TITLE :		DESIGN OF Shear column with Boundary Element					
SUB -TITLE :		DESIGN OF COLUMN FOR FLEXURE AND SHEAR					
CODE OF PRACTICE :		IS 456-2000 + 13920-2016					
DESIGN TYPE :		LIMIT STATE DESIGN					
NOTE :- 1) User to Input data in cell marked as Blue.							
2)	**Design follows Limit State Method.**						
User Input							**Reference / Comments**
PARAMETERS :	RCDC	SYMBOL			INPUT	UNITS	
column					W7		
Level					4.2 m To 7.858 m		
Width of column	column B	B	=		**500**	mm	User Input
Depth of column	column D	D	=		**800**	mm	User Input
Grade of Concrete	Grade Of Concrete	fck	=		**25**	N/mm^2	User Input
Grade of Steel (Main Steel)	Grade Of Steel	fy	=		**415**	N/mm^2	User Input
Grade of Steel (Shear reinforcement)	Grade Of Steel	fyshear	=		**415**	N/mm^2	constant
Cover to reinforcement	Clear Cover	Cc	=		**50**	mm	User Input
Floor to floor height of the column		hw	=		**12,800**	mm	User Input
Beam depth along D (left side)		db1	=		**800**	mm	User Input
Beam depth along D (Right side)		db2	=		**800**	mm	User Input
Beam depth along B (left side)		bb1	=		**800**	mm	User Input
Beam depth along B (right side)		bb2	=		**800**	mm	User Input
Maximum % steel		ptmax	=		**4.00**	%	User Input
Partial Factor of Safety for Material Concrete		γ_c	=		**1.50**	constant	User Input
Partial Factor of Safety for Material Steel		γ_s	=		**1.15**	constant	User Input
column Type	column Type		=		**UnBraced**		User Input
Minimum eccentricity check	Minimum eccentricity check		=		**One Axis at a Time**		User Input
Code defined D/B ratio	Code defined D/B ratio		=		**4**		
Effective Length Factor along Major Axis			=		**0.94**		User Input
Effective Length Factor along Minor axis			=		**0.85**		User Input
Minimum % reinforcement in column (User defined)			=		**0.40**	%	
Spacing Round Factor for Links			=		**25.00**	mm	
Clear Floor Height @ B	Clear Floor Height @ B		=		12,000	mm	=H-(bb1,bb2)
Clear Floor Height @ D	Clear Floor Height @ D		=		12,000	mm	=H-(db1,db2)
Flexural Design (Analysis Forces)							
Critical Analysis Load Combination					19		
Load Combination			=	[9] : 1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)			
Critical Location			=	Top Joint			
Axial force		Pu	=		**757.35**	kN	User Input
Bending Moment along D		Mux	=		**5.40**	kNm	User Input
Bending Moment along B		Muy	=		**-114.70**	kNm	User Input
Shear force from Analysis along D		Vux	=		**-94.24**	kN	User Input
Shear force from Analysis along B		Vuy	=		**208.82**	kN	User Input

Shear Design (Analysis Forces)						
Along D						
Critical Analysis Load Combination				16		
Load Combination				[6] : 1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)		
Shear force from Analysis along D		Vux	=	263.00	kN	
Axial force		Pu	=	573.29	kN	
Along B						
Critical Analysis Load Combination				18		
Load Combination				[8] : 1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 4: LOAD CASE 4 EQ-Y)		
Shear force from Analysis along B		Vux	=	184.21	kN	
Axial force		Pu	=	523.70	kN	
Reinforcement Provided in column						
Diameter of longitudinal reinforcement		dia	=	12	mm	User Input
Numbers of Rebars		Nos	=	20	Nos	User Input
Diameter of longitudinal reinforcement		dia	=	-	mm	User Input
Numbers of Rebars		Nos	=	-	Nos	User Input
No of Rebars Along B		Nos	=	7	Nos	User Input
No of Rebars Along D		Nos	=	5	Nos	User Input
Total area of Longitudinal reinforcement				2261.95	sqmm	
Shear Links						
Ductile Links						
Link Diameter			=	8	mm	
Link Spacing			=	70	mm	
Other Links						
Link Diameter			=	8	mm	
Link Spacing			=	175	mm	
No of Links along D			=	5		
No of Links along B			=	7		
Step 1) Check Code Defined D/B Ratio						
D/B Ratio				1.6		
Check	D/B Ratio		=	Hence, Design as Column		Clause 10.1.3 - IS 13920
Step 4) Effective Length Calculation						
Effective Length Factor along Major Axis				0.94		Annex-E
Effective Length Factor along Minor axis				0.85		Annex-E
Step 5) Minimum Eccentricity Check						
Check				Since Axial Force is compressive, Min. Eccentricity check to be performed		
Most critical case is with Min. Eccentricity				X-direction		Clause 25.4
Actual Eccentricity Along D :				Clear Floor Height @ D / 500 + B / 30		
				50.67	mm	
				Max (Actual Eccentricity,20)		
Minimum Eccentricity Along D :				50.67	mm	
Mminx				Pu x Minimum Eccentricity		
				38.37	kNm	Clause 25.4
Actual Eccentricity Along B :				-		
				0.00	mm	
Minimum Eccentricity Along B :				Max (Actual Eccentricity,20)		
				0.00	mm	
Mminy				-		
				0.00	kNm	

10 SPECIAL SHEAR WALLS

10.1 General Requirements

10.1.3 The minimum ratio of length of wall to its thickness shall be 4.

25.4 Minimum Eccentricity

All columns shall be designed for minimum eccentricity, equal to the unsupported length of column/ 500 plus lateral dimensions/30, subject to a minimum of 20 mm. Where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

25.3 Slenderness Limits for Columns

25.3.1 The unsupported length between end restraints shall not exceed 60 times the least lateral dimension of a column.

Step 5) Slenderness Check

Max Slenderness Ratio(Clear Floor Height @ B/B)			12000/500		
			24.00		
Check			<= 60, Hence OK		Clause 25.3
Column Is Unbraced Along D					
Slenderness Check Along D:					
Effective Length Factor along Major Axis			0.94		
Effective Length (Unsupported Length x Effective Length Factor)			12000X0.94		
			11280.00	mm	
Slenderness Ratio			Effective Length / D		
			14.10		
			column Slender Along D		
Slenderness moment along D			(Pu D/ 2000) (Ley/D)^2		
			60.23	kNm	Clause 39.7.1
Calculation of Slenderness Moment	Pu	=	757.35	kN	
	Pd	=	2237.17	kN	
	Puz	=	5178.58	kN	
Reduction factor 'k' for slenderness moment			(Puz - Pu) / (Puz - Pd) < = 1		
			1.50		
	k		1.00		Clause 39.7.1.1
Slenderness Moment along D	Mslndx		60.23	kNm	
Column Is Unbraced Along B					
Slenderness Check Along B:					
Effective Length Factor along Major Axis			0.85		
Effective Length (Unsupported Length x Effective Length Factor)			12000X0.85		
			10200.00	mm	
Slenderness Ratio			Effective Length / B		
			20.40		
			column Slender Along B		
Slenderness moment along B			(Pu D/ 2000) (Ley/D)^2		
			78.79	kNm	Clause 39.7.1
Calculation of Slenderness Moment	Pu	=	757.35	kN	
	Pb	=	2098.57	kN	
	Puz	=	5178.58	kN	
Reduction factor 'k' for slenderness moment			(Puz - Pu) / (Puz - Pd) < = 1		
			1.44		
	k		1.00		Clause 39.7.1.1
Slenderness Moment along B	Mslndy		78.79	kNm	

Calculation of Design Moment

Direction	Manalysis	Mmin (Abs)	Mdesign	Mslndx (Abs)	Mdesign-final
	A	B	C	E	F
Major Axis - Mux	5.40	38.37	38.37	60.23	98.60
Minor Axis - Muy	-114.70	0.00	-114.70	78.79	-193.49

Where

A = Moments directly from analysis
B = Moments due to minimum eccentricity
C = Maximum of analysis moment and min. eccentricity = Max (A,B)
E = Moment due to slenderness effect
F = Final design Moment = Max(C- Top Bottom , D- Top Bottom) + E

25.1.2 *Short and Slender Compression Members*

A compression member may be considered as short when both the slenderness ratios $\frac{l_{ex}}{D}$ and $\frac{l_{ey}}{b}$ are less than 12:

39.7.1 The additional moments M_{ax} and M_{ay} shall be calculated by the following formulae:

$$M_{ax} = \frac{P_u D}{2\,000}\left\{\frac{l_{ex}}{D}\right\}^2$$

$$M_{ay} = \frac{P_u b}{2\,000}\left\{\frac{l_{ey}}{b}\right\}^2$$

where

P_u = axial load on the member,
l_{ex} = effective length in respect of the major axis,
l_{ey} = effective length in respect of the minor axis,
D = depth of the cross-section at right angles to the major axis, and
b = width of the member.

39.7.1.1 The values given by equation **39.7.1** may be multiplied by the following factor:

$$k = \frac{P_{uz} - P_u}{P_{uz} - P_b} \le 1$$

$$P_{uz} = 0.45 f_{ck} \cdot A_c + 0.75 f_y \cdot A_{sc}$$

10.3 Design for Axial Force and Bending Moment

10.3.1 Design moment of resistance M_u of the wall section subjected to combined bending moment and compressive axial load shall be estimated in accordance with requirements of limit state design method given in IS 456, using the principles of mechanics involving equilibrium equations, strain compatibility conditions and constitutive laws.

The moment of resistance of slender rectangular structural wall section with uniformly distributed vertical reinforcement may be estimated using expressions given in Annex A. Expressions given in Annex A are not applicable for structural walls with boundary elements.

Final Critical Design Forces

Pu	=	757.35	kN
Mux	=	98.60	kNm
Muy	=	-193.49	kNm

Resultant Moment (Combined Action)

Moment Capacity Check

Pt Calculated	=	0.57	
Reinforcement Provided	=	20-T12	
Load Angle	=	Tan^{-1}(Muy/Mux)	
	=	63.00	deg
MRes	=	217.17	kNm
MCap	=	325.34	kNm
Capacity Ratio	=	MRes/ MCap	
	=	0.67	
Check		0.67<=1	

39.6 Members Subjected to Combined Axial Load and Biaxial Bending

The resistance of a member subjected to axial force and biaxial bending shall be obtained on the basis of assumptions given in **39.1** and **39.2** with neutral axis so chosen as to satisfy the equilibrium of load and moments about two axes. Alternatively such members may be designed by the following equation:

c) **The minimum number of longitudinal bars provided in a column shall be four in rectangular columns and six in circular columns.**

d) **The bars shall not be less than 12 mm in diameter.**

Shear Design (Analysis Forces)

Shear Calculation from Beam Capacity

Along D:

Height of column above level considered (hst1)	=	6000	mm
Height of column below level considered (hst2)	=	6000	mm
Height (hst)	=	12,800	mm

Along B:

Height of column above level considered (hst1)	=	6000	mm
Height of column below level considered (hst2)	=	6000	mm
Height (hst)	=	12,800	mm

Beam Size	Beam angle w.r.t. column Ly	Torsion moment	Moment Capacity Beam @ Top			
(mm)	(deg)	(kNm)	Mu (kNm)	Ast req (sqmm)	Ast pro (sqmm)	Mu cap (kNm)
400x800	0	0	308.43	1231.55	1344.6	353.25
400x800	270	0	263.36	1039.59	1231.5	325.12

Moment Capacity Beam @ Bottom				Resultant Moment			
Mu (kNm)	Ast req (sqmm)	Ast pro (sqmm)	Mu cap (kNm)	Top Ly (kNm)	Top Lx (kNm)	Bot Ly (kNm)	Bot Lx (kNm)
58.17	861.69	1005.3	271.67	353.25	0	271.67	0
137.72	861.69	1005.3	270.93	0	325.12	0	270.93

Effective moment for Column

	Mu Major (Along D) (kNm)		Mu Minor (Along B) (kNm)	
	Left	Right	Left	Right
Top	0	353.25	325.12	0
Bottom	0	271.67	270.93	0

Shear along D:

Sway Right

Vuy1 = 1.4 x (Left,Bottom + Right,Top)/hst

= 38.64 kN

Sway Left

Vuy2 = 1.4 x (Left,Top + Right,Bottom)/hst

= 29.71 kN

Shear along B:

Sway Left

Vux1 = 1.4 x (Left,Bottom + Right,Top)/hst

= 29.63 kN

Sway Right

Vux2 = 1.4 x (Left,Top + Right,Bottom)/hst

= 35.56 kN

7.5 Design Shear Force in Columns

The design shear force demand on columns is the larger of,

a) factored shear force demand as per linear structural analysis; and

b) factored equilibrium shear force demand when plastic hinges are formed at both ends of the beams given by:

1) For sway to right:

$$V_u = 1.4\frac{\left(M_u^{As} + M_u^{Bh}\right)}{h_{st}},$$

2) For sway to left:

$$V_u = 1.4\frac{\left(M_u^{Ah} + M_u^{Bs}\right)}{h_{st}},$$

where $M_u^{As}, M_u^{Ah}, M_u^{Bs}$ and M_u^{Bh} are design sagging and hogging moments of resistance of beams framing into the column on opposite faces A and B, respectively, with one hogging moment and the other sagging (*see* Fig. 11); and h_{st} the storey height. The design moments of resistance of beam sections shall be calculated as per IS 456.

Design for shear along D				
Critical Analysis Load Combination		:	16	
Critical Load Combination	[6] : 1.5 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X)			
Design shear force	Vuy	=	263.00	
Design shear, Maximum (Vuy,Vuy1,Vuy2)			263.00	kN
Axial Force	Pu	=	573.29	kN
Shear Stress	Tvy	=	Vuy / (0.8 x B X D))	
		=	0.7070	N/mm^2
Pt (50% of vertical reinforcement)		=	0.283	%
Beta		=	10.266	
Design shear strength,	Tc	=	0.3847	N/mm^2
Shear Strength Enhancement Factor		=	1 + 3 x Pu / (B x D x Fck)	
		=	1.1720	
Shear Strength Enhancement Factor (max)		=	1.50	
Shear Strength Enhancement Factor		=	1.1720	
Enhanced shear strength (Tc x Enhancement Factor)	Tc-e	=	0.451	N/mm^2
Design shear check		=	Tvy > Tc x Enhancement factor	
			Shear Reinforcement required along D	
Links for shear design along D				
Pt (20% of vertical reinforcement)		=	0.283	%
Effective Depth	Deff	=	744	mm
Shear resisted by concrete along D	VcD	=	167.73	kN
Shear to be resisted by shear reinforcement along D	VusD	=	95.27	kN
Area of shear reinforcement required,	Asv-d	=	354.86	sqmm
Master Link Rebar		=	8	mm
Number of legs provided		=	5	mm
Spacing of links prvd, Sv		=	175	mm
Asv Provided		=	1436.16	sqmm
Design for shear along B				
Critical Analysis Load Combination		:	23	
Critical Load Combination	[13] : 0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)			
Design shear force	Vux	=	184.21	kN
Design shear, Maximum (Vux,Vux1,Vux2)			184.21	kN
Axial Force	Pu	=	523.70	kN
Shear Stress	Tvx	=	Vux / (0.8 x B X D))	
		=	0.5757	N/mm^2
Pt (20% of vertical reinforcement)		=	0.283	%
Beta		=	10.266	
Design shear strength,	Tc	=	0.3847	N/mm^2
Shear Strength Enhancement Factor		=	1 + 3 x Pu / (B x D x Fck)	
		=	1.1571	
Shear Strength Enhancement Factor (max)		=	1.50	
Shear Strength Enhancement Factor		=	1.1571	
Enhanced shear strength (Tc x Enhancement Factor)	Tc-e	=	0.445	N/mm^2
Design shear check		=	Tvy > Tc x Enhancement factor	
			Shear Reinforcement required along B	

10.2 Design for Shear Force

10.2.1 Nominal shear stress demand τ_v on a wall shall be estimated as:

$$\tau_v = \frac{V_u}{t_w d_w},$$

where V_u is factored shear force, t_w thickness of the web, and d_w effective depth of wall section (along the length of the wall), which may be taken as 0.8 L_w for rectangular sections.

39.2 Design Shear Strength of Concrete

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$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\,(\sqrt{1.+5\beta}-1)}{6\beta}$$

where $\beta = 0.8\, f_{ck}/6.89\, p_t$, but not less than 1, and

$$P_t = \frac{100\, A_s}{b_w d}$$

40.2.2 ***Shear Strength of Members under Axial Compression***

For members subjected to axial compression P_u, the design shear strength of concrete, given in Table 19, shall be multiplied by the following factor :

$$\delta = 1 + \frac{3 P_u}{A_g f_{ck}} \text{ but not exceeding 1.5}$$

where

P_u = axial compressive force in Newtons,

A_g = gross area of the concrete section in mm^2, and

f_{ck} = characteristic compressive strength of concrete.

Links for shear design along B						
Pt (20% of vertical reinforcement)				=	0.283	%
Effective Depth			Beff	=	444	mm
Shear resisted by concrete along B			VcD	=	158.12	kN
Shear to be resisted by shear reinforcement along B			VusD	=	26.09	kN
Area of shear reinforcement required,			Asv-d	=	162.83	sqmm
Master Link Rebar				=	8	mm
Number of legs provided				=	7	mm
Spacing of links prvd, Sv				=	175	mm
Asv Provided				=	2010.62	sqmm
Design Of Links						
Main Links						
Links in the zone where special confining links are not required						
Normal Links						
Diameter of link				=	8	mm
				>	Max.longitudinal bar dia / 4	
				=	3	
Criterion for spacing of normal links						
Min. Longitudinal Bar dia X 16				=	192	mm
Min. dimension of column				=	500	mm
Maximum,300mm				=	300	mm
Least lateral edge dimension/2				=	250	mm
Spacing considered				=	175	mm
Special confining reinforcement as per IS 13920 - 2016						
6 X Smallest Longitudinal Bar Dia				=	72	mm
Hence Link spacing, Sv				=	70	mm
Hoop dimension, h					(B - 2 x Cover + 2 x Link Dia) / (No of Rebars Along B -1)	
Along B				=	104.00	mm
Along D					(D - 2 x Cover + 2 x Link Dia) / (No of Rebars Along D -1)	
				=	119.33	mm
		Max (Along B, Along D)			119.33	mm
Gross area of column, Ag		B x D		=	400000.00	sqmm
Core area of column, Ak					(B- 2 x cover to Link) x (D- 2 x cover to Link)	
					297856.00	sqmm
Area of special confining link, Ash1					(0.18 x S x h x (Fck/Fy) x (Ag/Ak-1))	
				=	31.062	sqmm
Area of special confining link, Ash2					(0.05 x S x h x (Fck/Fy))	
					25.161	sqmm
Area of special confining link, Ash					Maximum (Ash1,Ash2)	
					31.062	sqmm
Diameter of special confining link				=	8	mm
				=	Max. longitudinal bar dia / 4	
				=	3	mm
Zone for special confining links - criterion						
Max. Size of column,D				=	800	mm
				=	2000	mm
				=	450	mm
Hence length of confining zone				=	2000	mm
Table For Links						
Note: Ductile Design Of Links Is Applicable Only For Boundary Elements						

	Required			Provided	
	Normal Design	Shear Design	Ductile Design	Normal Zone	Ductile Zone
Link Dia.	8	---	8	8	8
Spacing	175	---	70	175	70

c) *Pitch and diameter of lateral ties*

1) *Pitch*—The pitch of transverse reinforcement shall be not more than the least of the following distances:
   i) The least lateral dimension of the compression members;
   ii) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied; and
   iii) 300 mm.
2) *Diameter*—The diameter of the polygonal links or lateral ties shall be not less than one-fourth of the diameter of the largest longitudinal bar, and in no case less than 16 mm.

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[*Page* 11, *clause* **8.1**(b)] — Substitute the following for the existing:

b) have a spacing not more than,
   2) 6 times diameter of the smallest longitudinal reinforcement bars; and

$$A_{sh} = Maximum\ of \begin{bmatrix} 0.18\ s_v\ h\ \dfrac{f_{ck}}{f_y}\left(\dfrac{A_g}{A_k}-1\right) \\ 0.05\ s_v\ h\ \dfrac{f_{ck}}{f_y} \end{bmatrix}$$

where

h = longer dimension of rectangular link measured to its outer face, which does not exceed 300 mm (*see* Fig. 10B), and

A_k = area of confined concrete core in rectangular link measured to its outer dimensions.