

## COLUMN DESIGN FOR SHEAR AND LINKS (DUCTILE SPECIAL FRAME)

### DESIGN CODE ACI 318M-2014

#### Input / Defaults

<i>ColumnNo</i> := C22		
<i>Location</i> := Bottom Joint		
<i>TypeOfColumn</i> := 3	-----	1- for Non-Ductile, 2 for Intermediate, 3 for Special
<i>B</i> := 600 <b>mm</b>	-----	Width of the Column
<i>D</i> := 900 <b>mm</b>	-----	Depth of the Column
<i>Pu_D</i> := 4112.05 <b>kN</b>	-----	factored axial force occurring simultaneously with Vu along D
<i>Pu_B</i> := 2604.49 <b>kN</b>	-----	factored axial force occurring simultaneously with Vu along B
<i>Mshear_D</i> := 100.96 <b>kN·m</b>	-----	factored Bending Moment occurring simultaneously with Vu along D
<i>Mshear_B</i> := 100.96 <b>kN·m</b>	-----	factored Bending Moment occurring simultaneously with Vu along B
<i>Vuy3</i> := 981.8 <b>kN</b>	-----	Ultimate Shear force at section considered along D
<i>Vux3</i> := 59.93 <b>kN</b>	-----	Ultimate Shear force at section considered along B
<i>f'c</i> := 25 <b>MPa</b>	-----	Grade of Concrete (Cylindrical Strength)
<i>fy</i> := 550 <b>MPa</b>	-----	Grade of Reinforcement for Main Reinforcement
<i>fyt</i> := 550 <b>MPa</b>	-----	Grade of Reinforcement for Secondary Reinforcement
<i>Cc</i> := 50 <b>mm</b>	-----	Nominal Cover to Beam Tension Reinforcement
<i>Es</i> := 200000 <b>MPa</b>	-----	Modulus of elasticity of reinforcement
<i>LuD</i> := 3400 <b>mm</b>	-----	Clear Floor Height @ lux
<i>LuB</i> := 3400 <b>mm</b>	-----	Clear Floor Height @ luy
<i>λ</i> := 1	-----	Modification factor for compressive strength

#### Reinforcement Provided

<i>φ1</i> := 19.1 <b>mm</b>	-----	Diameter of Reinforcement
<i>N1</i> := 18	-----	No of Rebar
<i>φ2</i> := 15.9 <b>mm</b>	-----	Diameter of Reinforcement
<i>N2</i> := 2	-----	No of Rebar

$$A_{st} := \frac{\pi \cdot \phi 1^2}{4} \cdot N1 + \frac{\pi \cdot \phi 2^2}{4} \cdot N2 = 5554.493 \text{ mm}^2 \quad \text{----- Area of Reinforcement Provided}$$

#### Shear reinforcement Provided

<i>φ3</i> := 9.5 <b>mm</b>	-----	Diameter of Link
<i>Bundled_1</i> := 1		
<i>Legs1</i> := 5	-----	Number of shear Legs along D
<i>Legs2</i> := 7	-----	Number of shear Legs along B
<i>Spc</i> := 250 <b>mm</b>	-----	Spacing of Non-ductile links provided
<i>φ4</i> := 9.5 <b>mm</b>	-----	Diameter of Ductile links
<i>Spc_Duct</i> := 75 <b>mm</b>	-----	Spacing of ductile links provided
<i>Bundled_2</i> := 1		

$$A_{svprv\_D} := \left( \frac{\pi \cdot \phi 3^2}{4} \cdot Legs1 \right) \cdot \frac{1}{Spc} \cdot Bundled\_1 = 1417.644 \frac{\text{mm}^2}{\text{m}} \quad \text{----- Area of Links Provided along D}$$

$$A_{svprv\_B} := \left( \frac{\pi \cdot \phi^3^2 \cdot Legs2}{4} \right) \cdot \frac{1}{Spc} \cdot Bundled\_1 = 1984.701 \frac{mm^2}{m}$$

----- Area of Links Provided along B

$$A_{svprv\_Duct} := \left( \frac{\pi \cdot \phi^4^2}{4} \right) \cdot \frac{1 \cdot m}{Spc\_Duct} \cdot Bundled\_2 = 945.096 mm^2$$

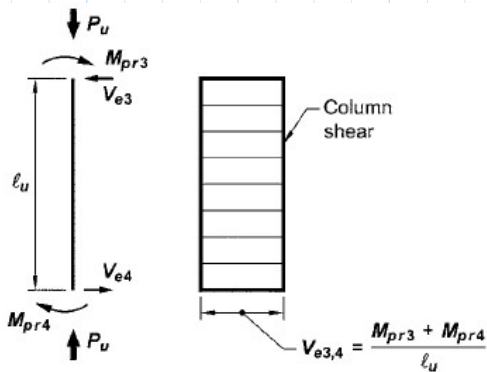
----- Area of Ductile Links Provided

$$f_{y\_s} := \begin{cases} \text{if } f_y > 420 \text{ MPa} & = 420 \text{ MPa} \\ & \parallel 420 \text{ MPa} \\ \text{else} & \\ & \parallel f_y \end{cases}$$

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

### Shear Force Calculation

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



- 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

$$LuD = 3.4 \text{ m}$$

$$Pu\_top := 2574.39 \text{ kN}$$

$$Mnt\_top := 1612.46 \text{ kN} \cdot \text{m}$$

$$Pu\_bot := 2625.44 \text{ kN}$$

$$Mnt\_bot := 1599.92 \text{ kN} \cdot \text{m}$$

$$V_{uy1} := \frac{(Mnt\_top + Mnt\_bot)}{LuD} = 944.818 \text{ kN}$$

Along B

$$LuB = 3.4 \text{ m}$$

$$Pu\_top := 2574.39 \text{ kN}$$

$$Mnt\_top := 1044.08 \text{ kN} \cdot \text{m}$$

$$Pu\_bot := 2625.44 \text{ kN}$$

$$Mnt\_bot := 1032.59 \text{ kN} \cdot \text{m}$$

$$V_{ux1} := \frac{(Mnt\_top + Mnt\_bot)}{LuD} = 610.785 \text{ kN}$$

Note:

The column moment capacity ( $Mnt\_top$  and  $Mnt\_bot$ ) is calculated for axial force ( $P_u$ ) which gives the maximum moment capacity. The PM curve is generated for the  $1.25 f_y$  reinforcement stress and the capacity is calculated. The PM curve available in RCDC is for the  $1.0 f_y$ .

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

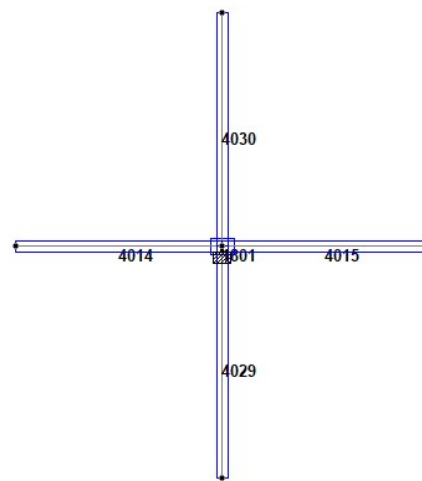
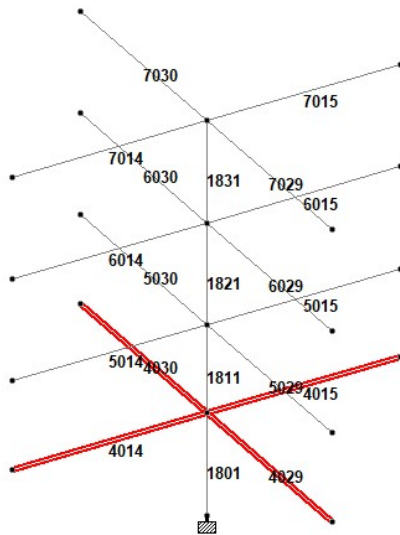
End moment  $M_{pr}$  for columns need not be greater than moments generated by the  $M_{pr}$  of the beams framing into the beam-column joints.  $V_e$  should not be less than that required by analysis of the structure.

Beams at Level: Top Joint

Beam Size (mm)	Beam angle w.r.t. column Ly (deg)	Torsion moment (kNm)	Moment Capacity Beam at Top				Moment Capacity Beam at Bottom				Resultant Moment			
			Mu (kNm)	Ast req (sqmm)	Ast pro (sqmm)	Mu cap (kNm)	Mu (kNm)	Ast req (sqmm)	Ast pro (sqmm)	Mu cap (kNm)	Top @ D (kNm)	Top @ B (kNm)	Bot @ D (kNm)	Bot @ B (kNm)
450 x 800	0	0	445.44	1663.32	1773.52	473.33	0	957.86	1013.44	277.05	473.33	0	277.05	0
450 x 800	90	0	637.26	2438.15	2533.6	660.2	0	1219.08	1266.8	343.7	0	660.2	0	343.7
450 x 800	180	0	491.2	1844.55	1900.2	505.14	0	957.86	1013.44	277.05	505.14	0	277.05	0
450 x 800	270	0	657.62	2522.83	2533.6	660.2	0	1261.42	1266.8	343.7	0	660.2	0	343.7

Effective Moment for Column

	Mu Major (Along D) (kNm)		Mu Minor (Along B) (kNm)	
	Left	Right	Left	Right
Top	505.14	473.33	660.2	660.2
Bottom	277.05	277.05	343.7	343.7



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

$$Mu_{left\_bot} := 277.05 \text{ kN} \cdot \text{m}$$

$$Mu_{left\_top} := 505.14 \text{ kN} \cdot \text{m}$$

$$Mu_{right\_bot} := 277.05 \text{ kN} \cdot \text{m}$$

$$Mu_{right\_top} := 473.33 \text{ kN} \cdot \text{m}$$

$$Mnt\_D := \max((Mu_{left\_bot} + Mu_{right\_top}), (Mu_{left\_top} + Mu_{right\_bot})) = 782.19 \text{ kN} \cdot \text{m}$$

$$V_{uy2} := \frac{Mnt\_D}{LuD} = 230.056 \text{ kN}$$

Along B

$$Mu_{left\_bot} := 343.7 \text{ kN} \cdot \text{m}$$

$$Mu_{left\_top} := 660.2 \text{ kN} \cdot \text{m}$$

$$Mu\_right\_bot := 343.7 \text{ kN} \cdot \text{m}$$

$$Mu\_right\_top := 660.2 \text{ kN} \cdot \text{m}$$

$$Mnt\_B := \max((Mu\_left\_bot + Mu\_right\_top), (Mu\_left\_top + Mu\_right\_bot)) = 1003.9 \text{ kN} \cdot \text{m}$$

$$Vux2 := \frac{Mnt\_B}{LuD} = 295.265 \text{ kN}$$

$$Vu'y := \min(Vuy1, Vuy2) = 230.056 \text{ kN}$$

$$Vu'x := \min(Vux1, Vux2) = 295.265 \text{ kN}$$

### Shear Design along D

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

$$Pu\_D = 4112.05 \text{ kN}$$

$$Mshear\_D = 100.96 \text{ kN} \cdot \text{m}$$

$$Vuy3 = 981.8 \text{ kN}$$

$$Vuy := \max(Vu'y, Vuy3) = 981.8 \text{ kN}$$

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

----- Strength Reduction Factor

$$deff := D - Cc - \frac{\phi 1}{2} = 840.45 \text{ mm}$$

$$pt := \frac{Ast}{2 \cdot B \cdot deff} = 0.00551$$

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

$$Ag := D \cdot B = 540000 \text{ mm}^2$$

$$Aeff\_y := deff \cdot B = 504270 \text{ mm}^2$$

$$Mm\_y := Mshear\_D - Pu\_D \cdot \frac{(4 \cdot D - deff)}{8} = -1317.466 \text{ kN} \cdot \text{m}$$

$$Vcy1 := 0.17 \cdot \left( 1 \cdot \text{MPa} + \left( \frac{Pu\_D}{3.5 \cdot Ag} \right) \right) \cdot \lambda \cdot \sqrt{f'c \cdot \text{MPa}} \cdot B \cdot \frac{deff}{\text{MPa}} = 1361.193 \text{ kN}$$

----- Clause 22.5.7.1

$$Vcy2 := \left( 0.16 \cdot \sqrt{f'c \cdot \text{MPa}} + 17 \cdot pt \cdot \text{MPa} \cdot \left( \frac{Vuy \cdot deff}{Mm\_y} \right) \right) \cdot B \cdot deff = 373.845 \text{ kN}$$

----- Table 22.5.6.1 (a)

$$Vcy3 := \left( 0.29 \cdot \sqrt{f'c} \cdot \sqrt{1 \cdot \text{MPa} + \left( 0.29 \cdot \frac{Pu\_D}{Ag} \right)} \right) \cdot B \cdot deff = 1309.695 \text{ kN}$$

----- Table 22.5.6.1 (b)

$$\phi Vcy := \begin{cases} \text{if } Pu\_D < 0 \\ \quad \parallel \\ \quad \parallel Vcy1 \cdot \phi \\ \quad \parallel \\ \quad \parallel \text{else if } Mm\_y < 0 \\ \quad \parallel \\ \quad \parallel Vcy3 \cdot \phi \\ \quad \parallel \\ \quad \parallel \text{else} \\ \quad \parallel \\ \quad \parallel \phi \cdot \min(Vcy2, Vcy3) \end{cases} = 785.817 \text{ kN}$$

$$Check1 := \begin{cases} \text{if } \phi V_{cy} \geq V_{uy} & = \text{"ShearReinfRequired"} \\ \quad \text{"ShearReinfNotRequired"} \\ \text{else} & \text{----- Clause 7.1.1} \\ \quad \text{"ShearReinfRequired"} \end{cases}$$

$$f_{y_s} = 420 \text{ MPa}$$

$$V_{sy} := \begin{cases} \text{if } \phi V_{cy} \geq V_{uy} & = 326.638 \text{ kN} \\ \quad 0 \text{ kN} \\ \text{else} \\ \quad \frac{(V_{uy} - \phi V_{cy})}{\phi} & \text{----- Clause 7.1.1} \end{cases}$$

$$V_{sy\_perm} := 0.66 \cdot \sqrt{f'_c \cdot \text{MPa}} \cdot B \cdot d_{eff} = 1664.091 \text{ kN}$$

$$Check2 := \begin{cases} \text{if } V_{sy\_perm} \geq V_{sy} & = \text{"Ok"} \\ \quad \text{"Ok"} \\ \text{else} \\ \quad \text{"Revise"} \end{cases}$$

$$Check3 := \begin{cases} \text{if } V_{uy} > 0.5 \cdot \phi V_{cy} & = \text{"Check for Min. Shear Reinf"} \\ \quad \text{"Check for Min. Shear Reinf"} \\ \text{else} \\ \quad \text{"Check for Min. Shear Reinf Not Req"} \end{cases}$$

$$Asv\_min1 := \max \left( 0.062 \cdot \sqrt{f'_c \cdot \text{MPa}} \cdot \frac{B}{f_{y_s}} \cdot 1000 \cdot \text{mm}, 0.35 \cdot \frac{B}{f_{y_s}} \cdot 1000 \cdot \text{MPa} \cdot \text{mm} \right) = 500 \text{ mm}^2$$

$$Asv\_min := \begin{cases} \text{if } V_{uy} > 0.5 \cdot \phi V_{cy} & = 500 \text{ mm}^2 \\ \quad Asv\_min1 \\ \text{else} \\ \quad 0 \text{ mm}^2 \end{cases}$$

$$Asv\_shear\_y := \begin{cases} \text{if } \phi V_{cy} \geq V_{uy} & = 925.35 \text{ mm}^2 \\ \quad 0 \text{ mm}^2 \\ \text{else} \\ \quad \frac{V_{sy} \cdot m}{f_{y_s} \cdot d_{eff}} \end{cases}$$

$$Asv\_req\_y := \frac{\max(Asv\_min, Asv\_shear\_y)}{m} = 925.35 \frac{\text{mm}^2}{m}$$

$$Check := \begin{cases} \text{if } Asv_{prv\_D} > Asv\_req\_y & = \text{"Ok"} \\ \quad \text{"Ok"} \\ \text{else} \\ \quad \text{"Increase Reinforcement"} \end{cases}$$

## Shear Design along B

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

$$Pu\_B = 2604.49 \text{ kN}$$

$$M_{shear\_B} := 109.65 \text{ kN} \cdot \text{m}$$

$$V_{ux3} = 59.93 \text{ kN}$$

$$V_{ux} := \max(V_{u'x}, V_{ux3}) = 295.265 \text{ kN}$$

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

----- Strength Reduction Factor

$$b_{eff} := B - C_c - \frac{\phi 1}{2} = 540.45 \text{ mm}$$

$$p_t := \frac{A_{st}}{2 \cdot D \cdot b_{eff}} = 0.00571$$

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

$$A_g := D \cdot B = 540000 \text{ mm}^2$$

$$A_{eff\_x} := b_{eff} \cdot D = 486405 \text{ mm}^2$$

$$M_{m\_x} := M_{shear\_B} - Pu\_B \cdot \frac{(4 \cdot B - b_{eff})}{8} = -495.747 \text{ kN} \cdot \text{m}$$

$$V_{cx1} := 0.17 \cdot \left( 1 \cdot \text{MPa} + \left( \frac{Pu\_B}{3.5 \cdot A_g} \right) \right) \cdot \lambda \cdot \sqrt{f'_c \cdot \text{MPa}} \cdot D \cdot \frac{b_{eff}}{\text{MPa}} = 983.186 \text{ kN}$$

----- Clause 22.5.7.1

$$V_{cx2} := \left( 0.16 \cdot \sqrt{f'_c \cdot \text{MPa}} + 17 \cdot p_t \cdot \text{MPa} \cdot \left( \frac{V_{ux} \cdot b_{eff}}{M_{m\_x}} \right) \right) \cdot D \cdot b_{eff} = 373.927 \text{ kN}$$

----- Table 22.5.6.1 (a)

$$V_{cx3} := \left( 0.29 \cdot \sqrt{f'_c} \cdot \sqrt{1 \cdot \text{MPa} + \left( 0.29 \cdot \frac{Pu\_B}{A_g} \right)} \right) \cdot D \cdot b_{eff} = 1092.332 \text{ kN}$$

----- Table 22.5.6.1 (b)

$$\phi V_{cx} := \begin{cases} \text{if } Pu\_B < 0 \\ \quad \parallel V_{cx1} \cdot \phi \\ \quad \parallel \text{else if } M_{m\_x} < 0 \\ \quad \parallel V_{cx3} \cdot \phi \\ \quad \parallel \text{else} \\ \quad \parallel \phi \cdot \min(V_{cx2}, V_{cx3}) \end{cases} = 655.4 \text{ kN}$$

$$Check1 := \begin{cases} \text{if } \phi V_{cx} \geq V_{ux} \\ \quad \parallel \text{“ShearReinfNotRequired”} \\ \quad \parallel \text{else} \\ \quad \parallel \text{“ShearReinfRequired”} \end{cases} = \text{“ShearReinfNotRequired”}$$

$$f_{y\_s} = 420 \text{ MPa}$$

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

----- Clause 7.1.1

$$Vsx_{perm} := 0.66 \cdot \sqrt{f'c \cdot MPa} \cdot D \cdot beff = 1605.137 \text{ kN}$$

$$Check2 := \begin{cases} \text{if } Vsx_{perm} \geq Vsx & = \text{"Ok"} \\ \text{else} & \\ \text{"Revise"} & \end{cases}$$

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

$$Asv_{min1} := \max \left( 0.062 \cdot \sqrt{f'c \cdot MPa} \cdot \frac{D}{fy_s} \cdot 1000 \cdot mm, 0.35 \cdot \frac{D}{fy_s} \cdot 1000 \cdot MPa \cdot mm \right) = 750 \text{ mm}^2$$

$$Asv_{min} := \begin{cases} \text{if } Vux > 0.5 \cdot \phi Vcx & = 0 \text{ mm}^2 \\ \text{else} & \\ Asv_{min1} & \end{cases}$$

$$Asv_{shear\_x} := \begin{cases} \text{if } \phi Vcx \geq Vux & = 0 \text{ mm}^2 \\ \text{else} & \\ \frac{Vsx \cdot m}{fy_s \cdot beff} & \end{cases}$$

$$Asv_{req\_x} := \frac{\max(Asv_{min}, Asv_{shear\_x})}{m} = 0 \frac{\text{mm}^2}{m}$$

$$Check := \begin{cases} \text{if } Asv_{prv\_D} > Asv_{req\_x} & = \text{"Ok"} \\ \text{else} & \\ \text{"Increase Reinforcement"} & \end{cases}$$

### Detailing of Links

#### Check for Minimum Diameter (Clause 25.7.2.2)

$$maxDia := \max(\phi1, \phi2) = 19.1 \text{ mm}$$

$$Bundled := 1$$

$$Effective\_Area := \frac{\pi}{4} \cdot maxDia^2 \cdot Bundled = 286.521 \text{ mm}^2$$

$$Effective\_Dia := \sqrt{\frac{Effective\_Area \cdot 4}{\pi}} = 19.1 \text{ mm}$$

$$Min\_Dia := \begin{cases} \text{if } Effective\_Dia > 35.8 \text{ mm} & = 9.5 \text{ mm} \\ \quad \parallel & \\ \quad \parallel 12.7 \text{ mm} & \\ \quad \text{else if } Bundled > 1 & \\ \quad \quad \parallel & \\ \quad \quad \parallel 12.7 \text{ mm} & \\ \quad \text{else} & \\ \quad \quad \parallel & \\ \quad \quad \parallel 9.5 \text{ mm} & \end{cases}$$

$$Check := \begin{cases} \text{if } \phi 3 \geq Min\_Dia & = \text{"Ok"} \\ \quad \parallel & \\ \quad \parallel \text{"Ok"} & \\ \quad \text{else} & \\ \quad \quad \parallel & \\ \quad \quad \parallel \text{"Increase Diameter"} & \end{cases}$$

#### Check for Minimum Area of Shear Reinforcement (Clause 7.10.5.1)

Along D

$$Asv\_minD := \max\left(0.062 \cdot \sqrt{f'c \cdot MPa} \cdot \frac{B}{fy\_s} \cdot 1000 \cdot mm, 0.35 \cdot \frac{B}{fy\_s} \cdot 1000 \cdot MPa \cdot mm\right) = 500 \text{ mm}^2$$

$$Check := \begin{cases} \text{if } Asvprv\_D \geq \frac{Asv\_minD}{m} & = \text{"Ok"} \\ \quad \parallel & \\ \quad \parallel \text{"Ok"} & \\ \quad \text{else} & \\ \quad \quad \parallel & \\ \quad \quad \parallel \text{"Increase Shear Reinf"} & \end{cases}$$

Along B

$$Asv\_minB := \max\left(0.062 \cdot \sqrt{f'c \cdot MPa} \cdot \frac{D}{fy\_s} \cdot 1000 \cdot mm, 0.35 \cdot \frac{D}{fy\_s} \cdot 1000 \cdot MPa \cdot mm\right) = 750 \text{ mm}^2$$

$$Check := \begin{cases} \text{if } Asvprv\_B \geq \frac{Asv\_minB}{m} & = \text{"Ok"} \\ \quad \parallel & \\ \quad \parallel \text{"Ok"} & \\ \quad \text{else} & \\ \quad \quad \parallel & \\ \quad \quad \parallel \text{"Increase Shear Reinf"} & \end{cases}$$

#### Check for Minimum Spacing (Clause 25.7.2.1)

$$Spc1 := 16 \cdot \min(\phi 1, \phi 2) = 254.4 \text{ mm}$$

$$Spc2 := 48 \cdot \phi 3 = 456 \text{ mm}$$

$$Spc3 := B = 600 \text{ mm}$$

#### Criterion for spacing for shear reinforcement (Clause 10.7.6.2)

Along D

$$Vsy := \begin{cases} \text{if } \phi Vcy \geq Vuy & = 326.638 \text{ kN} \\ \quad \parallel & \\ \quad \parallel 0 \text{ kN} & \\ \quad \text{else} & \\ \quad \quad \parallel & \\ \quad \quad \parallel \frac{(Vuy - \phi Vcy)}{\phi} & \end{cases}$$



$$V_{sy\_1} := 0.33 \cdot \sqrt{f'c \cdot MPa} \cdot A_{eff\_y} = 832.046 \text{ kN}$$

$$Spc4 := \begin{cases} \text{if } V_{sy} \leq V_{sy\_1} & = 420.225 \text{ mm} \\ \left\| \frac{d_{eff}}{2} \right\| \\ \text{else} \\ \left\| \frac{d_{eff}}{4} \right\| \end{cases}$$

$$Spc5 := \begin{cases} \text{if } V_{sy} \leq V_{sy\_1} & = 600 \text{ mm} \\ \left\| 600 \text{ mm} \right\| \\ \text{else} \\ \left\| 300 \text{ mm} \right\| \end{cases}$$

Along B

$$V_{sx} := \begin{cases} \text{if } \phi V_{cx} \geq V_{ux} & = 0 \text{ kN} \\ \left\| 0 \text{ kN} \right\| \\ \text{else} \\ \left\| \frac{(V_{uy} - \phi V_{cy})}{\phi} \right\| \end{cases}$$

$$V_{sx\_1} := 0.33 \cdot \sqrt{f'c \cdot MPa} \cdot A_{eff\_y} = 832.046 \text{ kN}$$

$$Spc6 := \begin{cases} \text{if } V_{sx} \leq V_{sx\_1} & = 270.225 \text{ mm} \\ \left\| \frac{b_{eff}}{2} \right\| \\ \text{else} \\ \left\| \frac{b_{eff}}{4} \right\| \end{cases}$$

$$Spc7 := \begin{cases} \text{if } V_{sx} \leq V_{sx\_1} & = 600 \text{ mm} \\ \left\| 600 \text{ mm} \right\| \\ \text{else} \\ \left\| 300 \text{ mm} \right\| \end{cases}$$

$$SpcReq := \min(Spc1, Spc2, Spc3, Spc4, Spc5, Spc6, Spc7) = 254.4 \text{ mm}$$

$$Check := \begin{cases} \text{if } Spc \leq SpcReq & = \text{"Ok"} \\ \left\| \left\| \text{"Ok"} \right\| \right\| \\ \text{else} \\ \left\| \left\| \text{"Reduce spacing"} \right\| \right\| \end{cases}$$

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

$$DSpc1 := 6 \cdot \min(\phi_1, \phi_2) = 95.4 \text{ mm}$$

$$DSpc2 := \frac{B}{4} = 150 \text{ mm}$$

$$DSpc3 := \begin{cases} \text{if } TypeOfColumn > 2 & = 1000 \text{ mm} \\ \quad \begin{cases} 1000 \text{ mm} \\ \text{else} \\ 24 \cdot \phi 3 \end{cases} \end{cases}$$

$$DSpc4 := \begin{cases} \text{if } TypeOfColumn > 2 & = 1000 \text{ mm} \\ \quad \begin{cases} 1000 \text{ mm} \\ \text{else} \\ 300 \text{ mm} \end{cases} \end{cases}$$

$$Hx := \max \left( \frac{(D - 2 \cdot Cc - \phi 1)}{Legs1 - 1}, \frac{(B - 2 \cdot Cc - \phi 1)}{Legs2 - 1} \right) = 195.225 \text{ mm}$$

$$DSpc5 := \min \left( \max \left( 100 \cdot \text{mm}, 10 \cdot \text{mm} + \frac{(350 \cdot \text{mm} - Hx)}{3} \right), 150 \cdot \text{mm} \right) = 100 \text{ mm}$$

$$DSpcReq := \min (DSpc1, DSpC2, DSpC3, DSpC4, DSpC5) = 95.4 \text{ mm}$$

$$Check := \begin{cases} \text{if } Spc\_Duct \leq DSpCReq & = \text{"Ok"} \\ \quad \begin{cases} \text{"Ok"} \\ \text{else} \\ \text{"Reduce spacing"} \end{cases} \end{cases}$$

#### 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)

$$Pu := 5405.69 \text{ kN}$$

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

$$Check2 := \begin{cases} \text{if } f'c \leq 60 \text{ MPa} & = \text{"f'c} < 60"} \\ \quad \begin{cases} \text{"f'c} < 60"} \\ \text{else} \\ \text{"f'c} > 60"} \end{cases} \end{cases}$$

$$totalNoOfRebars := N1 + N2 = 20$$

$$kn := \frac{totalNoOfRebars}{(totalNoOfRebars - 2)} = 1.111$$

$$kf := \max \left( \frac{f'c}{175 \cdot \text{MPa}} + 0.6, 1 \right) = 1$$

$$Ag = 540000 \text{ mm}^2$$

$$Spc\_Duct = 75 \text{ mm}$$

$$Bundled\_2 = 1$$

Along D

$$bc1 := B - 2 \cdot Cc + 2 \cdot \phi4 = 519 \text{ mm}$$

$$Ach := (D - 2 \cdot Cc + 2 \cdot \phi4) \cdot (B - 2 \cdot Cc + 2 \cdot \phi3) = 425061 \text{ mm}^2$$

$$Ash1 := 0.3 \cdot \left( \frac{Ag}{Ach} - 1 \right) \cdot \frac{f'c}{fyt} \cdot bc1 \cdot Spc\_Duct = 143.53 \text{ mm}^2$$

$$Ash2 := 0.09 \cdot \frac{f'c}{fyt} \cdot bc1 \cdot Spc\_Duct = 159.239 \text{ mm}^2$$

$$Ash3 := \begin{cases} \text{if } Pu > 0.3 \cdot Ag \cdot f'c & \\ \quad \left| \begin{array}{l} 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot bc1 \cdot Spc\_Duct \\ \text{also if } f'c > 60 \text{ MPa} \\ \quad \left| \begin{array}{l} 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot bc1 \cdot Spc\_Duct \\ \text{else} \\ \quad \left| \begin{array}{l} 0 \text{ mm}^2 \end{array} \right. \end{array} \right. & \\ \end{array} \right. & = 200.01 \text{ mm}^2 \end{cases}$$

$$Ash\_D := \max(Ash1, Ash2, Ash3) = 200.011 \text{ mm}^2$$

$$Ash\_D\_Provided := \frac{\pi \cdot \phi4^2}{4} \cdot Legs1 \cdot Bundled\_2 = 354.411 \text{ mm}^2$$

$$Check := \begin{cases} \text{if } Ash\_D \leq Ash\_D\_Provided & \\ \quad \left| \begin{array}{l} \text{"Ok"} \\ \text{else} \\ \quad \left| \begin{array}{l} \text{"Revise"} \end{array} \right. \end{array} \right. & = \text{"Ok"} \end{cases}$$

Along B

$$dc1 := D - 2 \cdot Cc + 2 \cdot \phi4 = 819 \text{ mm}$$

$$Ach := (D - 2 \cdot Cc + 2 \cdot \phi4) \cdot (B - 2 \cdot Cc + 2 \cdot \phi3) = 425061 \text{ mm}^2$$

$$Ash1 := 0.3 \cdot \left( \frac{Ag}{Ach} - 1 \right) \cdot \frac{f'c}{fyt} \cdot dc1 \cdot Spc\_Duct = 226.496 \text{ mm}^2$$

$$Ash2 := 0.09 \cdot \frac{f'c}{fyt} \cdot dc1 \cdot Spc\_Duct = 251.284 \text{ mm}^2$$

$$Ash3 := \begin{cases} \text{if } Pu > 0.3 \cdot Ag \cdot f'c & \\ \quad \left| \begin{array}{l} 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot dc1 \cdot Spc\_Duct \\ \text{also if } f'c > 60 \text{ MPa} \\ \quad \left| \begin{array}{l} 0.2 \cdot kn \cdot kf \cdot \frac{Pu}{fyt \cdot Ach} \cdot dc1 \cdot Spc\_Duct \\ \text{else} \\ \quad \left| \begin{array}{l} 0 \text{ mm}^2 \end{array} \right. \end{array} \right. & \\ \end{array} \right. & = 315.62 \text{ mm}^2 \end{cases}$$

$$Ash\_B := \max(Ash1, Ash2, Ash3) = 315.624 \text{ mm}^2$$

$$Ash\_B\_Provided := \frac{\pi \cdot \phi4^2}{4} \cdot Legs2 \cdot Bundled\_2 = 496.175 \text{ mm}^2$$

$Check := \begin{cases} \text{if } Ash\_D \leq Ash\_D\_Provided & = \text{“Ok”} \\ \text{“Ok”} \\ \text{else} \\ \text{“Revise”} \end{cases}$

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

$$Ash\_D\_Prv\_area := \frac{\pi \cdot \phi^3}{4} \cdot Legs1 \cdot Bundled\_2 \cdot \frac{1 \cdot m}{Spc\_Duct} = 4725.479 \text{ mm}^2$$

$$Asv\_req\_y = 925.35 \frac{1}{m} \cdot \text{mm}^2$$

$Check := \begin{cases} \text{if } Ash\_D\_Prv\_area > Asv\_shear\_y & = \text{“Ok”} \\ \text{“Ok”} \\ \text{else} \\ \text{“Revise”} \end{cases}$

$$Ash\_B\_Prv\_area := \frac{\pi \cdot \phi^3}{4} \cdot Legs2 \cdot Bundled\_2 \cdot \frac{1 \cdot m}{Spc\_Duct} = 6615.671 \text{ mm}^2$$

$$Asv\_req\_x = 0 \frac{1}{m} \cdot \text{mm}^2$$

$Check := \begin{cases} \text{if } Ash\_B\_Prv\_area > Asv\_shear\_x & = \text{“Ok”} \\ \text{“Ok”} \\ \text{else} \\ \text{“Revise”} \end{cases}$

**Length of Confining Zone (Clause 18.7.5.1)**

$$Z1 := \max(D, B) = 900 \text{ mm}$$

$$Z2 := \frac{\max(LuD, LuB)}{6} = 566.667 \text{ mm}$$

$$Z3 := 450 \text{ mm}$$

$$ZoneLength := \max(Z1, Z2, Z3) = 900 \text{ mm}$$

**RCDC Output - Design Calculation Report**

General Data		
Column No.	:	C22
Level	:	0 m To 4.2 m
Frame Type	=	Lateral
Response Modification Coefficient	=	3
Design Code	=	ACI 318M - 14
Grade Of Concrete (f'c)	=	C25 N/sqmm
Grade Of Steel (Main)	=	Fy550 N/sqmm
Grade Of Steel (Shear)	=	Fy550 N/sqmm
Grade Of Steel - Flexural Design	=	Fy420 N/sqmm
Grade Of Steel - Shear Design	=	Fy420 N/sqmm
Consider Ductile	=	Yes
Type of Frame	=	Special
Column B	=	600 mm
Column D	=	900 mm
Clear Cover, Cc	=	50 mm
Clear Floor Height @ Iux	=	3400 mm
Clear Floor Height @ Iuy	=	3400 mm
No Of Floors	=	1
No Of Columns In Group	=	1
Strength Reduction Factor $\phi$ (Shear)	=	0.6

<b>Shear Calculation (Analysis Forces)</b>	<b>Along D</b>	<b>Along B</b>
Lu (mm)	3400	3400
Pu Top (kN)	2574.39	2574.39
Mnt (kNm)	1612.46	1044.08
Pu Bottom (kN)	2625.44	2625.44
Mnb (kNm)	1599.92	1032.59
Vu1 (kN)	944.82	610.78
<b>Shear from Beam Capacity at Joint</b>		
Moment Mnt (kNm)	MAX((left,Bot + Right,Top), (left,Top + Right,Bot))	
	782.19	1003.9
Moment Mnb (kNm)	MAX((Left,Top + Right,Bot), (Right,Top + Left,Bot))	
	0	0
Lu (mm)	3400	3400
Vu2 (kN)	230.06	295.27
Critical Analysis Load Combination	5	17
Critical Load Combination	[1] : 1.4 (LOAD 1: LOAD CASE 1)	[13] : 0.9 (LOAD 1: LOAD CASE 1) -(LOAD 4: LOAD CASE 4 EQ-Y)
Nu (kN)	4112.05	2604.49
Mu (kNm)	100.96	109.65
Vu3 (kN)	981.8	59.93
Vu' (kN)	Minimum(Vu1, Vu2)	
	230.06	295.27
Design Shear, Vu (kN)	Maximum(Vu', Vu3)	
	981.8	295.27
$\lambda$	1	1
$\phi$	0.6	0.6
Deff (mm)	840.45	540.45
pw (50% of As provided)	0.006	0.006
Mm (kNm)	-1317.47	-495.75
$\phi Vc$ (kN)	785.82	655.4
Check	Vu > $\phi Vc$	Vu < $\phi Vc$
Link For Shear Design	Required	Not Required
<b>Shear Links Design</b>		
Vs (kN)	(Vu - $\phi Vc$ ) / $\phi Vc$	
	326.63	-
Vs Permissible (kN)	0.66 x sqrt( $f_c$ ) x b x deff	
	1664.09	-
Vs Permissible Check	Vs < Vs permissible; Hence, OK	
<b>Check for Minimum Shear Reinforcement</b>		
0.5 x $\phi Vc$ (kN)	392.91	-
Minimum Shear Reinforcement Check	Vu > 0.5 x $\phi Vc$ ; Hence, Minimum Shear reinforcement required	
Av/s minimum (sqmm/m)	500	-
Av/s shear (sqmm/m)	925.33	-
Av/s required (sqmm/m)	max (Av/s minimum , Av/s shear)	
	925.33	-
Link Rebar Number	10	-
Diameter of link (mm)	9.5	-
Numbers of legs provided	5	-
Spacing of Link Provided (mm)	250	-
Av/s provided (sqmm/m )	1417.6	-
Av/s provided check	Av/s required < Av/s provided; Hence, OK	