

BEAM DESIGN CALCULATION

Project Name : Software Validation - RCDC - Beam Design as per ACI 318
 Client Name : Mavens
 Engineer Name : APCA/RK
 Design File : C:\Users\arpitchawla\OneDrive - L&T
 Construction\Jobs\Miscellaneous\Software
 Validation\RCDC\Staad Model\FMO_P01_01(02.12.2021)-NV-2-
 Beam-1-0 m.rcdx
 Analysis File : C:\Users\arpitchawla\OneDrive - L&T
 Construction\Jobs\Miscellaneous\Software
 Validation\RCDC\Staad Model\FMO_P01_01(02.12.2021)-NV-2.STD
 Analysis Last Modified : 13-01-2022 10:14:41
 Level Designed : 0 m

Sr.No.	Symbol		Definitions
1	α	=	Angle formed with horizontal line along length of Beam
2	Ach	=	Cross sectional area of structural member measures to the outside edge of transverse reinforcement in 'sqmm'
3	Ag	=	Cross sectional area of concrete in 'sqmm'
4	Ash	=	Total cross sectional area transverse reinforcement (including cross ties) within spacing S in 'sqmm'
5	Avd	=	Area of diagonal reinforcement in coupler beam in 'sqmm'
6	As	=	Area of Tension reinforcement required in 'sqmm'
7	As,min	=	Minimum area of flexural reinforcement in 'sqmm'
8	As,nominal	=	Nominal area of reinforcement in 'sqmm'
9	Al	=	Area of longitudinal reinforcement required to resist torsion in 'sqmm'
10	Al,face	=	Area of longitudinal reinforcement required on each face to resist torsion in 'sqmm'
11	At Torsion	=	Area of closed stirrups resisting torsion in 'sqmm'
12	AstPrv	=	Area of longitudinal reinforcement provided at given section in 'sqmm'
13	Av	=	Area of shear reinforcement required per meter length in 'sqmm'
14	Av,min	=	Minimum area of shear reinforcement in as per clause 11.4.6.1 in 'sqmm'
15	Al,min	=	Minimum area of longitudinal torsional reinforcement as per clause 11.5.5.3 in 'sqmm'
16	Av Total Req'd	=	Total area of shear reinforcement required, including that for torsion in 'sqmm'
17	Av Total Prv	=	Total area of shear reinforcement provided, including that for torsion in 'sqmm'
18	Ao	=	Gross area enclosed by shear flow path in 'sqmm'
19	Aoh	=	Area enclosed by centerline of the outermost closed transverse torsional reinforcement as per clause 11.5.3.1 in 'sqmm'
20	Ast	=	Total area of longitudinal reinforcement calculated at a given section in 'sqmm'
21	Asr	=	Area of Skin reinforcement calculated for given section in 'sqmm'

22	Asc	=	Area of Compression reinforcement required for doubly reinforced section or if torsion exists in 'sqmm'
23	Asv Reqd Sway	=	Area of shear reinforcement required for sway condition in 'sqmm'
24	b	=	Width of the Beam in 'mm'
25	bw	=	Width of Web (For flanged Beam) in 'mm'
26	b'	=	C/C distance between longitudinal reinforcement along B in 'mm'
27	bc	=	Outside dimension of transverse reinforcement in 'mm'
28	Cc	=	Effective Cover to tension reinforcement in 'mm'
29	Cmin	=	Clear cover in 'mm'
30	c'	=	Effective cover to reinforcement at compression face in 'mm'
31	d	=	Effective depth of Beam in 'mm'
32	d'	=	C/C distance between longitudinal reinforcement along D in 'mm'
33	D	=	Depth of Beam in 'mm'
34	Es	=	Modulus of elasticity of steel in 'N/sqmm'
35	f'c	=	Specified compressive strength of concrete in cylinder in 'N/sqmm'
36	fs	=	Calculated tensile stress in reinforcement at service loads, 'N/sqmm'
37	Hf	=	Thickness of Flange in 'mm'
38	hx	=	Maximum C/C horizontal spacing of hoops legs on all faces in 'mm'
39	Icr	=	Moment Of Inertia Of concrete crack section
40	l	=	Effective Length Of Beam (Clear Span) in 'mm'
41	Legs	=	Number Of legs Of the shear reinforcement
42	Mcr	=	Cracking Moment
43	Mh	=	Hogging moments of resistance of member at the joint faces in 'kNm'
44	Mpr1	=	Hogging moments Of resistance Of member at the joint faces in 'kNm'
45	Mpr2	=	Sagging moments Of resistance Of member at the joint faces in 'kNm'
46	Ms	=	Sagging moments Of resistance Of member at the joint faces in 'kNm'
47	Mu	=	Factored Bending Moment at a section in 'kNm'
48	Mubal	=	Nominal flexural strength Of Singly Reinforced Section At Balance Neutral Axis in 'kNm'
49	Ptmin	=	Minimum percentage steel As per clause 10.5
50	PtPrv	=	Provided percentage steel
51	Stirrup	=	Bar mark representing shear stirrup
52	S	=	spacing Of confining links in 'mm'
53	SCalc	=	Stirrup spacing calculated As per Asv in 'mm'
54	Sprv	=	Stirrup spacing provided in 'mm'
55	Tcr	=	Cracking torque under pure Torsion in 'kNm'
56	Tu	=	Factored Torsional Moment at a section in 'kNm'
57		=	Shear due to Dead and Live load in Simply supported

	V^{D+L}		beam in 'kN'
58	V_e	=	Earthquake induced shear in 'kNm'
59	ϕV_c	=	Reduced Shear strength provided by concrete in 'kN'
60	ϕV_c sway	=	Reduced Shear strength provided by concrete for sway condition in 'kN'
61	V_u	=	Factored Shear Force at a section in 'kN'
62	$V_{u-A1}(\text{sway Left})$	=	$V^{D+L}_{\text{left}} - (M_{pr1_{\text{left}}} + M_{pr2_{\text{right}}} / L)$ in 'kN'
63	$V_{u-A2}(\text{sway Left})$	=	$V^{D+L}_{\text{left}} + (M_{pr2_{\text{left}}} + M_{pr1_{\text{right}}} / L)$ in 'kN'
64	$V_{u-B1}(\text{sway Right})$	=	$V^{DL}_{\text{Right}} - (M_{pr1_{\text{left}}} + M_{pr2_{\text{right}}} / L)$ in 'kN'
65	$V_{u-B2}(\text{sway Right})$	=	$V^{DL}_{\text{Right}} + (M_{pr2_{\text{left}}} + M_{pr1_{\text{right}}} / L)$ in 'kN'
66	V_{ud}	=	Design Shear Force due to sway in 'kN'
67	V_s	=	Nominal shear strength provided by shear reinforcement in 'kN'
68	V_s Sway	=	Nominal shear strength provided by shear reinforcement for sway condition in 'kN'
69	V_u sway	=	Max (V_{u-A1}, V_{u-A2}) & (V_{u-B1}, V_{u-B2}) in 'kN'
70	y	=	Neutral axis depth.
71	Φ	=	Strength reduction factor

All Forces are in 'kN', 'kNm', Stress in 'N/sqmm' & Dimension are in 'mm'.

Code References

Sr.No.	Item	Clause / Table
1.	P_{tmax}	: 7.3.3.1, 8.3.3.1, 9.3.3.1
2.	$A_{s,min}$ (flex) (B)	: 9.6.1.1, 9.6.1.2
3.	$A_{s,min}$: 9.6.1.3
4.	V_c	: 22.5
5.	A_{sv}	: 22.5.10.5 & 22.6.7
6.	Min Shear Reinf	: 9.6.3.1
7.	Max Stirrup Spacing	: 9.7.62
8.	Shear Reinf - Torsion	: 22.7.3.1
9.	Side Face Reinforcement	: 9.7.2.3
10.	T_{cr}	: 9.5.4.1
11.	$f_{s,perm}$: 10.6.4
12.	$f_{c,perm}$: 10.2.7.1
13.	W_{cr}	: Eq 4.2(a)
14.	P_{tmin}	: 18.6.3.1
15.	A_{smin}	: 18.6.3.1
16.	S_{clc}	: 18.6.4.1 & 18.6.4.4

Group : G3
: B5

Beam No

Analysis Reference (Member)⁰_m : 7

Beam Length : 6150 mm
 Breadth (B) : 200 mm
 Depth (D) : 550 mm
 Effective Depth (d) : 490 mm
 Design Code : ACI 318M - 14
 Beam Type : Regular Beam
 Grade Of Concrete (f'c) : C28 N/sqmm
 Grade Of Steel : Fy420 N/sqmm
 Clear Cover (Cmin) : 30 mm
 Es : 2×10^5 N/sqmm
 Mubal : 340.5 kNm
 As,min (flex) (B) : 326.67 sqmm
 As,nominal (Bn) : 127.4 sqmm
 As,min(user input)(B') : 127.4 sqmm

For Longitudinal Reinf						
	Beam Bottom			Beam Top		
	Left	Mid	Right	Left	Mid	Right
Critical L/C - Analysis	149	147	-	147	-	147
Critical L/C - RCDC	4	3	-	3	-	3
Mu (kNm)	5.68	37.83	-	43.89	-	62.76
As (flex) (sqmm) (C)	30.77	208.14	-	242.26	-	349.85
Asc (flex) (sqmm) (A)	-	-	-	-	-	-
Tu (kNm)	0.77	0.05	-	1.29	-	1.2
Tcr/4 (kNm)	2.66	2.66	-	2.66	-	2.66
Al, min(sqmm)(Tor.) (D)	-	-	-	-	-	-
Al (sqmm) (Tor.) (E)	-	-	-	-	-	-
Al (Dist) (sqmm) (D)	-	-	-	-	-	-
Ast (sqmm)	127.4	276.83	127.4	322.21	127.4	349.86
AstCrack (sqmm)	127.4	276.83	0	322.21	0	367.35
AstPrv (sqmm)	253.36	380.04	253.36	380.04	253.36	380.04
Reinforcement Provided	2-#13	3-#13	2-#13	3-#13	2-#13	3-#13

Note: Calculation of Ast

Ast = Max {B, C+D, A+D} (for Mu > 0 and C x 1.33 > B)
 Ast = Max{B', C x 1.33 + D, A+D} (for Mu > 0 and C x 1.33 < B)
 Ast = Bn (for Mu = 0)

Where,

A = Asc (flex) = Compression reinforcement required for bending moment
 B = As,min (flex) = Min area of flexural reinforcement
 Bn = As,nominal = Nominal area of reinforcement

C	=	As (flex)	=	Total area of longitudinal reinforcement calculated at a given section
D	=	Al (Dist)	=	Distributed longitudinal torsional reinforcement at section considered
Ast (Dist) (sqmm)	=		=	Max(Al,min (Tor), Al (Tor)) x ((2B) / (2B + 2D))

For Transverse Reinf			
	Left	Mid	Right
Critical L/C - RCDC	3	3	3
PtPrv (%)	0.388	0.388	0.388
Vu (kN)	56.24	22.84	62.37
Mu-Sect (kNm)	43.89	24.56	62.76
Φ Vc (kN)	65.27	64.44	64.59
Vs (kN)	-	-	-
Aoh (sqmm)	-	-	-
At (sqmm/m)	-	-	-
Av (sqmm/m)	166.67	166.67	166.67
Tu (kNm)	1.29	0.37	1.2
At Torsion (sqmm/m)	0	0	0
Av Total Reqd (sqmm/m)	166.67	166.67	166.67
Asv Reqd (sqmm/m)	166.67	166.67	166.67
Legs	2	2	2
Stirrup Rebar	10	10	10
SCalc (mm)	160	160	160
SPrv (mm)	160	160	160
Av Total Prv (sqmm/m)	886	886	886

Maximum Spacing Criteria

Basic

Spc1	=	245	mm
Spc2	=	600	mm

For Torsion

(X1 = 149.5, Y1 = 499.5)

Spc3	=	300	mm
Spc4=(X1+Y1)/4	=	162	mm

Skin reinforcement

Beam Width	=	200	mm
Beam Depth	=	550	mm
Depth	=	550 <= 900,	Hence Skin Reinforcement is not required.

Crack width as per ACI -224R-01						
	Beam Bottom			Beam Top		
	Left	Mid	Right	Left	Mid	Right
Critical L/C - Analysis	87	87	-	74	-	87

Critical L/C - RCDC	10002	10002	-	10001	-	10002
BM (Unfactored) (kNm)	5.04	27.44	0	31.44	0	47.49
Reinf. In 1st layer	2-#13	3-#13		3-#13		3-#13
sp (mm)	127.3	63.6		63.6		63.6
AstPrv (sqmm)	253.36	380.04		380.04		380.04
y (mm)	90.2	108		108		108
Icr (mm ⁴)	374593921.54	529954360.2		529954360.2		529954360.2
dc (mm)	36.35	36.35		36.35		36.35
Check for Stress in Concrete						
f _c (N/sqmm)	1.22	5.59		6.41		9.68
f _{c,perm} (N/sqmm)	12.6	12.6		12.6		12.6
Check for Stress in Reinforcement						
Fst (N/sqmm)	43.29	159.02		182.23		275.26
fs,perm (N/sqmm)	280	280		280		280
Crack Width Check						
Wcr (mm)	0.0365	0.0889		0.1019		0.1539
WcrPerm (mm)	0.25	0.25		0.25		0.25

Group	:	G3	
Beam No	:	B6	
Analysis Reference (Member)	⁰ _m :	8	
Beam Length	:	3650	mm
Breadth (B)	:	200	mm
Depth (D)	:	550	mm
Effective Depth (d)	:	490	mm
Design Code	:	ACI 318M - 14	
Beam Type	:	Regular Beam	
Grade Of Concrete (f'c)	:	C28	N/sqmm
Grade Of Steel	:	Fy420	N/sqmm
Clear Cover (Cmin)	:	30	mm
Es	:	2x10^5	N/sqmm
Mubal	:	340.5	kNm
As,min (flex) (B)	:	326.67	sqmm

As,nominal (Bn) : 127.4 sqmm
 As,min(user input)(B') : 127.4 sqmm

For Longitudinal Reinf						
	Beam Bottom			Beam Top		
	Left	Mid	Right	Left	Mid	Right
Critical L/C - Analysis	-	147	147	147	147	149
Critical L/C - RCDC	-	3	3	3	3	4
Mu (kNm)	-	9.29	5.39	33.27	4.33	17.61
As (flex) (sqmm) (C)	-	50.36	29.18	182.62	23.42	95.89
Asc (flex) (sqmm) (A)	-	-	-	-	-	-
Tu (kNm)	-	0.19	0.44	0.68	0.31	0.73
Tcr/4 (kNm)	-	2.66	2.66	2.66	2.66	2.66
Al, min(sqmm)(Tor.) (D)	-	-	-	-	-	-
Al (sqmm) (Tor.) (E)	-	-	-	-	-	-
Al (Dist) (sqmm) (D)	-	-	-	-	-	-
Ast (sqmm)	127.4	127.4	127.4	242.89	127.4	127.54
AstCrack (sqmm)	380.04	127.4	127.4	242.89	127.4	127.54
AstPrv (sqmm)	253.36	253.36	253.36	380.04	253.36	253.36
Reinforcement Provided	2-#13	2-#13	2-#13	3-#13	2-#13	2-#13

Note: Calculation of Ast

Ast = Max {B, C+D, A+D} (for Mu > 0 and C x 1.33 > B)
 Ast = Max{B', C x 1.33 + D, A+D} (for Mu > 0 and C x 1.33 < B)
 Ast = Bn (for Mu = 0)

Where,

A = Asc (flex) = Compression reinforcement required for bending moment
 B = As,min (flex) = Min area of flexural reinforcement
 Bn = As,nominal = Nominal area of reinforcement
 C = As (flex) = Total area of longitudinal reinforcement calculated at a given section
 D = Al (Dist) = Distributed longitudinal torsional reinforcement at section considered
 Ast (Dist) (sqmm) = Max(Al,min (Tor), Al (Tor)) x ((2B) / (2B + 2D))

For Transverse Reinf			
	Left	Mid	Right
Critical L/C - RCDC	3	3	3
PtPrv (%)	0.388	0.259	0.259
Vu (kN)	40.52	17.06	29.87
Mu-Sect (kNm)	33.27	1.75	13.83
Φ Vc (kN)	65.12	65.46	65.46
Vs (kN)	-	-	-
Aoh (sqmm)	-	-	-
At (sqmm/m)	-	-	-
Av (sqmm/m)	166.67	166.67	166.67
Tu (kNm)	0.68	0.18	0.81

At Torsion (sqmm/m)	0	0	0
Av Total Reqd (sqmm/m)	166.67	166.67	166.67
Asv Reqd (sqmm/m)	166.67	166.67	166.67
Legs	2	2	2
Stirrup Rebar	10	10	10
SCalc (mm)	160	160	160
SPrv (mm)	160	160	160
Av Total Prv (sqmm/m)	886	886	886

Maximum Spacing Criteria

Basic

Spc1	= 245	mm
Spc2	= 600	mm

For Torsion

(X1 = 149.5, Y1 = 499.5)

Spc3	= 300	mm
Spc4=(X1+Y1)/4	= 162	mm

Skin reinforcement

Beam Width	= 200	mm
Beam Depth	= 550	mm
Depth	= 550 <= 900,	Hence Skin Reinforcement is not required.

<u>Crack width as per ACI -224R-01</u>						
	Beam Bottom			Beam Top		
	Left	Mid	Right	Left	Mid	Right
Critical L/C - Analysis	-	74	74	74	74	87
Critical L/C - RCDC	-	10001	10001	10001	10001	10002
BM (Unfactored) (kNm)	0	6.67	3.84	23.56	2.96	14.91
Reinf. In 1st layer		2-#13	2-#13	3-#13	2-#13	2-#13
sp (mm)		127.3	127.3	63.6	127.3	127.3
AstPrv (sqmm)		253.36	253.36	380.04	253.36	253.36
y (mm)		90.2	90.2	108	90.2	90.2
Icr (mm ⁴)		374593921.54	374593921.54	529954360.2	374593921.54	374593921.54
dc (mm)		36.35	36.35	36.35	36.35	36.35
Check for Stress in Concrete						
f _c (N/sqmm)		1.61	0.92	4.8	0.71	3.59
f _{c,perm} (N/sqmm)		12.6	12.6	12.6	12.6	12.6
Check for						

Stress in Reinforcement						
Fst (N/sqmm)		57.21	32.91	136.54	25.4	127.93
fs,perm (N/sqmm)		280	280	280	280	280
Crack Width Check						
Wcr (mm)		0.0482	0.0277	0.0763	0.0214	0.1078
WcrPerm (mm)		0.25	0.25	0.25	0.25	0.25
