COLUMN DESIGN FOR FLEXURAL (NON DUCTILE-BRACED)

DESIGN CODE ACI 318M-2014

General Data

$ColumnNo$: C1

$Level$: 0 m to 4.2m

$FrameType := 1$ ----------- 1- for Non Ductile, 2 for Special

$B := 400\ mm$ ----------- Width of the Column

$D := 600\ mm$ ----------- Depth of the Column

$f'c := 25\ MPa$ ----------- Grade of Concrete (Cylindrical Strength)

$fy := 420\ MPa$ ----------- Grade of Main Reinforcement

$fyt := 420\ MPa$ ----------- Grade of Secondary Reinforcement

$Cc := 50\ mm$ ----------- Nominal Cover to Beam Tension Reinforcement

$Es := 200000\ MPa$ ----------- Modulus of elasticity of reinforcement

$\phi BM := 0.65$ ----------- Capacity reduction factor for Bending Moment

$\phi shear := 0.75$ ----------- Capacity reduction factor for Shear and torsion

$ptmax := 4$ ----------- Maximum % reinforcement

$ptmin := 1$ ----------- Minimum % reinforcement

$\varepsilon cu := 0.003$ ----------- Permissible Strain in Concrete

$lux := 5000\ mm$ ----------- Clear Floor Height along Major Direction@lux

$luy := 5400\ mm$ ----------- Clear Floor Height along Minor Direction@luy

$NoOfFloors := 1$ ----------- Number of Floors considered after merged of levels

$NoOfColumnsInGroup := 1$ ----------- Number of column in Group

$ColumnType := 1$ ----------- 1- for Braced, 2 for Un-Braced

$MinimumEccentricityCheck$ ----------- Simultaneously (Both Axis)

$CodeDefinedDBRatio := 4$

$$DBRatio := \begin{array}{l} \text{if } \dfrac{D}{B} < 4 \\ \quad \text{“DesignAsColumn”} \\ \text{else} \\ \quad \text{“DesignAsWall”} \end{array} = \text{“DesignAsColumn”}$$

Reinforcement Provided

$\phi 1 := 32.3\ mm$

$N1 := 4$

$\phi 2 := 28.7\ mm$

$N2 := 8$

$$Ast := \frac{\pi \cdot \phi 1^2}{4} \cdot N1 + \frac{\pi \cdot \phi 2^2}{4} \cdot N2 = 8452.989\ mm^2$$ ----------- Area of Reinforcement Provided

Flexural Design (Analysis Forces)

$AnalysisReferenceNo$ 501

$LoadCombination$ [9] : 1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)

$CriticalLoacation$ Top Joint

$Put := 627.54\ kN$ ----------- Ultimate moment from analysis at Top Node

$Muxt := 361.04\ kN \cdot m$ ----------- Ultimate moment from analysis along D at Top Node

$Muyt := 300.79\ kN \cdot m$ ----------- Ultimate moment from analysis along B at Top Node
$Vuxt := 91.59\ kN$ ----------- Ultimate Shear from analysis along D at Top Node
$Vuyt := -84.72\ kN$ ----------- Ultimate Shear from analysis along B at Top Node
$Pub := 627.54\ kN$ ----------- Ultimate moment from analysis at Bottom Node
$Muxb := -164.06\ kN \cdot m$ ----------- Ultimate moment from analysis along D at Bottom Node
$Muyb := -266.94\ kN \cdot m$ ----------- Ultimate moment from analysis along B at Bottom Node
$Vuxb := 91.59\ kN$ ----------- Ultimate Shear from analysis along D at Bottom Node
$Vuyb := -84.72\ kN$ ----------- Ultimate Shear from analysis along B at Bottom Node

Sway Calculation (Stability Index)

For_Global_X_Direction

LoadCombination [13] : 1.2(LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2)-1.2 (LOAD 3: LOAD CASE 3 EQ-X)

$StoreyHeight(A) := 6200\ mm$ ----------- Height of Story Considered for design
$GravityLoad(B) := 4931.57\ kN$ ----------- Summation of Axial Load of Story selected
$RelativeDisplacement(C) := 1.25\ mm$ ----------- Relative Displacement for Story selected
$StoreyShear(D) := 120.05\ kN$ ----------- Story Shear for Story selected

$$StabilityIndex\_Q := \frac{GravityLoad(B)}{StoreyHeight(A)} \cdot \frac{RelativeDisplacement(C)}{StoreyShear(D)} = 0.008$$

----------- Clause 6.6.4.4.1

$$Check := \begin{array}{l} \text{if } StabilityIndex\_Q \le 0.05 \\ \quad \text{“Non Sway Frame(Braced)”} \\ \text{else} \\ \quad \text{“Sway Frame(UnBraced”} \end{array} = \text{“Non Sway Frame(Braced)”}$$

----------- Clause 6.6.4.3

For_Global_Y_Direction

LoadCombination [13] : 1.2(LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2)+1.2 (LOAD 3: LOAD CASE 3 EQ-Y)

$StoreyHeight(A) := 6200\ mm$ ----------- Height of Story Considered for design
$GravityLoad(B) := 4931.57\ kN$ ----------- Summation of Axial Load of Story selected
$RelativeDisplacement(C) := 2.7\ mm$ ----------- Relative Displacement for Story selected
$StoreyShear(D) := 480.19\ kN$ ----------- Story Shear for Story selected

$$StabilityIndex\_Q := \frac{GravityLoad(B)}{StoreyHeight(A)} \cdot \frac{RelativeDisplacement(C)}{StoreyShear(D)} = 0.004$$

$$Check := \begin{array}{l} \text{if } StabilityIndex\_Q \le 0.05 \\ \quad \text{“Non Sway Frame(Braced)”} \\ \text{else} \\ \quad \text{“Sway Frame(UnBraced”} \end{array} = \text{“Non Sway Frame(Braced)”}$$

----------- Clause 6.6.4.3

Effective Length Factor

$EffectiveLengthFactorAlongD := 1.2$
$EffectiveLengthFactorAlongB := 1.2$

Calculation of Slenderness Check

Along D:

$EffectiveLengthD := EffectiveLengthFactorAlongD \cdot luy = 6480\ mm$

$A := D \cdot B = 240000\ mm^2$ ----------- Area of Cross Section

$IxxD := B \cdot \frac{D^3}{12} = \left(7.2 \cdot 10^9\right)\ mm^4$ ----------- Moment of Inertia

$rD := \sqrt{\left(\frac{IxxD}{A}\right)} = 173.205\ mm$ ----------- Radius of Gyration

$k\_D := EffectiveLengthFactorAlongD = 1.2$

$Actual\_Slender\_D := \frac{EffectiveLengthD}{rD} = 37.412$

$$M1 := \begin{array}{l} \text{if abs}(Muxt) > \text{abs}(Muxb) \\ \quad Muxb \\ \text{else} \\ \quad Muxt \end{array} = -164.06\ kN \cdot m$$

----------- Smaller Design Bending Moment at the ends of the the column. Clause 6.2.5.1(b)

$$M2 := \begin{array}{l} \text{if abs}(Muxb) > \text{abs}(Muxt) \\ \quad Muxb \\ \text{else} \\ \quad Muxt \end{array} = 361.04\ kN \cdot m$$

----------- Higher Design Bending Moment at the ends of the the column. Clause 6.2.5.1(b)

$LerPerD := min\left(40, 34 - 12 \cdot \frac{M1}{M2}\right) = 39.453$ ----------- Clause 6.2.5.1(b)

$$Check1 := \begin{array}{l} \text{if } LerPerD > Actual\_Slender\_D \\ \quad \text{“Column Not Slender Along B”} \\ \text{else if } Actual\_Slender\_D < 100 \\ \quad \text{“Slender\_Use Approximate method”} \\ \text{else} \\ \quad \text{“Slender\_P–delta effect (revise)”} \end{array} = \text{“Column Not Slender Along B”}$$

Along B:

$EffectiveLengthB := EffectiveLengthFactorAlongB \cdot lux = 6000\ mm$

$A := D \cdot B = 240000\ mm^2$ ----------- Area of Cross Section

$IxxB := D \cdot \frac{B^3}{12} = \left(3.2 \cdot 10^9\right)\ mm^4$ ----------- Moment of Inertia

$rB := \sqrt{\left(\frac{IxxB}{A}\right)} = 115.47\ mm$ ----------- Radius of Gyration

$$M1 := \begin{array}{l} \text{if } \text{abs}(Muyt) > \text{abs}(Muyb) \\ \quad \| Muyb \\ \text{else} \\ \quad \| Muyt \end{array} = -266.94\ kN \cdot m$$

----------- Smaller Design Bending Moment at the ends of the the column. Clause 6.2.5

$$M2 := \begin{array}{l} \text{if } \text{abs}(Muyb) > \text{abs}(Muyt) \\ \quad \| Muyb \\ \text{else} \\ \quad \| Muyt \end{array} = 300.79\ kN \cdot m$$

----------- Higher Design Bending Moment at the ends of the the column. Clause 6.2.5

$$Actual\_Slender\_B := \frac{EffectiveLengthB}{rB} = 51.962$$

$$LerPerB := min\left(40, 34 - 12 \cdot \frac{M1}{M2}\right) = 40$$

----------- Clause 6.2.5.1(b)

$$Check1 := \begin{array}{l} \text{if } LerPerB > Actual\_Slender\_B \\ \quad \| \text{“Column Not Slender Along B”} \\ \text{else if } Actual\_Slender\_B < 100 \\ \quad \| \text{“Slender\_Use Approximate method”} \\ \text{else} \\ \quad \| \text{“Slender\_P–delta effect (revise)”} \end{array} = \text{“Slender\_Use Approximate method”}$$

Calculation of Slenderness Moment - Braced (Non-Sway) Frame

Along B:

$\beta dns := 0.6$ ----------- Clause 6.6.4.4.4

$$Ec := 4700 \cdot \sqrt{\left(\frac{f'c}{MPa}\right)} = 23500$$

----------- Clause 19.2.2.1

$$Ig := D \cdot \frac{B^3}{12} = \left(3.2 \cdot 10^9\right)\ mm^4$$

----------- Moment of Inertia of Section

$$EI := 0.288675 \cdot Ec \cdot Ig = \left(2.171 \cdot 10^{13}\right)\ mm^4$$

$M1min := Put \cdot (15 \cdot mm + 0.03 \cdot B) = 16.944\ kN \cdot m$ ----------- Clause 6.6.4.5.4

$M2min := Put \cdot (15 \cdot mm + 0.03 \cdot B) = 16.944\ kN \cdot m$ ----------- Clause 6.6.4.5.4

$$Cm := \begin{array}{l} \text{if } M2min > M2 \\ \quad \| 1 \\ \text{else} \\ \quad \| min\left(\left(0.6 + 0.4 \cdot \left(\frac{M1}{M2}\right)\right), 0.4\right) \end{array} = 0.245$$

----------- Clause 6.6.4.5.3

$$Pc := \pi \cdot \pi \cdot \frac{EI \cdot kN \cdot 1000}{\left(EffectiveLengthB^2\right) \cdot m \cdot m} = 5951.47\ kN$$

----------- Clause 6.6.4.4.2

$$\delta := \max\left(1, \frac{Cm}{\left(1 - \frac{Put}{0.75 \cdot Pc}\right)}\right) = 1$$

----------- Clause 6.6.4.5.2

$Mc1 := \mathrm{sign}(Muyt) \cdot \delta \cdot \max(\mathrm{abs}(Muyt), M1min) = 300.79\ m \cdot kN$

----------- Clause 6.6.4.5.3

$Mc2 := \mathrm{sign}(Muyb) \cdot \delta \cdot \max(\mathrm{abs}(Muyb), M2min) = -266.94\ m \cdot kN$

----------- Clause 6.6.4.5.3

$1.4\ Muyt = 421.106\ 1 \cdot m \cdot kN$

$1.4\ Muyb = -373.716\ 1 \cdot m \cdot kN$

$Mc1\_final := \mathrm{sign}(Mc1) \cdot min(\mathrm{abs}(1.4\ Muyt), \mathrm{abs}(Mc1)) = 300.79\ m \cdot kN$

----------- Clause 6.2.5.3

$Mc2\_final := \mathrm{sign}(Mc2) \cdot min(\mathrm{abs}(1.4\ Muyb), \mathrm{abs}(Mc2)) = -266.94\ m \cdot kN$

----------- Clause 6.2.5.3

Final Design Forces for Flexural Design

At Top Node:

$Put = 627.54\ kN$

$Mux := Muxt = 361.04\ m \cdot kN$

$Muy := Mc1\_final = 300.79\ m \cdot kN$

At Bottom Node:

$Pub = 627.54\ kN$

$Mux := Muxb = -164.06\ m \cdot kN$

$Muy := Mc2\_final = -266.94\ m \cdot kN$

Final Critical Design Forces

At Top Node:

$Put = 627.54\ kN$

$Mux\_Final := Muxt = 361.04\ m \cdot kN$

$Muy\_Final := Mc1\_final = 300.79\ m \cdot kN$

ϕPn, Max Check

$fy\_1 := fy = 420\ MPa$ ----------- Clause 22.4.2.1

$LoadCombination$ [1] : 1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 2: LOAD CASE 2)

$CriticalLocation$ Bottom Joint

$Pu := 863.41\ kN$ ----------- Factored Axial force

$Mux1 := -188.66\ kN \cdot m$ ----------- Factored Bending Moment along Major Direction

$Muy1 := -37.88\ kN \cdot m$ ----------- Factored Bending Moment along Minor Direction

$Ag := B \cdot D = 240000\ mm^2$ ----------- Cross Section Area

$Ast = 8452.989\ mm^2$ ----------- Area of Reinforcement Provided

$pt := \dfrac{Ast \cdot 100}{Ag} = 3.522$ ----------- % Reinforcement Provided

$\phi Pnmax := 0.8 \cdot \phi BM \cdot (0.85 \cdot f'c \cdot (Ag - Ast) + (Ast \cdot fy\_1)) = 4404.727\ kN$

----------- Clause 22.4.2.2

$$Check := \left\| \begin{array}{l} \text{if } Pu \le \phi Pnmax \\ \quad \| \text{“Ok”} \\ \text{else} \\ \quad \| \text{“Revise”} \end{array} \right| = \text{“Ok”}$$

Minimum Ast Calculation

$fy\_2 := fy = 420\ MPa$ ----------- Clause 22.4.2.1

$LoadCombination$ [1] : 1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 2: LOAD CASE 2)

$Pu\_max := 863.41\ kN$

$$AstReq := \frac{0.442 \cdot f'c \cdot Ag - Pu\_max}{(0.442 \cdot f'c) - (0.52 \cdot fy\_2)} = -8.626 \cdot 10^3\ mm^2$$

----------- Clause 22.4.2.2

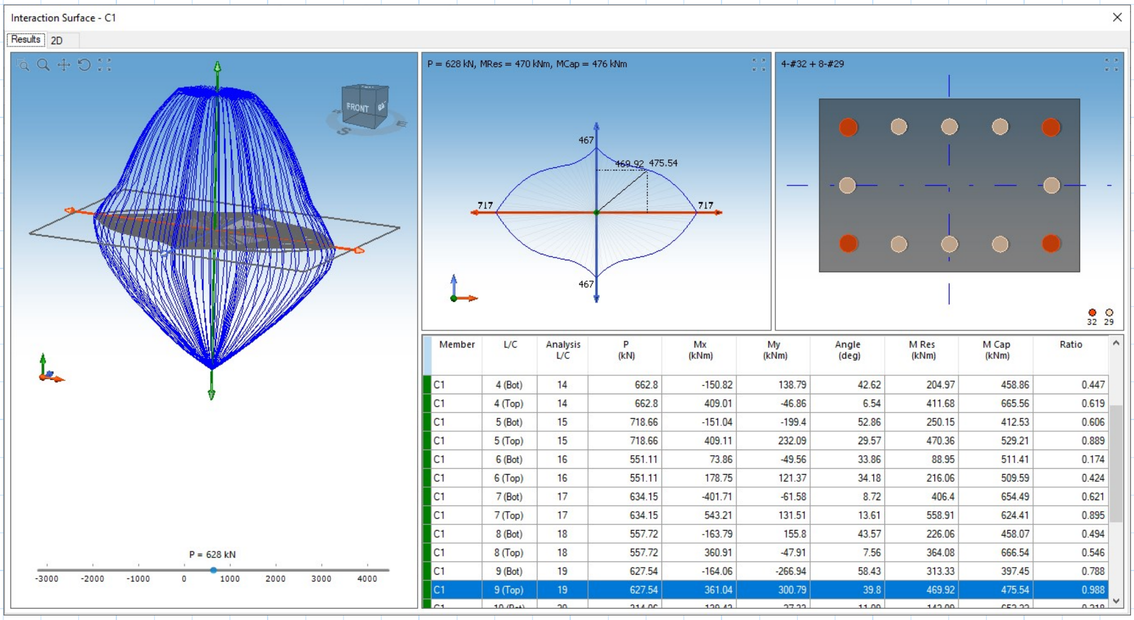
$$pt := \begin{cases} \text{if } AstReq \le 0 \\ \quad 0 \\ \text{else} \\ \quad \dfrac{AstReq}{Ag} \end{cases} = 0$$

$ptmin := \max(0.5, pt) = 0.5$ ----------- Clause 10.3.1.2

$UserDefinedpt := 1$

$Finalpt := \max(ptmin, UserDefinedpt) = 1$

PM Curve



Member	L/C	Analysis L/C	P (kN)	Mx (kNm)	My (kNm)	Angle (deg)	M Res (kNm)	M Cap (kNm)	Ratio
C1	4 (Bot)	14	662.8	-150.82	138.79	42.62	204.97	458.86	0.447
C1	4 (Top)	14	662.8	409.01	-46.86	6.54	411.68	665.56	0.619
C1	5 (Bot)	15	718.66	-151.04	-199.4	52.86	250.15	412.53	0.606
C1	5 (Top)	15	718.66	409.11	232.09	29.57	470.36	529.21	0.889
C1	6 (Bot)	16	551.11	73.86	-49.56	33.86	88.95	511.41	0.174
C1	6 (Top)	16	551.11	178.75	121.37	34.18	216.06	509.59	0.424
C1	7 (Bot)	17	634.15	-401.71	-61.58	8.72	406.4	654.49	0.621
C1	7 (Top)	17	634.15	543.21	131.51	13.61	558.91	624.41	0.895
C1	8 (Bot)	18	557.72	-163.79	155.8	43.57	226.06	458.07	0.494
C1	8 (Top)	18	557.72	360.91	-47.91	7.56	364.08	666.54	0.546
C1	9 (Bot)	19	627.54	-164.06	-266.94	58.43	313.33	397.45	0.788
C1	9 (Top)	19	627.54	361.04	300.79	39.8	469.92	475.54	0.988

Resultant Moment (Combined Action)
Moment Capacity Check

$$Ptcalculated := \frac{Ast \cdot 100}{Ag} = 3.52$$ ----------- % Reinforcement Provided

$LoadAngle := 39.8$ ----------- tan-1 (Muy_Final / Mux_Final)

$$Mres := \sqrt{Mux\_Final^2 + Muy\_Final^2} = 469.92\ kN \cdot m$$

----------- Resultant Bending Moment

$\phi Mcap := 475.54\ kN \cdot m$ ----------- Moment Capacity from PM Curve

$$CapacityRatio := \frac{Mres}{\phi Mcap} = 0.988$$

----------- Clause 10.4.2

$$Check := \left\| \begin{array}{l} \text{if } CapacityRatio < 1 \\ \quad \left\| \text{“Ok”} \right. \\ \text{else} \\ \quad \left\| \text{“Revise”} \right. \end{array} \right\| = \text{“Ok”}$$

----------- Clause 10.4.2

Design Data for All Load Combination

Column/Wall	:	C1
Level	:	0 m To 6.2 m
Frame Type	=	Non-Ductile
Design Code	=	ACI 318M - 14
Grade Of Concrete (f'c)	=	25 N/sqmm
Grade Of Steel (Main)	=	420 N/sqmm
Grade Of Steel (Shear)	=	420 N/sqmm
Column B	=	400 mm
Column D	=	600 mm
Clear Cover	=	50 mm
Pt	=	3.52 %

Design Table :

Member	LOC	L/C	Analysis L/C No	Pu	Analysis	Msldr or MC		Design			Mcap	Capacity Ratio
					Mx	My	Mx	My	Mux	Muy	MuRes		
				(kN)	(kNm)	(kNm)	(kNm)	(kNm)	(kNm)	(kNm)	(kNm)	(kNm)	
501	BOT	1	11	863.41	-188.66	-37.88	-	-37.88	-188.66	-37.88	192.43	620	0.31
501	TOP	1	11	863.41	511.33	115.77	-	115.77	511.33	115.77	524.27	612.45	0.856
501	BOT	2	12	657.51	39.3	-25.5	39.3	-25.5	39.3	-25.5	46.85	512.76	0.091
501	TOP	2	12	657.51	263.27	88.56	263.27	88.56	263.27	88.56	277.77	593.96	0.468
501	BOT	3	13	723.95	-341.16	-35.11	-	-35.11	-341.16	-35.11	342.96	664.04	0.516
501	TOP	3	13	723.95	554.85	96.67	-	96.67	554.85	96.67	563.21	640.46	0.879
501	BOT	4	14	662.8	-150.82	138.79	-	138.79	-150.82	138.79	204.97	458.86	0.447
501	TOP	4	14	662.8	409.01	-46.86	-	-46.86	409.01	-46.86	411.68	665.56	0.619
501	BOT	5	15	718.66	-151.04	-199.4	-	-199.4	-151.04	-199.4	250.15	412.53	0.606
501	TOP	5	15	718.66	409.11	232.09	-	232.09	409.11	232.09	470.36	529.21	0.889
501	BOT	6	16	551.11	73.86	-49.56	73.86	-49.56	73.86	-49.56	88.95	511.41	0.174
501	TOP	6	16	551.11	178.75	121.37	178.75	121.37	178.75	121.37	216.06	509.59	0.424
501	BOT	7	17	634.15	-401.71	-61.58	-	-61.58	-401.71	-61.58	406.4	654.49	0.621
501	TOP	7	17	634.15	543.21	131.51	-	131.51	543.21	131.51	558.91	624.41	0.895
501	BOT	8	18	557.72	-163.79	155.8	-	155.8	-163.79	155.8	226.06	458.07	0.494
501	TOP	8	18	557.72	360.91	-47.91	-	-47.91	360.91	-47.91	364.08	666.54	0.546
501	BOT	9	19	627.54	-164.06	-266.94	-	-266.94	-164.06	-266.94	313.33	397.45	0.788
501	TOP	9	19	**627.54**	361.04	300.79	-	300.79	361.04	300.79	469.92	475.54	0.988
501	BOT	10	20	314.06	139.43	-27.33	139.43	-27.33	139.43	-27.33	142.09	652.22	0.218
501	TOP	10	20	314.06	34.35	70.79	34.35	70.79	34.35	70.79	78.69	394.3	0.2
501	BOT	11	21	397.1	-336.14	-39.35	-	-39.35	-336.14	-39.35	338.44	680.13	0.498
501	TOP	11	21	397.1	398.82	80.94	-	80.94	398.82	80.94	406.95	648.25	0.628
501	BOT	12	22	320.67	-98.22	178.03	-	178.03	-98.22	178.03	203.33	398.99	0.51
501	TOP	12	22	320.67	216.52	-98.48	-	-98.48	216.52	-98.48	237.87	569.03	0.418
501	BOT	13	23	390.48	-98.49	-244.72	-	-244.72	-98.49	-244.72	263.79	391.06	0.675
501	TOP	13	23	390.48	216.65	250.21	-	250.21	216.65	250.21	330.97	434.64	0.761