TITLE :	DESIGN OF BEAM						
SUB -TITLE :	DESIGN OF BEAM FOR FLEXURE,SHEAR AND TORSION						
CODE OF PRACTICE :	ACI-318M-11						
CODE TITLE :	BUILDING CODE REQUIREMENT FOR STRUCTURAL CONCRETE						
DESIGN TYPE :	ULTIMATE STATE DESIGN						
NOTE :- 1) User to Input data in cell marked as Blue.							
2) Design follows Limit State Method.							
3) Forces of one section has been considered for design							
Step 1) User Input							
PARAMETERS :		**Referance from RCDC**	**SYMBOL**		**UNITS**	**Reference / Comments**	
				Metric			
Beam No				B24			
Reference section of Beam				5057_5058_5059			
Type of Beam				intermediate			
Width of Beam		Breadth (B)	B	400	mm	User Input	
Depth of Beam		Depth (D)	D	1,000	mm	User Input	
Ultimate moment from analysis		Mu (kNm)	Mu	738.76	kN-m	User Input	
Ultimate Shear force at section considered		Vu (kN)	Vu	383.01	kN	User Input	
Ultimate Moment correspomding to Vu		Mu-Sect (kNm)	Mut	598.81	kN-m	User Input	
Ultimate Torsion force at section considered, for BM		Tu (kNm)	Tu,BM	18.16	kN-m	User Input	
Ultimate Torsion force at section considered, For Shear		Tu (kNm)	Tu, Shear	36.30	kN-m	User Input	
Ultimate Torsion force at section considered, For SFR		Tu (kNm)	Tu,SFR	22.60	kN-m	User Input	
Ultimate Axial force		Pu (kN)	Pu	-	kN	User Input	
characteristic compressive strength of concrete		Grade Of Concrete (f'c)	f'c	40	N/sqmm	User Input	
characteristic strength of reinforcement		Grade Of Steel	fy	500	N/sqmm	User Input	
Modulus of elasticity of reinf.		Es	Es	200,000	N/sqmm	Constant	
Cover to tension reinforcement		Clear Cover (Cmin)	Cc	50	mm	User Input	
Cover to compression reinforcement		Clear Cover (Cmin)	Cc'	50	mm	User Input	
Diameter of tenson reinforcement		Reinforcement	dia1	15.90	mm	User Input	
Diameter of comression reinf.		Reinforcement	dia2	15.90	mm	User Input	
Diameter of shear reinf.		Reinforcement	dia3	9.50	mm	User Input	
Diameter of SFR		Reinforcement	dia4	15.90	mm	User Input	
Number of reinf. layers at tension face		Reinforcement	n1	1.00	Nos	User Input	
Number of reinf. layers at compression face		Reinforcement	n2	1.00	Nos	User Input	
Partial factor of safety for Moment		Reinforcement	Φ1	0.90	constant	Clause 9.3.2.1 (Default)	
Partial factor of safety for Shear		Constant	Φ2	0.75	constant	Clause 9.3.2.3 (Default)	
Partial factor of safety for Shear (Seismic)		Constant	Φ2.1	0.60	constant	Clause 9.3.4 (Default)	
Beam Span available from Analysis		Beam Length		7,650	mm	User Input	
Clear length of beam			ln, Clear	7,100	mm	User Input	
Maximum % reinforcement		Maximum(Settings)	ptmax	4	%	User Input (General & Reinf. settings)	
Minimum % reinforcement		Minimum(Settings)	ptmin	0.13	%	User Input (General & Reinf. settings)	
Detailing of Tension reinforcement							
Number of reinforcement at first layer				4	nos	User Input	
Number of reinforcement at second layer				0	nos	User Input	
Reinforcement diameter at first layer				25.4	mm	User Input	
Reinforcement diameter at second layer				0	mm	User Input	
Detailing of Compression reinforcement							
Number of reinforcement at first layer				5	nos	User Input	
Number of reinforcement at second layer				0	nos	User Input	
Reinforcement diameter at first layer				15.90	mm	User Input	
Reinforcement diameter at second layer				0	mm	User Input	
Detailing of Shear reinforcement							
Reinforcement diameter				9.5	mm	User Input	
Reinforcement Spacing				125	mm	User Input	
No of Legs				2	nos	User Input	
SFR reinforcement							
Number of reinforcement at both faces				4	nos	User Input	
Reinforcement diameter				15.90	mm	User Input	

9.3.2.1 — Tension-controlled sections
Strength reduction factor ϕ 0.90

9.3.2.3 — Shear and torsion 0.75

9.3.4 — For structures that rely on intermediate precast structural walls in Seismic Design Category D, E, or F, special moment frames, or special structural walls to resist earthquake effects, E, ϕ shall be modified as given in (a) through (c):

(a) For any structural member that is designed to resist E, ϕ for shear shall be 0.60 if the nominal shear strength of the member is less than the shear corresponding to the development of the nominal flexural strength of the member. The nominal flexural strength shall be determined considering the most critical factored axial loads and including E;

11.4.2 — The values of f_y and f_{yt} used in design of shear reinforcement shall not exceed 420 MPa

11.5.3.4 — The values of f_y and f_{yt} used for design of torsional reinforcement shall not exceed 420 MPa.

characterstic yield strength of reinf. for shear		fyt	420.00	N/sqmm	clause 11.4.2
characterstic yield strength of reinf. for shear		fytorsion	420.00	N/sqmm	clause 11.5.3.4
Effective depth at tension face	Effective Depth (d)	deff	920.00	mm	=(D-Cc-20-20/2)
Effective cover at compression reinf.		d'	60.00	mm	=Cc +20/2
constant		β1	0.764286	constant	clause 10.2.7.3
Step 2) Design for singly reinforced section					
Minimum area of reinforcement (user input)	As,min(user input)(B')	Ast min (user)	478.40	sqmm	=ptmin x B x deff
Balance neutral axis (*d)		Cb	0.428571		clause 10.3
Area of reinf. for balance neutral axis		Ast bal	8,196.64	sqmm	=0.85*f'c*B*deff*β1*Cb)/fy
Minimum Area of reinf.	As,min (flex) (B)	Ast min	1,163.72	sqmm	clause 10.5.1
Minimum Pt	Min pt		0.316228	%	=Ast min/(B*deff)x100
Calculation of Mu balance	Mubal	Mu bal	3152.95	kN-m	=(0.85*f'c*B*β1*Cb*deff*(deff-((β1*cb*deff)/2)))/10^6
Check for singly or doubly			Singly Reinforced		=IF(Mu bal>Mu,"Singly Reinforced","Doubly reinforced")
% reinf. required for Torsion			0.000	%	=Al (Dist) / (b*deff)*100
% reinf. required for BM		pt req	0.5035475	%	=0.85*fck/fy*(1-SQRT(1-(2*Mu*10^6/(Φ1*0.85*fck*B*deff^2)))
Area of reinf. required for BM	As (flex) (sqmm) (C)		1853.05	sqmm	=pt reqxB*deff/100
Check for Mmin as per			0.5035475	%	clause 10.5.3
Area of reinf. Required	Ast (sqmm)	Ast req	1,853.05	sqmm	=max (As (flex) , As,min(user input))
Step 3) Design for doubly reinforced section					
Moment balance after Mu balance		Mu2	-	kN-m	
Area of reinf. Required for Mu2		Ast2	-	sqmm	
total area of tension reinforcement for Mu		Ast total	1853.05	sqmm	
Strain in compression reinf.		ε's	0.002620		Clause 10.3 (Fig 10.3.3)
Stress in compression reinf.		fsc	500	N/sqmm	clause 10.3
Area of compression reinf.	Asc (flex) (sqmm) (A)	Asc	0.00	sqmm	
Check for Max % reinf.			OK		
Area of tension reinf. required			1853.05	sqmm	
% tension reinf. required		pt%	0.50	%	
Area of Compression reinf. reqd(Doubly Or Torsion)	Al (Dist) (sqmm) (D)		0.00	sqmm	
Total area of tension reinforcement provided	AstPrv (sqmm)	Asv prv	2026.83	sqmm	
Step 3a) Design for Torsion, BM					
Perimeter of centerline of outer link		Ph	2,440	mm	=((B-(2*Cc)+(10))+(D-(2*Cc)+(10)))*2
Area enclosed by centerline of outer link	Aoh	Aoh	282,100	sqmm	=(B-(2*Cc)+(10))*(D-(2*Cc)+(10))
Check for cross section			OK		clause 11.5.3.1
Cracking Torque / 4	Tcr/4 (kNm)	Tcr/4	22.50	kN-m	clause 11.5.1(a)
Check for torsion to be considered or not		**Check-1**	Neglect		clause 11.5.1(a)
Additional shear reinf. due to Torsion		At/s	-	sqmm/mm	clause 11.5.3.6,11.5.5.3
Additional longitudinal reinf. due to Torsion	Al (sqmm) (Tor.) (E)		-	sqmm	clause 11.5.3.7
Minimum Additional longitudinal reinf. due to Torsion	Al, min(sqmm)(Tor.)	Almin	-	sqmm	clause 11.5.5.3
Final Additional longitudinal reinf. due to Torsion	Al (sqmm) (Tor)		-	sqmm	=IF(Check-1="Neglect","-",MAX(Al (sqmm),Al, min))
Distribution of torsion longitudinal reinf. At top and bottom	Al (Dist) (sqmm) (D)		0.00	sqmm	=IF(Check-1="Neglect",0,(Al (sqmm) (Tor)/(2*B+2*D))*B)
Step 4) Design for Shear					
Vu*d /Mushear Ratio			0.588		Clause 11.2.2.1
Shear due to Dead load		V,DL	-281.44	kN	User Input
Shear due to Live load		V,LL	-52.72	kN	User Input
Ast provided at Top left		Ast,prv L top	2026.84	sqmm	User Input
Ast provided at Bottom left		Ast,prv L bot	992.8	sqmm	User Input
Ast provided at Top right		Ast,prv R top	2026.84	sqmm	User Input
Ast provided at Bottom right		Ast,prv R bot	992.8	sqmm	User Input
Moment at left end - for DL (M at both ends +ve is assumed as hogging)		M_LH_DL	153.02	kN-m	User Input
Moment at right end -for DL (M at both ends +ve is assumed as hogging)		M_RH_DL	456.74	kN-m	User Input
Moment at left end -for LL (M at both ends +ve is assumed as hogging)		M_LH_LL	24.9	kN-m	User Input
Moment at right end -for LL (M at both ends +ve is assumed as hogging)		M_RH_LL	91.64	kN-m	User Input
depth of stress block,a top (left)		"a" L top	74.52	mm	Clause 21.3.3/21.5.4
depth of stress block,a bottom (left)		"a" L bot	36.50	mm	Clause 21.3.3/21.5.4

10.2.7.3 — For f'_c between 17 and 28 MPa, β_1 shall be taken as 0.85. For f'_c above 28 MPa, β_1 shall be reduced linearly at a rate of 0.05 for each 7 MPa of strength in excess of 28 MPa, but β_1 shall not be taken less than 0.65.

10.5.1 $A_{s,min} = \dfrac{0.25\sqrt{f'_c}}{f_y} b_w d$

and not less than $1.4 b_w d / f_y$.

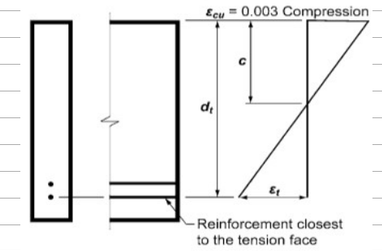


Fig. R10.3.3—Strain distribution and net tensile strain.

10.5.3 — The requirements of 10.5.1 and 10.5.2 need not be applied if, at every section, A_s provided is at least one-third greater than that required by analysis.

p_h = perimeter of centerline of outermost closed transverse torsional reinforcement, mm,

11.5.3.1 — The cross-sectional dimensions shall be such that:

(a) For solid sections

$$\sqrt{\left(\frac{V_u}{b_w d}\right)^2 + \left(\frac{T_u p_h}{1.7 A_{oh}^2}\right)^2} \le \phi\left(\frac{V_c}{b_w d} + 0.66\sqrt{f'_c}\right) \quad (11\text{-}18)$$

11.5.1 $T_{cr}/4 = \phi 0.083 \lambda \sqrt{f'_c}\left(\dfrac{A_{cp}^2}{p_{cp}}\right)$

11.5.5.2 $(A_v + 2A_t) = 0.062\sqrt{f'_c}\dfrac{b_w s}{f_{yt}}$

but shall not be less than $(0.35 b_w s)/f_{yt}$.

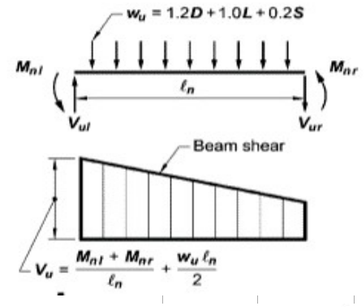
11.5.5.3 $A_{\ell,min} = \dfrac{0.42\sqrt{f'_c} A_{cp}}{f_y} - \left(\dfrac{A_t}{s}\right) p_h \dfrac{f_{yt}}{f_y}$

11.2.2.1

but not greater than $0.29\lambda\sqrt{f'_c}\, b_w d$. When computing V_c by Eq. (11-5), $V_u d / M_u$ shall not be taken greater than 1.0, where M_u occurs simultaneously with V_u at section considered.

To determine the maximum beam shear, it is assumed that its nominal moment strengths ($\phi = 1.0$) are developed simultaneously at both ends of its clear span. As indicated in Fig. R21.3.3, the shear associated with this condition [$(M_{nl} + M_{nr})/\ell_n$] is added algebraically to the shear due to the factored gravity loads to obtain the design shear for the beam. For the example shown, both the dead load w_D and the live load w_L have been assumed to be uniformly distributed. Effects of E acting vertically are to be included if required by the general building code.

depth of stress block,a top (Right)		"a" R top	74.52	mm	Clause 21.3.3/21.5.4	
depth of stress block,a bottom (Right)		"a" R bot	36.50	mm	Clause 21.3.3/21.5.4	
Hogging moments of resistance of member, left top.	Mh (kNm)	Mpr1,L top	894.59	kN-m	Clause 21.3.3/21.5.4	
Sagging moments of resistance of member ,left bottom	Ms (kNm)	Mpr2,L bot	-447.63	kN-m	Clause 21.3.3/21.5.4	
Hogging moments of resistance of member , right top.	Mh (kNm)	Mpr1,R top	894.59	kN-m	Clause 21.3.3/21.5.4	
Sagging moments of resistance of member ,right bottom	Ms (kNm)	Mpr2,R bot	-447.63	kN-m	Clause 21.3.3/21.5.4	
V-left-DL-due to Moment	V-left-DL-due to Moment		-42.78	kN	=(M_LH_DL)-(M_RH_DL)/(ln clear/1000)	
V-left-LL-due to Moment	V-left-LL-due to Moment		-9.40	kN	=(M_LH_LL)-(M_RH_LL)/(ln clear/1000)	
V-due-Sway-Right	V-due-Sway-Right		-189.04	kN	=(Mpr2,L bot)-(Mpr1,R top)/(ln clear/1000)	
V-left-Sway-Left	V-due-Sway-Left		189.04	kN	=(Mpr1,L top)-(Mpr2,R bot)/(ln clear/1000)	
Simply Supported VDL		SS VDL	-238.66	kN	=(V,DL-V-left)-DL-due to Moment	
Simply Supported VLL		SS VLL	-43.32	kN	=(V,LL-V-left)-LL-due to Moment	
Shear due to Dead and Live load	V^{D+L} (kN)	V_{d+L}	281.98	kN	=SS VDL + SS VLL	
Vu-A1(sway left)	Sway-Left (kN)	Vu-A1(left)	471.0	kN	=(SS VDL+SS VLL))+(V-due-Sway-Right))*-1	
Vu-A1(sway Right)	Sway-Right (kN)	Vu-A1(Right)	92.9	kN	=(SS VDL+SS VLL))+(V-due-Sway-Left))*-2	
Vu-Sway	Vu-Sway (kN)	Vu-Sway	471.0	kN	=Max (Vu-A1(left) , Vu-A1(Right))	
Vu from 2*Eq combination	(only intermediate frame)	Vu for 2Eq	458.62	kN	clause 21.3.3.2 (User Input)	
Vud	Vud (kN)	Vud	471.03	kN	clause 21.3.3.2	
Case-1 (design analysis shear)			This is Govering Case			
Pt provided at section (max of top and bottom)	PtPrv (%)		0.551	%	=Asv prv / (B x deff)*100	
Shear Capacity of Concrete,Vc	Φ Vc (kN)	Φ Vc	294.50	kN	clause 11.2.2.1	
Minimum Shear Reinforcement	Av (sqmm/m)	Asvmin	373.45	Sqmm/m	clause 11.4.6.3	
Shear to be resisted by Reinforcement	Vs (kN)	Vs	118.01	kN	clause 11.4.7.2	
Check For Maximum Vs		Vs max	OK	kN	clause 11.4.7.9	
Area of Shear Reinforcement,Asv		Asv	305.42	Sqmm/m	=(1000*(Vs)*1000)/(deff*fyt))	
Toal area of Shear Reinforcement required	Av Total Reqd		786.01	Sqmm/m	=MAX(Asv+At/s*1000*2,Asvmin)	
Area of outer shear reinforcement required	At Torsion		480.59	Sqmm/m	=IF(Check-2="neglect",0,At/s*2*1000)	
case-2 (sway left right shear)			-			
Shear Capacity of Concrete,Vc	Φ Vc (kN)	Φ Vc	305.13	kN	clause 11.2.2.1	
Minimum Shear Reinforcement		Asvmin	373.45	Sqmm/m	clause 11.4.6.1	
Shear to be resisted by Reinforcement		Vs	221.19	kN	clause 11.4.7.2	
Check For Maximum Vs		Vs max	OK	kN	clause 11.4.7.9	
Area of Shear Reinforcement,Asv		Asv,shear	572.44	Sqmm/m	clause 11.4.7.2	
Toal area of Shear Reinforcement required		Asv	572.44	Sqmm/m	=MAX(Asvmin,Asv,shear)	
final area of shear reinforcement required	Asv Reqd		786.01	Sqmm/m	=MAX(Av Total Reqd,Asv)	
final area of shear reinforcement provided	Av Total Prv		1134.11	Sqmm/m		
Check			OK			
Step 4b) Design for Torsion,Shear						
Check for cross section			OK		clause 11.5.3.1	
			OK		ductile shear w/o torsion	
Cracking Torque / 4	Tcr/4 (kNm)	Tcr/4	22.50	kN-m	clause 11.5.1(a)	
Check for torsion to be considered or not		**Check-2**	consider		clause 11.5.1(a)	
Additional shear reinf. due to Torsion		At/s	0.240295	sqmm/mm	clause 11.5.3.6,11.5.5.3	
Additional longitudinal reinf. due to Torsion			586.32	sqmm	clause 11.5.3.7	
Minimum Additional longitudinal reinf. due to Torsion		Almin	1538.73	sqmm	clause 11.5.5.3	
Spacing Criteria	Spc1 (deff/2)	sp1	460	mm	clause 11.4.5.1	
	Spc2	sp2	300	mm	clause 11.4.5.1	
for torsion	Spc3	sp3	300	mm	clause 11.5.6.1	
	Spc4 (ph/8)	sp4	305	mm	clause 11.5.6.1	
For Ductile (intermediate / Special)	Spc5 = 6 x Small Longitudinal Dia	sp5	127	mm	clause 21.3.4.2 & 21.5.3.2	
	Spc6 (only intermediate frame)	sp6	228	mm	clause 21.3.4.2 & 21.5.3.5	
	Spc7 = d / 4	sp7	230	mm	clause 21.3.4.2 & 21.5.3.3	
	Spc8	sp8	300	mm	clause 21.3.4.2 & 21.5.3.4	



$$A_{v,\,min} = 0.062\sqrt{f_c'}\frac{b_w s}{f_{yt}} \qquad (11\text{-}13)$$

but shall not be less than $(0.35 b_w s)/f_{yt}$.

11.4.7.9 — V_s shall not be taken greater than $0.66\sqrt{f_c'}\, b_w d$.

11.2.2.1 $V_c = \left(0.16\lambda\sqrt{f_c'} + 17\rho_w \frac{V_u d}{M_u}\right) b_w d$

$= 0.29\lambda\sqrt{f_c'}\, b_w d.$

$$A_{v,\,min} = 0.062\sqrt{f_c'}\frac{b_w s}{f_{yt}} \qquad (11\text{-}13)$$

but shall not be less than $(0.35 b_w s)/f_{yt}$.

11.4.7.2 $V_s = \frac{A_v f_{yt} d}{s}$

11.4.7.9 — V_s shall not be taken greater than $0.66\sqrt{f_c'}\, b_w d$.

11.5.3.1 — The cross-sectional dimensions shall be such that:

(a) For solid sections

$$\sqrt{\left(\frac{V_u}{b_w d}\right)^2 + \left(\frac{T_u p_h}{1.7 A_{oh}^2}\right)^2} \le \phi\left(\frac{V_c}{b_w d} + 0.66\sqrt{f_c'}\right) \qquad (11\text{-}18)$$

11.5.1 $T_{cr/4} = \phi 0.083\lambda\sqrt{f_c'}\left(\frac{A_{cp}^2}{p_{cp}}\right)$

11.5.5.3 $A_{t,min} = \frac{0.42\sqrt{f_c'}\, A_{cp}}{f_y} - \left(\frac{A_t}{s}\right) p_h \frac{f_{yt}}{f_y}$

11.5.6.1 — The spacing of transverse torsion reinforcement shall not exceed the smaller of $p_h/8$ or 300 mm.

21.3.4.2 — Spacing of hoops shall not exceed the smallest of (a), (b), (c), and (d):

(a) $d/4$;

(b) Eight times the diameter of the smallest longitudinal bar enclosed;

(c) 24 times the diameter of the hoop bar;

(d) 300 mm

Step 5) Design for Torsion, SFR						
Check for cross section			OK		clause 11.5.3.1	
Ultimate Torsion force at section considered, For SFR	Tu	Tu,SFR	22.60	kN-m		
Cracking Torque / 4	Tcr/4	Tcr/4	22.50	kN-m	clause 11.5.1(a)	
Check for torsion to be considered or not		**Check-3**	Hence Skin Reinforcement is Provided			
Additional shear reinf. due to Torsion		At/s	0.166667	sqmm/mm	clause 11.5.3.6,11.5.5.3	
Additional longitudinal reinf. due to Torsion	Al (sqmm) (Tor.)		406.67	sqmm	clause 11.5.3.7	
Minimum Additional longitudinal reinf. due to Torsion	Al, min(Tor.)	Almin	1718.38	sqmm	clause 11.5.5.3	
Final Additional longitudinal reinf. due to Torsion		Al (sqmm) (Tor)	1718.38	sqmm	=IF(Check-3="Neglect","-",MAX(Al (sqmm) (Tor.),Al, min(sqmm)(Tor.)))	
Step 5a) Design for Skin Reinforcement						
Check for Skin Reinforcement		**Check-4**	Required		Clause 10.6.7	
Distribution of torsion longitudinal reinf. as skin reinf	Asr		1,227.4	sqmm	=IF(Check-4="Neglect",0,(Al (sqmm) (Tor)/(2*B+2*D))*D)	
Skin Reinforcement Spacing	Maximum Permissible Spacing		194	mm	Clause 10.6.4	
Numbers of reinforcement on each face			3.0	nos		
Area of Skin Reinf.on each face			595.7	sqmm / face		
Skin Reinforcement on both face	Asr		1227.4	sqmm		
SFR provided	Asr provided		1,588.45	sqmm		
Check			OK			

21.5.3.2 — Spacing of the hoops shall not exceed the smallest of (a), (b), and (c):

(a) $d/4$;

(b) Six times the diameter of the smallest primary flexural reinforcing bars excluding longitudinal skin reinforcement required by 10.6.7; and

(c) 150 mm

10.6.4 $$s = 380\left(\frac{280}{f_s}\right) - 2.5c_c \qquad (10\text{-}4)$$