TITLE :	DESIGN OF BEAM					
SUB -TITLE :	DESIGN OF BEAM FOR FLEXURE,SHEAR AND TORSION					
CODE OF PRACTICE :	IS 456 : 2002					
CODE TITLE :	PLANE AND REINFORCED CONCRETE					
DESIGN TYPE :	LIMIT 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 :	SYMBOL	USER INPUT	UNITS	***Reference / Comments***		
Beam No		B6		*User Input*		
Reference section of Beam		Top Left		*User Input*		
Width of Beam	B	400	mm	*User Input*		
Depth of Beam	D	900	mm	*User Input*		
Thickness of Slab	Df	0	mm			
Type of beam		Rectangular		*User Input*		
Bending Moment from Analysis at section considered	Mu	1,026.51	kN-m	*User Input*		
Shear force from analysis at section considered	Vu	628.28	kN	*User Input*		
Torsion force from analysis at section considered	Tu	61.05	kN-m	*User Input*		
characteristic compressive strength of concrete (Cube Strength)	fck	25.00	N/mm^2	*User Input*		
characteristic strength of reinforcement	fy	415.00	N/mm^2	*User Input*		
Cover to tension reinforcement	Cc	25.00	mm	*User Input*		
Cover to compression reinforcement	Cc'	25.00	mm	*User Input*		
Diameter of tenson reinforcement	dia1	20.00	mm	*User Input*		
Diameter of comression reinforcement	dia2	20.00	mm	*User Input*		
Diameter of shear reinforcement	dia3	10.00	mm	*User Input*		
Diameter of SFR	dia4	12.00	mm	*User Input*		
Number of legs for shear reinforcement		2	nos	*User Input*		
Number of reinforcement layers at tension face	n1	2.00	Nos	*User Input*		
Number of reinforcement layers at compression face	n2	2.00	Nos	*User Input*		
Depth of flange		100	mm	*User Input*		
Partial Factor of Safety for Material Concrete	ɣm concrete	1.50	constant	*Clause 36.4.2.1*		
Partial Factor of Safety for Material Steel	ɣm steel	1.15	constant	*Clause 36.4.2.1*		
Detailing of Tension reinforcement						
Number of reinforcement at first layer		4	nos	*User Input*		
Number of reinforcement at second layer		3	nos	*User Input*		
Reinforcement diameter at first layer		32	mm	*User Input*		
Reinforcement diameter at second layer		25	mm	*User Input*		
Detailing of Compression 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		20	mm	*User Input*		
Reinforcement diameter at second layer		16	mm	*User Input*		
characterstic yield strength of einforcement for shear	fyt	415.00	N/mm^2	*Clause 26.5.1.6*		
Effective depth at tension face	deff	845.00	mm	*User Input*		
Effective cover at compression reinforcement	d'	55.00	mm			

f_y = characteristic strength of the stirrup reinforcement in N/mm^2 which shall not be taken greater than 415 N/mm^2.

Step 2) Design for singly reinforced section					
Equivalent Bending moment due to torsion	Mt	116.71	kN-m	*Clause 41.4.2*
Equivalent Moment due to torsion	Me1	1143.22	kN-m	*Clause 41.4.2*
Balance neutral axis	Xu bal	(0.0035/(0.0055+(0.87*fy/(2*10^5))))*deff		*Clause 38.1*
		404.85	mm	
limiting moment of resistance of a section without compression reinforcement,	Mu lim	0.36*fck*Xu bal*B*(deff-0.416*Xu bal)/10^6		
		986	kN-m	*Clause 38.1*
Mu/bd^2	R	4.003		
Check		Doubly reinforced.refer step-3		
Minimum % reinforcement	Ptmin	0.205	%	*Clause 26.5.1.1*
Ast minimum	Astmin	692.29	sqmm	*Clause 26.5.1.1*
Area of tension reinforcement required	Ast req	-	sqmm	*Annex -G (G.1)*
% tension steel required	ptcalc	-	%	
Area of compression reinforcement for torsion	Asc req	-	sqmm	*Clause 41.4.2.1*
Step 3) Design of doubly reinforced section				
Determining area of compression reinforcement				
Strain at level of compression reinforcement	εsc	=0.0035*(1-(d'/Xu bal))		
		0.003025		
stress in compression reinforcement	fsc	354.14	N/sqmm	*Annex -G (G.1)*
Area of compression reinforcement	Asc req	561.67	sqmm	*Annex -G (G.1)*
% compression steel required		(Asc req*100/(B*deff))*0.87*fy/(fsc-0.446*fck)		
		0.175	%	
Ast of tension reinf. required for balance section	Ast1	4036.68	sqmm	*Annex -G (G.1)*
Area of tension reinforcement required for doubly section	Ast2	550.92	sqmm	*Annex -G (G.1)*
Total Area of tension reinforcement	Ast req	4,587.6	sqmm	*Annex -G (G.1)*
% tension steel required	ptcalc	1.357	%	
Area of tension reinforcement provided	Ast provided	4690	sqmm	
Check for tension reinforcement		OK		
Area of compression reinforcement provided	Asc provided	1257	sqmm	
Check for compression reinforcement		OK		

$$M_{u,\lim} = 0.36 \frac{x_{u,\max}}{d}\left(1 - 0.42 \frac{x_{u,\max}}{d}\right) bd^2 f_{ck}$$

The longitudinal reinforcement shall be designed to resist an equivalent bending moment, M_{e1}, given by

$$M_{e1} = M_u + M_t$$

where

M_u = bending moment at the cross-section, and

$$M_t = T_u \left(\frac{1 + D/b}{1.7}\right)$$

$$M_u - M_{u,\lim} = f_{sc} A_{sc} (d - d')$$

where

M_u, $M_{u,\lim}$, d are same as in G-1.1,

f_{sc} = design stress in compression reinforcement corresponding to a strain of

$$0.003\,5 \frac{(x_{u,\max} - d')}{x_{u,\max}}$$

The total area of tension reinforcement shall be obtained from the following equation :

$$A_{st} = A_{st1} + A_{st2}$$

where

A_{st} = area of the total tensile reinforcement,

A_{st1} = area of the tensile reinforcement for a singly reinforced section for $M_{u,\lim}$, and

$A_{st2} = A_{sc} f_{sc} / 0.87 f_y$.

Step 4) Design of Shear reinforcement					
shear due to torsion	Vtu	244.20	kN		*Clause B-6.3*
Total shear	Vut	872.48	kN		*Clause B-6.3*
Nominal shear stress	Tv	2.58	N/sqmm		*Clause 40.1 and 41.3.1*
Maximum shear stress	Tcmax	3.1	N/sqmm		*Table 20*
Check		OK			
Design strength of concrete	Tc	0.72	N/sqmm		*Table 19*
Shear Capacity of Concrete	Vc	244.15	kN		*Table 19*
Shear to be carries by Reinforcement	Vus=Vut-Vc	628.33	kN		*Clause 40.4 (a)*
Total shear reinforcement required	Asv req	2059.50	sqmm/m		*Clause 40.4 (a)*
C/C distance between corner bars in direction of width	b1	318.00	mm		
C/C distance between corner bars in direction of depth	d1	818.00	mm		
shear reinforcement to be provided at outer link	Asv torsion	1500.96	sqmm/m		*Clause 41.4.3*
Area of Shear reinforcement provided	Asv Total Prv	2094.40	sqmm/m		
Stirrups Spacing Criteria					
Short dimension of stirrups	x1	360	mm		*Clause 26.5.1.7*
long dimension of stirrups	y1	860	mm		*Clause 26.5.1.7*
	spc1	634	mm		*Clause 26.5.1.5*
	Spc2	300	mm		*Clause 26.5.1.5*
	Spc3	360	mm		*Clause 26.5.1.7*
	Spc4	305	mm		*Clause 26.5.1.7*
Spacing of links	SvCalc	75	mm		
Spacing required for outer stirrups		105	mm		
Spacing to be provided	SvPrv	75	mm		
Step 5) Side face reinforcement					
Width of Beam	B	400	mm		
Depth of Beam (Web Depth) D- Df	D	900	mm		
Torsion		61.05>0	kN-m		*Clause 26.5.1.7*
		900>750			*Clause 26.5.1.3*
Check		SFR required			*Clause 26.5.1.3*
Total side face reinforcement required	ASFR	360	Sqmm		*Clause 26.5.1.3*
Numbers of reinf required		2			
Area of SFR provided	ASFR Provided	452.39	Sqmm		
Check for spacing		OK			*Clause 26.5.1.3*
Spacing Criteria					
Provided Spacing		231.33	mm		
	<= beam Width	400	mm		*Clause 26.5.1.7*
	Not Greater Than	300	mm		*Clause 26.5.1.7*

B-6.4.3 *Transverse Reinforcement*

Two legged closed hoops enclosing the corner longitudinal bars shall have an area of cross-section A_{sv}, given by

$$A_{sv} = \frac{T.s_v}{b_1 d_1 \sigma_{sv}} + \frac{V.s_v}{2.5 d_1 \sigma_{sv}}$$, but the total transverse reinforcement shall not be less than

$$\frac{(\tau_{ve} - \tau_c)\, b.s_v}{\sigma_{sv}}$$

26.5.1.7 *Distribution of torsion reinforcement*

When a member is designed for torsion (*see* **41** or **B-6**) torsion reinforcement shall be provided as below:

a) The transverse reinforcement for torsion shall be rectangular closed stirrups placed perpendicular to the axis of the member. The spacing of the stirrups shall not exceed the least of x_1, $\frac{x_1 + y_1}{4}$ and 300 mm, where x_1 and y_1 are respectively the short and long dimensions of the stirrup.

b) Longitudinal reinforcement shall be placed as close as is practicable to the corners of the cross-section and in all cases, there shall be at least one longitudinal bar in each corner of the ties. When the cross-sectional dimension of the member exceeds 450 mm, additional longitudinal bars shall be provided to satisfy the requirements of minimum reinforcement and spacing given in **26.5.1.3.**

26.5.1.3 *Side face reinforcement*

Where the depth of the web in a beam exceeds 750 mm, side face reinforcement shall be provided along the two faces. The total area of such reinforcement shall be not less than 0.1 percent of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness whichever is less.