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

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**Result Summary**

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

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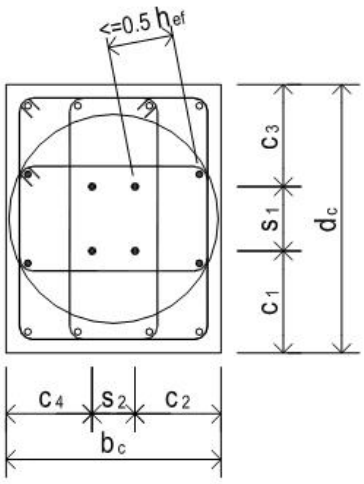
**Design Code Reference**

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

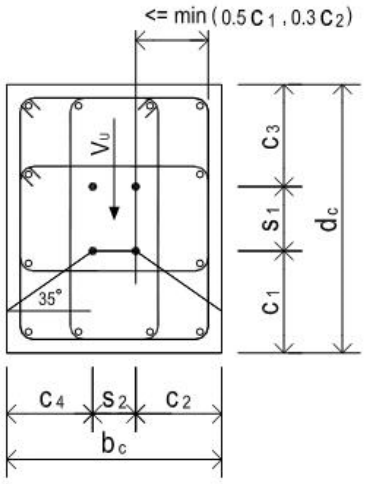
**Code Reference**

**Anchor Bolt Data**

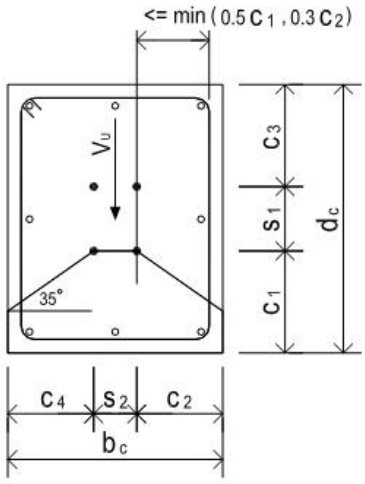
| | | | | | |
|---|---|---|---|---|---|
| Factored tensile force | $N_u$= 20.00 | [kips] | | | |
| Factored shear force | $V_u$= 25.00 | [kips] | | | |
| Concrete strength | $f'_c$= 5.2 | [ksi] | | | |
| Anchor bolt material | = F1554 Grade 36 | | | | |
| Anchor tensile strength | $f_{uta}$=58.0 | [ksi]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




Ver. Reinft For Tension




Hor. Ties For Shear - 4 Legs




Hor. Ties For Shear - 2 Legs

PIP STE05121

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

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

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

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

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

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

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

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

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

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

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

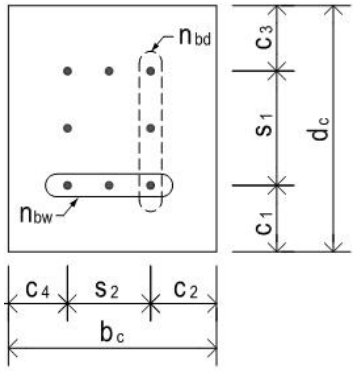
For anchor reinft shear breakout strength calc: 100% hor. tie bars develop full yield strength

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

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

No of anchor bolt carrying tension $n_t$= 4.0

No of anchor bolt carrying shear $n_s$= 4.0




Bolt No Input for Side Face Blowout Check

For side-face blowout check use

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

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

Anchor bolt head type: Heavy Hex

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

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

Anchor bolt 1/8" (3mm) corrosion allowance = No — ACI 318-11

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

Seismic design category SDC >= C = Yes — D.3.3.1

Anchor bolt load E <= 0.2U — Tensile= No, Shear= No — D.3.3.4.1 & D.3.3.5.1

Anchor bolt satisfies opion — Tensile= Option 4, Shear= Option 3 — D.3.3.4.3 & D.3.3.5.3

Strength reduction factors — ACI 318-11

| | | | |
|---|---|---|---|
| Anchor reinforcement | $\phi_s$=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) |

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**CONCLUSION**

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

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

| **Seismic Design** | | | ACI 318-11 |
|---|---|---|---|
| **Tension** | Applicable | OK | D.3.3.4 |
| Seismic SDC>=C and E>0.2U , Option 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 | | | |

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| **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 |

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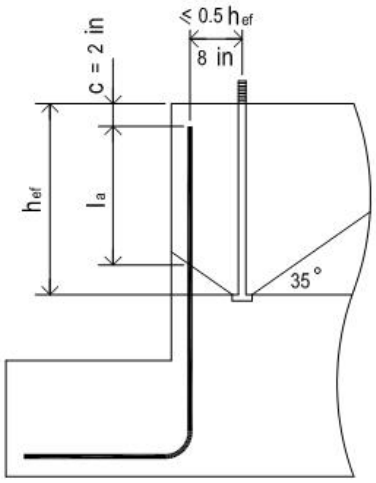
**CACULATION**

| **Anchor Rod Tensile Resistance** | | | | ACI 318-11 |
|---|---|---|---|---|
| $\phi_{t,s} N_{sa} = \phi_{t,s} n_t A_{se} f_{uta}$ | =105.44 | [kips] | | D.5.1.2 (D-2) |
| ratio=0.19 | >$N_u$ | | OK | |

**Anchor Reinft Tensile Breakout Resistance** ACI 318-11

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

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

**Anchor Pullout Resistance** ACI 318-11

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

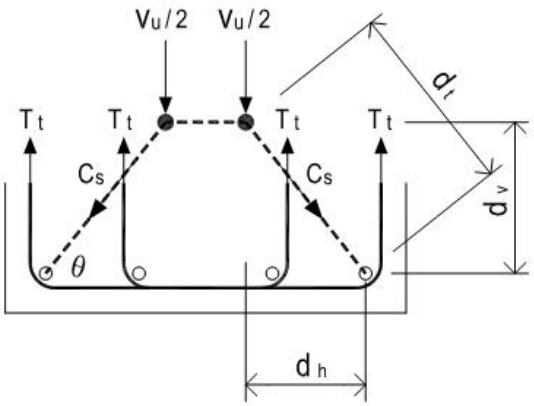
**Side Blowout Resistance**

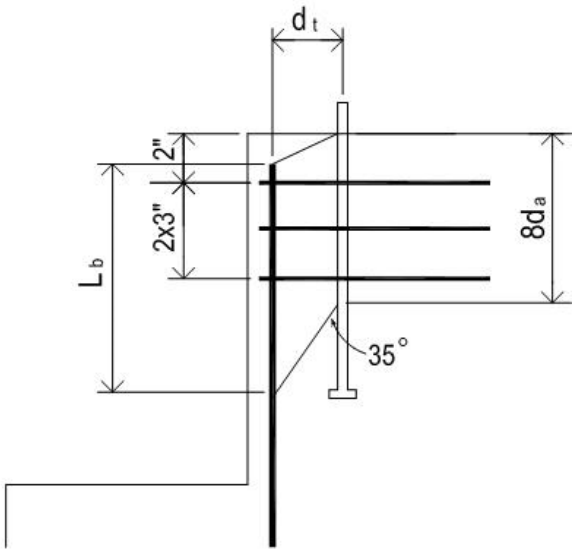
Failure Along Pedestal Width Edge ACI 318-11

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

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

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




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

## Strut Bearing Strength

ACI 318-11

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

* Bearing of anchor bolt

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

* Bearing of ver reinft bar

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

## Tie Reinforcement

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

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

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

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

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

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

**Tension Shear Interaction** ACI 318-11

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

**Seismic Design**

| | | | |
|---|---|---|---|
| Tension | Applicable | | OK |

Option 4 is selected. ACI 318-11

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

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 |

Option 3 is selected. ACI 318-11

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

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