TITLE :	DESIGN OF BEAM					
SUB -TITLE :	DESIGN OF BEAM FOR FLEXURE,SHEAR AND TORSION					
CODE OF PRACTICE :	BS EN1992-1-1-2004					
DESIGN TYPE :	ULTIMATE STATE DESIGN					
NOTE :- 1) User to Input data in cell marked as Blue.						
2) Design follows Ultimate Limit State Method.						
Step 1) User Input	**Reference from RCDC / Formula**	**Symbol**	**Formulations**	**Units**	**Reference / Comments**	
PARAMETERS :						
Design Code			BS EN			
Beam No			B1			
Reference section of Beam			Top Right			
Analysis Reference			4.2m:4005			
Type of Beam			Non-Ductile			
Location			Right			
Width of Beam	Breadth (bw)	B	450	mm	user Input	
Depth of Beam	Depth (h)	D	700	mm	user Input	
Length of beam	Beam length	L	8000	mm	user Input	
Nominal Cover to Beam	Clear Cover (cnom)	Cc	20	mm	user Input	
Effective depth to tension reinforcement	Effective Depth (d)	d	650	mm		
Grade of Concrete (Cylindrical Strength)	Grade Of Concrete (f_{ck}) (Cylindrical)	f_{ck}	20	N/sqmm	user Input	
Grade of Steel	Grade Of Steel (f_{yk})	f_{yk}	420	N/sqmm	user Input	
Analysis Result						
Type of Critical Combination for Flexural and Torsion			Persistant and transient		user Input	
Type of Critical Combination for Shear and Torsion			Accenential		user Input	
Type of Critical Combination for Torsion			Persistant and transient		user Input	
Bending Moment	Mu (kNm)	Mu	994.05	kN-m	user Input	
Axial Force		N_{Ed}	0	kN	user Input	
Shear Force	VEd (kN)	V_{Ed}	736.46	kN	user Input	
Torsional Moment- Flexural	T_{Ed} (Flexural Design) (kNm)	T_{ed}	0	kN-m	user Input	
Torsional Moment - Shear	T_{Ed} (Shear Design) (kNm)	T_{Ed}	0	kN-m	user Input	
Torsional Moment- Torsion	T_{Ed} (Torsion Design) (kNm)	T_{ed}	0	kN-m	user Input	
Angle between shear reinforcement and the longitudinal		α	90	Degree	Cl.9.2.2-Constant	
Percentage Steel						
Minimum		ptmin	0.13	%	user Input	
Maximum		ptmax	4	%	user Input	
Nominal		ptnominal	0.2	%	user Input	
Provided Reinforcement						
Diameter of main Reinforcement (1st Layer)			32	mm	user Input	
No of Rebar (1st layer)			4	Nos	user Input	
Diameter of main Reinforcement (2nd Layer)			32	mm	user Input	
No of Rebar (2nd layer)			3	Nos	user Input	
Diameter of main Reinforcement (3rd Layer)			40	mm	user Input	
No of Rebar (3rd layer)			0	Nos	user Input	
Area of Longitudinal reinforcement			5629.73	sqmm	user Input	
Diameter of Shear Reinforcement			8	mm	user Input	
No of Legs of Shear Reinforcement			4	Nos	user Input	
Spacing of Shear Reinforcement			130	mm	user Input	
Diameter of SFR			0	mm	user Input	
SFR Numbers at Each Face			0	Nos	user Input	
Partial Factor of Safety for Material Concrete for persistant and transient Loads	Partial Factor for Concrete (Y_c)	Yc	1.5	constant	table 2.1	
Partial Factor of Safety for Material Concrete for accenential loads	Partial Factor for Concrete (Y_{cd})	Ycd	1.2	constant	table 2.1	
Partial Factor of Safety for Material Steel for persistant and transient Loads	Partial Factor for Reinforcement (Y_s)	Ys	1.15	constant	table 2.1	
Partial Factor of Safety for Material Steel for accenential loads	Partial Factor for Reinforcement (Y_{sd})	Ysd	1	constant	table 2.1	
Elastic Modulus	Es	Es	200000	N/sqmm	Constant	

		αct	1	constant	Cl. 3.1.6(2)	
Co-efficient		k1	0.15	constant	Cl. 6.2.2	
		α_{cw}	1	constant	Cl. 6.2.3 (3)	
Moment Distribution Ratio (No distribution)		δ	1		clause 5.5	
Mean value of axial tensile strength of Concrete		f_{ctm}	2.21	N/sqmm	table 3.1	
		$f_{ctk\ 0.05}$	1.55	N/sqmm	table 3.1	
Co-efficient taking account long term effects of load		αcc	1.00		Cl. 3.1.6	
Strength reduction factor for Torsion		v = v1	0.55		Cl. 6.2.2 (6.6N)	
	K'	K'	0.21			
Effective depth to compression reinforcement		d2	50	mm		
Calculation of Tension Reinforcement						
Partial Factor of Safety for Material Concrete		Yc	1.5	constant	table 2.1	
Partial Factor of Safety for Material Steel		Ys	1.15	constant	table 2.1	
Design value of Steel yield strength	(fyk / Ys)	fyd	365.22	N/sqmm		
Tensile Strength of Concrete		f_{ctd}	1.03	N/sqmm	Cl. 3.1.6(2)	
K = MEd / (bwd2 fck)	Mu/(bd^2xfck)	K	0.26			
beam Design type (Singly OR Doubly)			Doubly Reinforced			
Lever Arm for tension reinforcement	z	z	490.30	mm		
% reinforcement for BM	ρ (%) (Flexural)	ρ (%)	1.83	%		
Area of Reinforcement for BM	A_s (sqmm)		-	sqmm		
Area of Torsion reinforcement required	A_{sl} (sqmm)		-	sqmm	Cl.7.3.3,(3)	
Torsion reinforcement distributed at top and bottom face	Asl,dist (sqmm)		0.00	sqmm	Cl.7.3.3,(3)	
SFR to be provided at Each Face		A_{sl}, dist/ face	0.00	sqmm		
Area of reinf for BM + torsion reinf. Distributed	As + Asl,dist /2 (sqmm)		-	sqmm	Cl.7.3.3,(3)	
Minimum tension Reinforcement	As,min (flex) (B)	A_s,min	400.24	sqmm	Cl. 9.2.1.1	
Maximum Reinforcement--user input	$A_s$max (ptmax x B X D)	$A_s$max	12600	sqmm		
Minimum Reinforcement-user input	As,min (user input)(B')	$A_s$min	410	sqmm		
Nominal Reinforcement-user input	$A_{s,nominal}$ (Bn)	$A_s$nominal	630.00	sqmm		
Area of tension Reinforcement	$A_{s,reqd}$ (sqmm)	A_s	-	sqmm		
Calculation for Doubly reinforced Section						
Excess Moment Calculation	M' (Excess Moment for Doubly Reinforced section) (kNm)	M'	195.53	kN-m		
Distance of N.A.	x (Distance of N.A.) (mm)	x	399.24	mm		
Compressive Stress in Steel,fsc = 700 x (x - d2) / x <= fyk	fsc (Compressive Stress in Steel) (N/sqmm)	f_{sc}	365	N/sqmm		
Compression Steel	Asc (Area of Compression Reinf.) (sqmm) (C)	As2	892.28	sqmm		
Area of Reinforcement for BM	A_s (sqmm)		5351.63	sqmm		
Area of reinf for BM + torsion reinf. Distributed	As + Asl,dist /2 (sqmm)		5351.63	sqmm		
Area of tension Reinforcement	$A_{s,reqd}$ (sqmm)	A_s	5351.63	sqmm		
Determine Design Torsional Stress						
Gross Area of Section	BXD	A_g	315000	sqmm	Cl. 6.3.2	
Outer Perimeter of the cross section	2xB+2XD	u	2300	mm	Cl. 6.3.2	
Effective wall thickness	Ag / u	t_{ef}	137	mm	Cl. 6.3.2	
Area enclosed by perimeter uk	(B-tef) x (D- tef)	A_k	176257	sqmm	Cl. 6.3.2	
Perimeter of the area Ak	2 x (B-tef) x 2x (D- tef)	uk	1752	mm		
Calculation for Torsional Cracking Moment $T_{Rd,c}$						
Torsional Cracking Moment	$T_{Rd,c}$	$T_{Rd,c}$	49.80	kN-m	Cl. 6.3.2	
Check			Igonre torsion reinf			
Torsional Stress	t_{Ed} (N/sqmm)	t_{Ed}	-	N/sqmm	Cl. 6.3.2	
Permissible Torsional Stress						
t_{Rd},max @ cot θ = 2.5		t_{Rd},max,cot θ = 2.5	-	N/sqmm	Cl. 6.3.2	
t_{Rd},max @ cot θ = 2.6		t_{Rd},max,cot θ = 1	-	N/sqmm	Cl. 6.3.2	
Minimum area of reinforcement within tensile zone	As,min (Tor) (sqmm)	As,min	-	sqmm	Cl.7.3.3,(3)	
Check for Torsional Stress						

$$f_{ctm}=0,30\times f_{ck}^{(2/3)} \le C50/60$$
$$f_{ctm}=2,12\cdot \ln(1+(f_{cm}/10)) > C50/60$$

$$f_{ctk;0,05} = 0,7\times f_{ctm}$$
5% fractile

$$K' = 0.60\delta - 0.18\,\delta^2 - 0.21$$
where $\delta \le 1.0$

$$z = \frac{d}{2}\left[1+\sqrt{1-3.53K}\right] \le 0.95d$$

$$A_{s2} = \frac{(K-K')\,f_{ck}\,bd^2}{f_{sc}(d-d_2)}$$
where
$$f_{sc} = 700\left[\frac{x-d_2}{x}\right] \le f_{yd}$$

$$A_s = \frac{K' f_{ck}\,bd^2}{f_{yd}\,z} + A_{s2}\frac{f_{sc}}{f_{yd}}$$

Determine θ		θ	-	Degree	Cl. 6.3.2
Design Torsional Resistance Stress	$t_{Rd,max}$	tRd,max	-	N/sqmm	Cl. 6.3.2
Area of Longitudinal reinforcement required for Torsion		A_{sl}	-	sqmm	Cl. 6.3.2
Shear Design					
Partial Factor of Safety for Material Concrete		Ɣc	1.2	constant	table 2.1
Partial Factor of Safety for Material Steel		Ɣs	1	constant	table 2.1
Design value of Steel yield strength	(fyk / Ɣs)	fyd	420.00	N/sqmm	
Design Tield of Shear Reinforcement	0.8 x fyd	fywd	336.00	N/sqmm	Cl. 6.3.2 (3) Note
Tensile Strength of Concrete	αct x fctk 0.05 / Ɣc	f_{ctd}	1.29	N/sqmm	Cl. 3.1.6(2)
Design value of concrete compressive strength	fck x αcc / Ɣc	fcd	16.67	N/sqmm	
% reinforcement provided at section considered	PtPrv (%)	PtPrv (%)	1.92	%	
Calculation for Torsional Cracking Moment $T_{Rd,c}$					
Torsional Cracking Moment	$T_{Rd,c}$	$T_{Rd,c}$	62.25	kN-m	Cl. 6.3.2
Torsional Stress	t_{Ed} (N/sqmm)	t_{Ed}	0.000	N/sqmm	Cl. 6.3.2
Permissible Torsional Stress					
t_{Rd},max @ cot θ = 2.5		t_{Rd},max,cot θ = 2.5	6.345	N/sqmm	Cl. 6.3.2
t_{Rd},max @ cot θ = 1		t_{Rd},max,cot θ = 1	9.200	N/sqmm	Cl. 6.3.2
Check for Torsional Stress					
Determine θ		θ	-	Degree	Cl. 6.3.2
		Cot θ	-		
Design Torsional Resistance Stress	$t_{Rd,max}$	tRd,max	6.34	N/sqmm	Cl. 6.3.2
Design Torsional Resistance Moment	$T_{Rd,max}$	TRd,max	153.16	kN-m	Cl. 6.3.2
	V_t	V_t	0.00	kN	Cl. 6.3.2
Design shear stress					
	v_{Ed} + Vt	vEd + Vt	736.46	kN	
	v_{Ed}	v_{Ed}	2.52	N/sqmm	
Area of Concrete (BxD)		A_c	315000	sqmm	
Compressive stress due to axial Load		σ_{cp}	0.00	N/sqmm	
Co-efficient		k	1.55		Cl. 6.2.2
Strength reduction factor		v_{min}	0.30		Cl. 6.2.2
		$C_{Rd,c}$	0.15		Cl. 6.2.2
Shear Resistance of member without shear reinforcement in terms of stress	$v_{Rd,c}$	$v_{Rd,c}$	0.79	N/sqmm	Cl. 6.2.2
Shear Resistance of member without shear reinforcement in terms of Force	$V_{Rd,c}$	$V_{Rd,c}$	230.32	kN	
Interaction Ratio	(TEd / TRd,c) + (VEd / VRd,c)		3.20		Cl. 6.2.2
		v1 = v	0.55		Cl. 6.2.2
v_{Rd},max cot θ = 2.5		v_{Rd},max cot θ = 2.5	3.17	N/sqmm	Cl. 6.2.2
v_{Rd},max cot θ = 1		v_{Rd},max cot θ = 1	4.60	N/sqmm	Cl. 6.2.2
	$v_{Rd,max}$	vRd,max	3.17	N/sqmm	Cl. 6.2.2
maximum Shear resistance in terms of Force	$V_{Rd,max}$	$V_{Rd,max}$	835.138	kN	Cl. 6.2.2
Design Torsional Resistance Moment	TRd,max	TRd,max	153.16	kN	Cl. 6.3.2
(T_{Ed} / $T_{Rd,max}$) + (V_{Ed} / $V_{Rd,max}$)	(T_{Ed} / $T_{Rd,max}$) + (V_{Ed} / $V_{Rd,max}$)		0.8818		Cl. 6.3.2
Calculation for spacing of shear reinf.					
Strut Inclination angle		θ	21.80	degree	
Area of Shear Reinforcement required for Shear	A_{sw} (sqmm)	A_{sw} /s	1498.698	sqmm/m	
Maximum Area of Shear Reinforcement		A_{swmax} /s	6160.71	sqmm/m	
Check for Maximum Shear reinforcement			OK		
Spacing of Reinforcement required for Shear		s	134.16	mm	
Minimum Shear Reinforcement Ratio		$\rho_{w,min}$	0.000851835		Cl.9.2.3
Minimum Area of Shear Reinforcement		A_{sw} min	383.33	sqmm/m	
final Area of Shear Reinforcement Required	$A_{sw\ (Sqmm)}$	$A_{sw\ (Sqmm)}$	1498.70	sqmm/m	
Maximum Spacing based on Minimum Asw		$S_{shear,min}$	520.00	mm	
Maximum Longitudinal Spacing			487.50	mm	Cl.9.2.2 (6)

$$\frac{\sum A_{sl} f_{yd}}{u_k} = \frac{T_{Ed}}{2A_k}\cot\theta$$

$$\theta = 0.5 \sin^{-1}\left[\frac{v_{Ed}}{0.20 f_{ck}\,(1 - f_{ck}/250)}\right]$$

$$T_{Ed} / T_{Rd,c} + V_{Ed} / V_{Rd,c} \le 1{,}0$$

$$T_{Ed} / T_{Rd,max} + V_{Ed} / V_{Rd,max} \le 1{,}0$$

$$V_{Rd,max} = \alpha_{cw}\, b_w\, z\, \nu_1\, f_{cd}/(\cot\theta + \tan\theta)$$

$$\theta = 0.5 \sin^{-1}\left[\frac{v_{Ed}}{0.20 f_{ck}\,(1 - f_{ck}/250)}\right]$$

Spacing Criteria	S_{PC1} = 0.75d	S_{PC1}	487	mm		
	S_{PC2}	S_{PC2}	300	mm		
Spacing Required	$s_{reqd.}$ (sqmm)	s_{reqd}	130	mm		
Spacing Provided	s_{prov} (sqmm)	s_{prov}	130	mm		
Area of ShearReinforcement provided	$A_{sw,prov.}$ (sqmm)	$A_{sw,prov}$	1546.63	sqmm		
Check			OK			
SFR Design						
Breadth (bw)	Breadth (bw)		450	mm		
Depth (h)	Depth (h)		700	mm		
Check	Check for SFR	No side face reinforcement required			Cl. 7.3.3 (3)	
Partial Factor of Safety for Material Concrete		Yc	-	constant	table 2.1	
Partial Factor of Safety for Material Steel		Ys	-	constant	table 2.1	
Torsional Moment- Torsion	T_{ed}	T_{ed}	0.00	kN-m		
Torsional Cracking Moment	$T_{Rd,c}$	$T_{Rd,c}$	49.80	kN-m	Cl. 6.3.2	
Check		Igonre torsion reinf				

Calculate area of shear reinforcement:

$$\frac{A_{sw}}{s} = \frac{v_{Ed}\, b_w}{f_{ywd} \cot \theta}$$