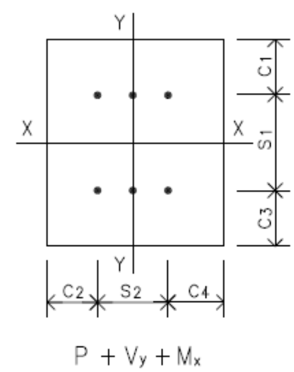
Anchor group axial tensile force	P = from user load input	= -13.14	[kips]	in tension
No of anchors in the group	n_t =	= 1		
Single anchor tensile force	$T = P / n_t$	= **13.14**	[kips]	

Strength reduction factor	ϕ_{tc} = 0.70 pullout strength is always Condition B			ACI 318-19 17.5.3(c)
	$\phi_{tc} N_{pn} = \phi_{tc} \Psi_{cP} N_p$	= **36.56**	[kips]	
Seismic design strength reduction	= x 1.0 not applicable	= **36.56**	[kips]	ACI 318-19 17.10.5.4(c)
	ratio = **0.36**	> T	OK	

Anchor Side Blowout Resistance **N/A**

Anchor Inputs

Anchor edge distance	c_1 = 19.675	[in]	c_2 = 12.473	[in]
	c_3 = 177.175	[in]	c_4 = 12.473	[in]
Anchor out-out spacing	s_1 = 0.000	[in]	s_2 = 0.000	[in]



Anchor edge distance - min	$c_{a1} = \min(c_1, c_2, c_1, c_4)$	= 12.473	[in]	
Anchor embedment depth	h_{ef} = from user input	= 18.000	[in]	
Side blowout check is required on this edge or not	= check if $h_{ef} > 2.5\ c_{a1}$	= False		ACI 318-19 17.6.4.1
	Side blowout check is NOT required			ACI 318-19 17.6.4.1

Anchor Group Governing Tensile Resistance

Anchor group governing tensile resistance is the minimum value of the resistance values in the following limit states

No of anchors in anchor group resisting tension	n_t = from Anchor Forces Calculation above	= 1	
Anchor rod tensile resistance	$n_t \phi N_{sa}$ = 1 x 26.36	= 26.36	[kips]
Anchor concrete breakout resistance	ϕN_{cbg} = from anchor conc breakout calc above	= 35.08	[kips]
Anchor pullout resistance	$n_t \phi N_{pm}$ = 1 x 36.56	= 36.56	[kips]
Anchor side blowout resistance	ϕN_{sbg} = from anchor side blowout calc above	= N/A	
Anchor group governing tensile resistance	ϕN_n = minimum of above values	= **26.36**	[kips]

Anchor Shear Resistance and Tension - Shear Interaction		**N/A**

There is no shear load from user load input or shear key is used and all shear is taken by shear key, so
Anchor Shear Resistance and Tension - Shear Interaction checks are Not Applicable

Anchor Seismic Design		**N/A**
Seismic - Tension	Not Applicable	ACI 318-19 17.10.5.1
Seismic SDC < C or E <= 0.2U , additional seismic requirements in ACI 318-19 17.10.5.3 is NOT required		ACI 318-19 17.10.5.3
Seismic - Shear	Not Applicable	ACI 318-19 17.10.6.1
There is no shear load applied to anchor/anchor group, so Seismic Shear check is NOT required		