COLUMN DESIGN FOR SHEAR AND LINKS (DUCTILE SPECIAL FRAME)

DESIGN CODE ACI 318-2014

Input / Defaults

$ColumnNo$: C21

$Location$: Bottom Joint

$TypeOfColumn := 3$ ----------- 1- for Non-Ductile, 2 for Intermediate, 3 for Special

$B := 30\ in$ ----------- Width of the Column

$D := 36\ in$ ----------- Depth of the Column

$Pu\_D := 1240.19\ kip$ ----------- factored axial force occurring simultaneously with Vu along D

$Pu\_B := 788.73\ kip$ ----------- factored axial force occurring simultaneously with Vu along B

$Mshear\_D := 47.9\ kip \cdot ft$ ----------- factored Bending Moment occurring simultaneously with Vu along D

$Mshear\_B := 12.67\ kip \cdot ft$ ----------- factored Bending Moment occurring simultaneously with Vu along D

$Vuy3 := 277.38\ kip$ ----------- Ultimate Shear force at section considered along D

$Vux3 := 9.4\ kip$ ----------- Ultimate Shear force at section considered along B

$f'c := 3.5\ ksi$ ----------- Grade of Concrete (Cylindrical Strength)

$fy := 60\ ksi$ ----------- Grade of Reinforcement for Main Reinforcement

$fyt := 60\ ksi$ ----------- Grade of Reinforcement for Secondary Reinforcement

$Cc := 2\ in$ ----------- Nominal Cover to Beam Tension Reinforcement

$Es := 29007\ ksi$ ----------- Modulus of elasticity of reinforcement

$LuD := 69\ in$ ----------- Clear Floor Height @ lux

$LuB := 69\ in$ ----------- Clear Floor Height @ luy

$\lambda := 1$ ----------- Modification factor for compressive strength

Reinforcement Provided

$\phi1 := 1\ in$ ----------- Diameter of Reinforcement

$N1 := 4$ ----------- No of Rebar

$\phi2 := 0.75\ in$ ----------- Diameter of Reinforcement

$N2 := 18$ ----------- No of Rebar

$$Ast := \frac{\pi \cdot \phi1^2}{4} \cdot N1 + \frac{\pi \cdot \phi2^2}{4} \cdot N2 = 11.094\ in^2$$ ----------- Area of Reinforcement Provided

Shear reinforcement Provided

$\phi3 := 0.375\ in$ ----------- Diameter of Link

$Bundled\_1 := 1$

$Legs1 := 6$ ----------- Number of shear Legs along D

$Legs2 := 7$ ----------- Number of shear Legs along B

$Spc := 12\ in$ ----------- Spacing of Non-ductile links provided

$\phi4 := 0.5\ in$ ----------- Diameter of Ductile links

$Spc\_Duct := 4\ in$ ----------- Spacing of ductile links provided

$Bundled\_2 := 1$

$$Asvprv\_D := \left(\frac{\pi \cdot \phi3^2}{4} \cdot Legs1\right) \cdot \frac{1}{Spc} \cdot Bundled\_1 = 0.663\ \frac{in^2}{ft}$$

----------- Area of Links Provided along D

$$Asvprv\_B := \left(\frac{\pi \cdot \phi 3^2}{4} \cdot Legs2\right) \cdot \frac{1}{Spc} \cdot Bundled\_1 = 0.773 \ \frac{in^2}{ft}$$

----------- Area of Links Provided along B

$$Asvprv\_Duct := \left(\frac{\pi \cdot \phi 4^2}{4}\right) \cdot \frac{1 \cdot ft}{Spc\_Duct} \cdot Bundled\_2 = 0.589 \ in^2$$

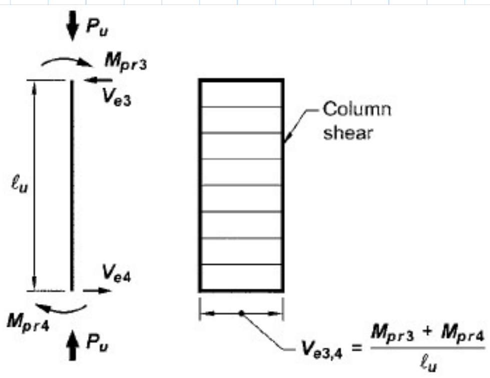
----------- Area of Ductile Links Provided

$$fy\_s := \begin{array}{l} \text{if } fy > 60 \ ksi \\ \quad 60 \ ksi \\ \text{else} \\ \quad fy \end{array} = 60 \ ksi$$

----------- Permissible yield strength of transverse reinforcement
Table 20.2.2.4a

Shear Force Calculation

Shear as per Column Flexural Capacity (Fig. R18.6.5)



2. End moments M_{pr} based on steel tensile stress of 1.25 f_y, where f_y is specified yield strength. (Both end moments should be considered in both directions, clockwise and counter-clockwise).

18.7.6.1.1 The design shear force V_e shall be calculated from considering the maximum forces that can be generated at the faces of the joints at each end of the column. These joint forces shall be calculated using the maximum probable flexural strengths, M_{pr}, at each end of the column associated with the range of factored axial forces, P_u, acting on the column. The column shears need not exceed those calculated from joint strengths based on M_{pr} of the beams framing into the joint. In no case shall V_e be less than the factored shear calculated by analysis of the structure.

Along D

$LuD = 69 \ in$

$Pu\_top := 788.73 \ kip$

$Mnt\_top := 1493.55 \ kip \cdot ft$

$Pu\_bot := 797.09 \ kip$

$Mnt\_bot := 1486.79 \ kip \cdot ft$

$$Vuy1 := \frac{(Mnt\_top + Mnt\_bot)}{LuD} = 518.32 \ kip$$

Along B

$LuB = 69 \ in$

$Pu\_top := 788.73 \ kip$

$Mnt\_top := 1239.38 \ kip \cdot ft$

$Pu\_bot := 797.09 \ kip$

$Mnt\_bot := 1232.81 \ kip \cdot ft$

$$Vux1 := \frac{(Mnt\_top + Mnt\_bot)}{LuB} = 429.946 \ kip$$

Note:
The column moment capacity (Mnt_top and Mnt_bot) is calculated for axial force (Pu) which gives the maximum moment capacity. The PM curve is generated for the 1.25 fy reinforcement stress and the capacity is calculated. The PM curve available in RCDC is for the 1.0 fy.

Shear as per Beam Flexural Capacity (Fig. R18.6.5)

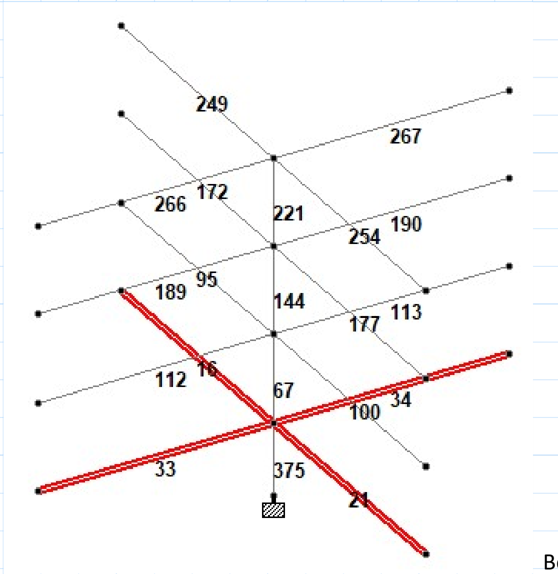
End moment M_{pr} for columns need not be greater than moments generated by the M_{pr} of the beams framing into the beam-column joints. V_e should not be less than that required by analysis of the structure.

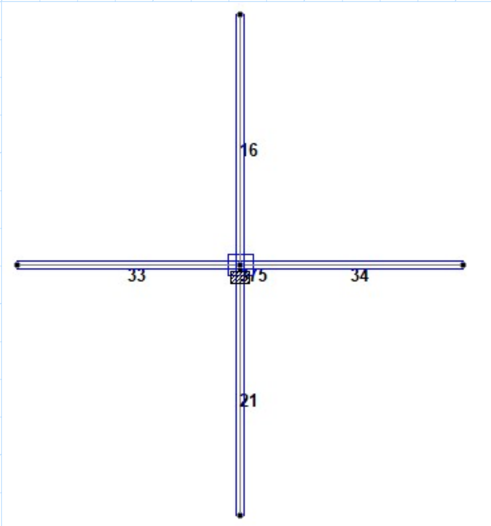
Beams at Level: Top Joint

Beam Size	Beam angle w.r.t. column Ly	Torsion moment	Moment Capacity Beam at Top				Moment Capacity Beam at Bottom				Resultant Moment			
			Mu	Ast req	Ast pro	Mu cap	Mu	Ast req	Ast pro	Mu cap	Top @ D	Top @ B	Bot @ D	Bot @ B
(in)	(deg)	(kip-ft)	(kip-ft)	(in^2)	(in^2)	(kip-ft)	(kip-ft)	(in^2)	(in^2)	(kip-ft)	(kip-ft)	(kip-ft)	(kip-ft)	(kip-ft)
12 x 30	90	0.21	445.23	4.05	4.12	451.9	0	2.03	2.16	253.12	0	451.9	0	253.12
12 x 30	0	0.01	340.54	2.99	3.14	355.97	0	1.5	1.57	187.51	355.97	0	187.51	0
12 x 30	270	0.07	451.94	4.12	4.32	470.21	0	2.06	2.16	253.12	0	470.21	0	253.12
12 x 30	180	0.01	340.12	2.99	3.14	355.97	0	1.49	1.57	187.51	355.97	0	187.51	0

Effective Moment for Column

	Mu Major (Along D) (kip-ft)		Mu Minor (Along B) (kip-ft)	
	Left	Right	Left	Right
Top	355.97	355.97	470.21	451.9
Bottom	187.51	187.51	253.12	253.12





Beam position with respect to column

Note:
The beam position is identified with respect to the column Ly (Major) axis. Beams are designed for the end bending moments (Mu) and area of reinforcement (Ast req) is calculated. The reinforcement is detailed for the area of reinforcement required. The Beam section capacity is calculated based on the area of reinforcement provided (Ast prv).

Along D

$$Mu\_left\_bot := 187.51\ kip \cdot ft$$
$$Mu\_left\_top := 355.97\ kip \cdot ft$$
$$Mu\_right\_bot := 187.51\ kip \cdot ft$$
$$Mu\_right\_top := 355.97\ kip \cdot ft$$
$$Mnt\_D := \max\left(\left(Mu\_left\_bot + Mu\_right\_top\right), \left(Mu\_left\_top + Mu\_right\_bot\right)\right) = 543.48\ kip \cdot ft$$
$$Vuy2 := \frac{Mnt\_D}{LuD} = 94.518\ kip$$

Along B

$$Mu\_left\_bot := 253.12\ kip \cdot ft$$
$$Mu\_left\_top := 470.21\ kip \cdot ft$$

$Mu\_right\_bot := 253.12\ kip \cdot ft$

$Mu\_right\_top := 451.9\ kip \cdot ft$

$Mnt\_B := \max((Mu\_left\_bot + Mu\_right\_top), (Mu\_left\_top + Mu\_right\_bot)) = 723.33\ kip \cdot ft$

$$Vux2 := \frac{Mnt\_B}{LuD} = 125.797\ kip$$

$Vu'y := min(Vuy1, Vuy2) = 94.518\ kip$

$Vu'x := min(Vux1, Vux2) = 125.797\ kip$

Shear Design along D

Critical Load Combination [1] : 1.4 (LOAD 1: LOAD CASE 1)

$Pu\_D = 1240.19\ kip$

$Mshear\_D = 47.9\ kip \cdot ft$

$Vuy3 = 277.38\ kip$

$Vuy := \max(Vu'y, Vuy3) = 277.38\ kip$

$$\phi := \begin{array}{l} \text{if } TypeOfColumn > 2 \\ \quad 0.6 \\ \text{else} \\ \quad 0.75 \end{array} = 0.6$$

----------- Strength Reduction Factor

$$deff := D - Cc - \frac{\phi 1}{2} = 33.5\ in$$

$$pt := \frac{Ast}{2 \cdot B \cdot deff} = 0.00552$$

----------- 50% of total reinforcement assumed as Tension Reinforcement

$Ag := D \cdot B = 1080\ in^2$

$Aeff\_y := deff \cdot B = 1005\ in^2$

$$Mm\_y := Mshear\_D - Pu\_D \cdot \frac{(4 \cdot D - deff)}{8} = -1379.61\ kip \cdot ft$$

$$Vcy1 := 2 \cdot \left(1 \cdot psi + \left(\frac{Pu\_D}{500 \cdot Ag}\right)\right) \cdot \lambda \cdot \sqrt{f'c \cdot psi} \cdot B \cdot \frac{deff}{psi} = 392.015\ kip$$

----------- Clause 22.5.7.1

$$Vcy2 := \left(1.9 \cdot \sqrt{f'c \cdot psi} + 2500 \cdot pt \cdot psi \cdot \left(\frac{Vuy \cdot deff}{Mm\_y}\right)\right) \cdot B \cdot deff = 105.184\ kip$$

----------- Table 22.5.6.1 (a)

$$Vcy3 := \left(3.5 \cdot \sqrt{f'c} \cdot \sqrt{1 \cdot psi + \left(\frac{Pu\_D}{500 \cdot Ag}\right)}\right) \cdot B \cdot deff = 377.837\ kip$$

----------- Table 22.5.6.1 (b)

$$\phi Vcy := \begin{array}{l} \text{if } Pu\_D < 0 \\ \quad Vcy1 \cdot \phi \\ \text{else if } Mm\_y < 0 \\ \quad Vcy3 \cdot \phi \\ \text{else} \\ \quad \phi \cdot min(Vcy2, Vcy3) \end{array} = 226.702\ kip$$

$$Check1 := \begin{array}{l} \text{if } \phi Vcy \geq Vuy \\ \quad \text{“ShearReinfNotRequired”} \\ \text{else} \\ \quad \text{“ShearReinfRequired”} \end{array} = \text{“ShearReinfRequired”}$$

----------- Clause 7.1.1

$$fy\_s = 60 \; ksi$$

$$Vsy := \begin{array}{l} \text{if } \phi Vcy \geq Vuy \\ \quad 0 \; kip \\ \text{else} \\ \quad \dfrac{(Vuy - \phi Vcy)}{\phi} \end{array} = 84.463 \; kip$$

----------- Clause 7.1.1

$$Vsy\_perm := 8 \cdot \sqrt{f'c \cdot psi} \cdot B \cdot deff = 475.653 \; kip$$

$$Check2 := \begin{array}{l} \text{if } Vsy\_perm \geq Vsy \\ \quad \text{“Ok”} \\ \text{else} \\ \quad \text{“Revise”} \end{array} = \text{“Ok”}$$

$$Check3 := \begin{array}{l} \text{if } Vuy > 0.5 \cdot \phi Vcy \\ \quad \text{“Check for Min. Shear Reinf”} \\ \text{else} \\ \quad \text{“Check for Min. Shear Reinf Not Req”} \end{array} = \text{“Check for Min. Shear Reinf”}$$

$$Asv\_min1 := \max\left(0.75 \cdot \sqrt{f'c \cdot psi} \cdot \frac{B}{fy\_s} \cdot 12 \cdot in, 50 \cdot \frac{B}{fy\_s} \cdot 12 \cdot psi \cdot in\right) = 0.3 \; in^2$$

$$Asv\_min := \begin{array}{l} \text{if } Vuy > 0.5 \cdot \phi Vcy \\ \quad Asv\_min1 \\ \text{else} \\ \quad 0 \; in^2 \end{array} = 0.3 \; in^2$$

$$Asv\_shear\_y := \begin{array}{l} \text{if } \phi Vcy \geq Vuy \\ \quad 0 \; in^2 \\ \text{else} \\ \quad \dfrac{Vsy \cdot ft}{fy\_s \cdot deff} \end{array} = 0.504 \; in^2$$

$$Asv\_req\_y := \frac{\max(Asv\_min, Asv\_shear\_y)}{ft} = 0.504 \; \frac{in^2}{ft}$$

$$Check := \begin{array}{l} \text{if } Asvprv\_D > Asv\_req\_y \\ \quad \text{“Ok”} \\ \text{else} \\ \quad \text{“Increase Reinforcement”} \end{array} = \text{“Ok”}$$

Shear Design along B

Critical Load Combination [13] : 0.9 (LOAD 1: LOAD CASE 1) -(LOAD 4: LOAD CASE 4 EQ-Y)

$Pu\_B = 788.73\ kip$

$Mshear\_B = 12.67\ kip \cdot ft$

$Vux3 = 9.4\ kip$

$Vux := \max(Vu'x, Vux3) = 125.797\ kip$

$\phi := \begin{cases} \text{if } TypeOfColumn > 2 \\ \quad 0.6 \\ \text{else} \\ \quad 0.75 \end{cases} = 0.6$ ----------- Strength Reduction Factor

$beff := B - Cc - \frac{\phi 1}{2} = 27.5\ in$

$pt := \frac{Ast}{2 \cdot D \cdot beff} = 0.0056$ ----------- 50% of total reinforcement assumed as Tension Reinforcement

$Ag := D \cdot B = 1080\ in^2$

$Aeff\_x := beff \cdot D = 990\ in^2$

$Mm\_x := Mshear\_B - Pu\_B \cdot \frac{(4 \cdot B - beff)}{8} = -747.304\ kip \cdot ft$

$Vcx1 := 2 \cdot \left(1 \cdot psi + \left(\frac{Pu\_B}{500 \cdot Ag}\right)\right) \cdot \lambda \cdot \sqrt{f'c \cdot psi} \cdot D \cdot \frac{beff}{psi} = 288.232\ kip$

----------- Clause 22.5.7.1

$Vcx2 := \left(1.9 \cdot \sqrt{f'c \cdot psi} + 2500 \cdot pt \cdot psi \cdot \left(\frac{Vux \cdot beff}{Mm\_x}\right)\right) \cdot D \cdot beff = 105.932\ kip$

----------- Table 22.5.6.1 (a)

$Vcx3 := \left(3.5 \cdot \sqrt{f'c} \cdot \sqrt{1 \cdot psi + \left(\frac{Pu\_B}{500 \cdot Ag}\right)}\right) \cdot D \cdot beff = 321.558\ kip$

----------- Table 22.5.6.1 (b)

$\phi Vcx := \begin{cases} \text{if } Pu\_B < 0 \\ \quad Vcx1 \cdot \phi \\ \text{else if } Mm\_x < 0 \\ \quad Vcx3 \cdot \phi \\ \text{else} \\ \quad \phi \cdot min(Vcx2, Vcx3) \end{cases} = 192.93\ kip$

$Check1 := \begin{cases} \text{if } \phi Vcx \ge Vux \\ \quad \text{"ShearReinfNotRequired"} \\ \text{else} \\ \quad \text{"ShearReinfRequired"} \end{cases} = \text{"ShearReinfNotRequired"}$

$fy\_s = 60\ ksi$

$$Vsx := \begin{cases} \text{if } \phi Vcx \geq Vux & \| \ 0\ kip \\ \text{else} & \| \ \dfrac{(Vux - \phi Vcx)}{\phi} \end{cases} = 0\ kip$$

----------- Clause 7.1.1

$$Vsx\_perm := 8 \cdot \sqrt{f'c \cdot psi} \cdot D \cdot beff = 468.554\ kip$$

$$Check2 := \begin{cases} \text{if } Vsx\_perm \geq Vsx & \| \ \text{“Ok”} \\ \text{else} & \| \ \text{“Revise”} \end{cases} = \text{“Ok”}$$

$$Check3 := \begin{cases} \text{if } Vux > 0.5 \cdot \phi Vcx & \| \ \text{“Check for Min. Shear Reinf”} \\ \text{else} & \| \ \text{“Check for Min. Shear Reinf Not Req”} \end{cases} = \text{“Check for Min. Shear Reinf”}$$

$$Asv\_min1 := \max\left(0.75 \cdot \sqrt{f'c \cdot psi} \cdot \frac{D}{fy\_s} \cdot 12 \cdot in, 50 \cdot \frac{D}{fy\_s} \cdot 12 \cdot psi \cdot in\right) = 0.36\ in^2$$

$$Asv\_min := \begin{cases} \text{if } Vux > 0.5 \cdot \phi Vcx & \| \ Asv\_min1 \\ \text{else} & \| \ 0\ in^2 \end{cases} = 0.36\ in^2$$

$$Asv\_shear\_x := \begin{cases} \text{if } \phi Vcx \geq Vux & \| \ 0\ in^2 \\ \text{else} & \| \ \dfrac{Vsx \cdot ft}{fy\_s \cdot beff} \end{cases} = 0\ in^2$$

$$Asv\_req\_x := \frac{\max(Asv\_min, Asv\_shear\_x)}{ft} = 0.36\ \frac{in^2}{ft}$$

$$Check := \begin{cases} \text{if } Asvprv\_D > Asv\_req\_x & \| \ \text{“Ok”} \\ \text{else} & \| \ \text{“Increase Reinforcement”} \end{cases} = \text{“Ok”}$$

Detailing of Links

<u>Check for Minimum Diameter (Clause 25.7.2.2)</u>

$$maxDia := \max(\phi 1, \phi 2) = 1\ in$$

$$Bundled := 1$$

$$Effective\_Area := \frac{\pi}{4} \cdot maxDia^2 \cdot Bundled = 0.785\ in^2$$

$$Effective\_Dia := \sqrt{\frac{Effective\_Area \cdot 4}{\pi}} = 1\ in$$

$$Min\_Dia := \begin{cases} \text{if } Effective\_Dia > 1.41\ in \\ \quad 0.5\ in \\ \text{else if } Bundled > 1 \\ \quad 0.5\ in \\ \text{else} \\ \quad 0.375\ in \end{cases} = 0.375\ in$$

$$Check := \begin{cases} \text{if } \phi 3 \ge Min\_Dia \\ \quad \text{“Ok”} \\ \text{else} \\ \quad \text{“Increase Diameter”} \end{cases} = \text{“Ok”}$$

Check for Minimum Spacing (Clause 25.7.2.1)

$$Spc1 := 16 \cdot min(\phi 1, \phi 2) = 12\ in$$

$$Spc2 := 48 \cdot \phi 3 = 18\ in$$

$$Spc3 := B = 30\ in$$

Criterion for spacing for shear reinforcement (Clause 10.7.6.2)

Along D

$$Vsy := \begin{cases} \text{if } \phi Vcy \ge Vuy \\ \quad 0\ kip \\ \text{else} \\ \quad \dfrac{(Vuy - \phi Vcy)}{\phi} \end{cases} = 84.463\ kip$$

$$Vsy\_1 := 4 \cdot \sqrt{f'c \cdot psi} \cdot Aeff\_y = 237.826\ kip$$

$$Spc4 := \begin{cases} \text{if } Vsy \le Vsy\_1 \\ \quad \dfrac{deff}{2} \\ \text{else} \\ \quad \dfrac{deff}{4} \end{cases} = 16.75\ in$$

$$Spc5 := \begin{cases} \text{if } Vsy \le Vsy\_1 \\ \quad 24\ in \\ \text{else} \\ \quad 12\ in \end{cases} = 24\ in$$

Along B

$$Vsx := \begin{cases} \text{if } \phi Vcx \ge Vux \\ \quad 0\ kip \\ \text{else} \\ \quad \dfrac{(Vuy - \phi Vcy)}{\phi} \end{cases} = 0\ kip$$

$$Vsx\_1 := 4 \cdot \sqrt{f'c \cdot psi} \cdot Aeff\_y = 237.826\ kip$$

$$Spc6 := \begin{cases} \text{if } Vsx \le Vsx\_1 \\ \quad \dfrac{beff}{2} \\ \text{else} \\ \quad \dfrac{beff}{4} \end{cases} = 13.75\ in$$

$$Spc7 := \begin{cases} \text{if } Vsx \le Vsx\_1 \\ \quad 24\ in \\ \text{else} \\ \quad 12\ in \end{cases} = 24\ in$$

$$SpcReq := min(Spc1, Spc2, Spc3, Spc4, Spc5, Spc6, Spc7) = 12\ in$$

$$Check := \begin{cases} \text{if } Spc \le SpcReq \\ \quad \text{"Ok"} \\ \text{else} \\ \quad \text{"Reduce spacing"} \end{cases} = \text{"Ok"}$$

Check for Minimum Area of Shear Reinforcement (Clause 7.10.5.1)

Along D

$$Asv\_minD := \max\left(0.75 \cdot \sqrt{f'c \cdot psi} \cdot \frac{B}{fy\_s} \cdot 12 \cdot in, 50 \cdot \frac{B}{fy\_s} \cdot 12 \cdot psi \cdot in\right) = 0.3\ in^2$$

$$Check := \begin{cases} \text{if } Asvprv\_D \ge \dfrac{Asv\_minD}{ft} \\ \quad \text{"Ok"} \\ \text{else} \\ \quad \text{"Increase Shear Reinf"} \end{cases} = \text{"Ok"}$$

Along B

$$Asv\_minB := \max\left(0.75 \cdot \sqrt{f'c \cdot psi} \cdot \frac{D}{fy\_s} \cdot 12 \cdot in, 50 \cdot \frac{D}{fy\_s} \cdot 12 \cdot psi \cdot in\right) = 0.36\ in^2$$

$$Check := \begin{cases} \text{if } Asvprv\_B \ge \dfrac{Asv\_minB}{ft} \\ \quad \text{"Ok"} \\ \text{else} \\ \quad \text{"Increase Shear Reinf"} \end{cases} = \text{"Ok"}$$

The criterion for spacing of Ductile links (Clause 18.4.3.3 and 18.7.5.3)

$$DSpc1 := 6 \cdot min(\phi 1, \phi 2) = 4.5\ in$$

$$DSpc2 := \frac{B}{4} = 7.5\ in$$

$$DSpc3 := \begin{cases} \text{if } TypeOfColumn > 2 \\ \quad 100\ in \\ \text{else} \\ \quad 24 \cdot \phi 3 \end{cases} = 100\ in$$

$$DSpc4 := \begin{cases} \text{if } TypeOfColumn > 2 \\ \quad 100\ in \\ \text{else} \\ \quad 12\ in \end{cases} = 100\ in$$

$$Hx := \max\left(\frac{(D - 2 \cdot Cc - \phi 1)}{Legs1 - 1}, \frac{(B - 2 \cdot Cc - \phi 1)}{Legs2 - 1}\right) = 6.2\ in$$

$$DSpc5 := min\left(\max\left(4\ in, 4\ in + \frac{(14 \cdot in - Hx)}{3}\right), 6\ in\right) = 6\ in$$

$$DSpcReq := min(DSpc1, DSpc2, DSpc3, DSpc4, DSpc5) = 4.5\ in$$

$$Check := \begin{cases} \text{if } Spc\_Duct \le DSpcReq \\ \quad \text{“Ok”} \\ \text{else} \\ \quad \text{“Reduce spacing”} \end{cases} = \text{“Ok”}$$

Special confining reinforcement as per ACI (18.7.5.2)

Critical Load Combination [2] : 1.2 (LOAD 1: LOAD CASE 1) +1.6 (LOAD 2: LOAD CASE 2)

$$Pu := 1455.69\ kip$$

$$Check1 := \begin{cases} \text{if } Pu \le 0.3 \cdot Ag \cdot f'c \\ \quad \text{“Pu<0.3xAgxf'c”} \\ \text{else} \\ \quad \text{“Pu>0.3xAgxf'c”} \end{cases} = \text{“Pu>0.3xAgxf'c”}$$

$$Check2 := \begin{cases} \text{if } f'c \le 60\ ksi \\ \quad \text{“f'c<60”} \\ \text{else} \\ \quad \text{“f'c>60”} \end{cases} = \text{“f'c<60”}$$

$$totalNoOfRebars := N1 + N2 = 22$$

$$kn := \frac{totalNoOfRebars}{(totalNoOfRebars - 2)} = 1.1$$

$$kf := \max\left(\frac{f'c}{25000 \cdot psi} + 0.6, 1\right) = 1$$

$$Ag = 1080\ in^2$$

$$Spc\_Duct = 4\ in$$

$$Bundled\_2 = 1$$

Along D

$$bc1 := B - 2 \cdot Cc + 2 \cdot \phi 4 = 27\ in$$

$$Ach := (D - 2 \cdot Cc + 2 \cdot \phi 3) \cdot (B - 2 \cdot Cc + 2 \cdot \phi 3) = 876.063\ in^2$$

$$Ash1 := 0.3 \cdot \left(\frac{Ag}{Ach} - 1\right) \cdot \frac{f'c}{fyt} \cdot bc1 \cdot Spc\_Duct = 0.44\ in^2$$

$$Ash2 := 0.09 \cdot \frac{f'c}{fyt} \cdot bc1 \cdot Spc\_Duct = 0.567\ in^2$$

$$Ash3 := \begin{array}{l} \text{if } Pu > 0.3 \cdot Ag \cdot f'c \\ \quad 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot bc1 \cdot Spc\_Duct \\ \text{also if } f'c > 60\ ksi \\ \quad 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot bc1 \cdot Spc\_Duct \\ \text{else} \\ \quad 0\ in^2 \end{array} = 0.66\ in^2$$

$$Ash\_D := \max(Ash1, Ash2, Ash3) = 0.658\ in^2$$

$$Ash\_D\_Provided := \frac{\pi \cdot \phi 4^2}{4} \cdot Legs1 \cdot Bundled\_2 = 1.178\ in^2$$

$$Check := \begin{array}{l} \text{if } Ash\_D \le Ash\_D\_Provided \\ \quad \text{“Ok”} \\ \text{else} \\ \quad \text{“Revise”} \end{array} = \text{“Ok”}$$

Along B

$$dc1 := D - 2 \cdot Cc + 2 \cdot \phi 4 = 33\ in$$

$$Ach := (D - 2 \cdot Cc + 2 \cdot \phi 3) \cdot (B - 2 \cdot Cc + 2 \cdot \phi 3) = 876.063\ in^2$$

$$Ash1 := 0.3 \cdot \left(\frac{Ag}{Ach} - 1\right) \cdot \frac{f'c}{fyt} \cdot dc1 \cdot Spc\_Duct = 0.538\ in^2$$

$$Ash2 := 0.09 \cdot \frac{f'c}{fyt} \cdot dc1 \cdot Spc\_Duct = 0.693\ in^2$$

$$Ash3 := \begin{array}{l} \text{if } Pu > 0.3 \cdot Ag \cdot f'c \\ \quad 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot dc1 \cdot Spc\_Duct \\ \text{also if } f'c > 60\ ksi \\ \quad 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot dc1 \cdot Spc\_Duct \\ \text{else} \\ \quad 0\ in^2 \end{array} = 0.8\ in^2$$

$$Ash\_B := \max(Ash1, Ash2, Ash3) = 0.804\ in^2$$

$$Ash\_B\_Provided := \frac{\pi \cdot \phi 4^2}{4} \cdot Legs2 \cdot Bundled\_2 = 1.374\ in^2$$

$$Check := \begin{array}{l} \text{if } Ash\_D \le Ash\_D\_Provided \\ \quad \text{“Ok”} \\ \text{else} \\ \quad \text{“Revise”} \end{array} = \text{“Ok”}$$

Checking of Ductile Links provided against the Area of Shear Reinforcement Required

$$Ash\_D\_Prv\_area := \frac{\pi \cdot \phi 4^2}{4} \cdot Legs1 \cdot Bundled\_2 \cdot \frac{1 \cdot ft}{Spc\_Duct} = 3.534\ in^2$$

$$Asv\_req\_y = 0.504\ \frac{1}{ft} \cdot in^2$$

$$Check := \begin{array}{l} \text{if } Ash\_D\_Prv\_area > Asv\_shear\_y \\ \quad \text{"Ok"} \\ \text{else} \\ \quad \text{"Revise"} \end{array} = \text{"Ok"}$$

$$Ash\_B\_Prv\_area := \frac{\pi \cdot \phi 3^2}{4} \cdot Legs2 \cdot Bundled\_2 \cdot \frac{1 \cdot ft}{Spc\_Duct} = 2.319\ in^2$$

$$Asv\_req\_x = 0.36\ \frac{1}{ft} \cdot in^2$$

$$Check := \begin{array}{l} \text{if } Ash\_B\_Prv\_area > Asv\_shear\_x \\ \quad \text{"Ok"} \\ \text{else} \\ \quad \text{"Revise"} \end{array} = \text{"Ok"}$$

Length of Confining Zone (Clause 18.7.5.1)

$$Z1 := \max(D, B) = 36\ in$$

$$Z2 := \frac{\max(LuD, LuB)}{6} = 11.5\ in$$

$$Z3 := 18\ in$$

$$ZoneLength := \max(Z1, Z2, Z3) = 36\ in$$

RCDC Output - Design Calculation Report

General Data

Column No.	:	C21
Level	:	-8.25 ft To 0 ft
Frame Type	=	Lateral
Response Modification Coefficient	=	3
Design Code	=	ACI 318 - 14
Grade Of Concrete (f'c)	=	C3.5 ksi
Grade Of Steel (Main)	=	Fy60 ksi
Grade Of Steel (Shear)	=	Fy60 ksi
Grade Of Steel - Flexural Design	=	Fy60 ksi
Grade Of Steel - Shear Design	=	Fy60 ksi
Consider Ductile	=	Yes
Type of Frame	=	Special
Column B	=	30 in
Column D	=	36 in
Clear Cover, Cc	=	2 in
Clear Floor Height @ lux	=	69 in
Clear Floor Height @ luy	=	69 in
No Of Floors	=	1
No Of Columns In Group	=	1
Strength Reduction Factor φ (Shear)	=	0.6

Shear Calculation (Analysis Forces)	Along D	Along B
Lu (in)	69	69
Pu Top (kip)	788.73	788.73
Mnt (kip-ft)	1493.55	1239.38
Pu Bottom (kip)	797.09	797.09
Mnb (kip-ft)	1486.79	1232.81
Vu1 (kip)	518.32	429.95
Shear from Beam Capacity at Joint		
Moment Mnt (kip-ft)	MAX((left,Bot + Right,Top), (left,Top + Right,Bot))	
	543.48	723.33
Moment Mnb (kip-ft)	MAX((Left,Top + Right,Bot), (Right,Top + Left,Bot))	
	0	0
Lu (in)	69	69
Vu2 (kip)	94.52	125.8
Critical Analysis Load Combination	100	108
Critical Load Combination	[1] : 1.4 (LOAD 1: DEAD LOAD)	[9] : 0.9 (LOAD 1: DEAD LOAD) +(LOAD 4: EQ-Y)
Nu (kip)	1240.19	788.73
Mu (kip-ft)	47.9	12.67
Vu3 (kip)	277.38	9.4
Vu' (kip)	Minimum(Vu1, Vu2)	
	94.52	125.8
Design Shear, Vu (kip)	Maximum(Vu', Vu3)	
	277.38	125.8
λ	1	1
φ	0.6	0.6
Deff (in)	33.5	27.5
ρw (50% of As provided)	0.006	0.006
Mm (kip-ft)	-1379.62	-747.31
φVc (kip)	226.7	192.93
Check	Vu > φVc	Vu < φVc
Link For Shear Design	Required	Not Required
Shear Links Design		
Vs (kip)	(Vu - φVc) / φVc	
	84.47	-
Vs Permissible (kip)	8 x sqrt(f'c) x b x deff	
	475.64	-
Vs Permissible Check	Vs < Vs permissible; Hence, OK	-
Check for Minimum Shear Reinforcement		-
0.5 x φVc (kip)	113.35	-
Minimum Shear Reinforcement Check	Vu > 0.5 x φVc; Hence, Minimum Shear reinforcement required	-
Av/s minimum (in^2/ft)	0.3	-
Av/s shear (in^2/ft)	0.5	-
Av/s required (in^2/ft)	max (Av/s minimum , Av/s shear)	
	0.5	-
Link Rebar Number	3	-
Diameter of link (in)	0.37	-
Numbers of legs provided	6	-
Spacing of Link Provided (in)	12	-
Av/s provided (in^2/ft)	0.66	-
Av/s provided check	Av/s required < Av/s provided; Hence, OK	-