DESIGN OF COLUMN
DESIGN OF COLUMN FOR FLEXURE
EUROCODE 2 (BS EN 1992 -1 -1 2004)
DESIGN OF CONCRETE STRUCTURES PART (1-1) : GENERAL RULES FOR BUILDING
ULTIMATE LIMIT STATE

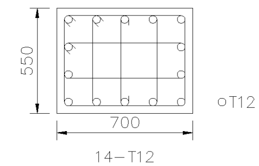
NOTE :- 1) User to Input data in cell marked as Yellow.
2) Design follows Ultimate Limit State Method.
3) Procedure Applicable only if Concrete class is less than or equal to C50/60.

Step 1) User Input / Defaults / Pre-calculations

PARAMETERS :	SYMBOL	RECOMMENDED VALUE	USER INPUT	UNITS	REMARKS / CLAUSE NUMBERS	
Column Number		-	C7			
Ultimate axial force (bottom Joint)	Ned	-	2,630.64	kN	*from staad results (ULS comb)*	
Ultimate axial force (top Joint)	Ned	-	2,440.57	kN	*from staad results (ULS comb)*	
Bending Moment from Analysis at top node along D	MtopD	-	-333.18	kNm	*from staad results (ULS c anti-clock wise moment consodered as +Ve*	
Bending Moment from Analysis at bottom node along D	MbotD	-	48.34	kNm	*from staad results (ULS c anti-clock wise moment consodered as +Ve*	
Bending Moment from Analysis at top node along B	MtopB	-	-296.75	kNm	*from staad results (ULS c anti-clock wise moment consodered as +Ve*	
Bending Moment from Analysis at bottom node along B	MbotB	-	-505.58	kNm	*from staad results (ULS c anti-clock wise moment consodered as +Ve*	
Shear force from Analysis along D(max of top and bottom node)	SFD	-	26.11	kN	*from staad results (ULS comb)*	
Shear force from Analysis along B(max of top and bottom node)	SFB	-	47.70	kN	*from staad results (ULS comb)*	
Ultimate axial force Top			2,440.57	kN	*As per number of members for merged levels*	
Ultimate axial force Bottom			2,630.64			
Bending Moment from Analysis Min along D			48.34	kNm	*As per number of members for merged levels*	
Bending Moment from Analysis Max along D			-333.18	kNm	*As per number of members for merged levels*	
Bending Moment from Analysis Min along B			-296.75	kNm	*As per number of members for merged levels*	
Bending Moment from Analysis Max along B			-505.58	kNm		
Extra height			-			
Grade of Concrete (Cylindrical Strength)	f_{ck}	-	50.00	N/mm^2	*input from user*	
Grade of Steel	f_{yk}	-	485.00	N/mm^2	*input from user*	
Strain of Concrete	ε_c	-	0.0035	-	*Refer table 3.1,BS EN 1992-1-1:2004.*	
Strain of Steel	ε_s	-	-	-	-	
Actual Length of column abstracted from Analysis file	H	-	8,000.00	mm	*from staad results*	
Floor to floor height of the column along B	Hb	-	9,100.00			
Floor to floor height of the column along D	Hd	-	9,300.00			
Beam depth along D (left side)	db1		600.00	mm	*from staad results*	
Beam depth along D (Right side)	db2		600.00	mm	*from staad results*	
Beam depth along B (left side)	bb1		600.00	mm	*from staad results*	
Beam depth along B (right side)	bb2		600.00	mm	*from staad results*	
Partial Factor of Safety for Material Concrete	γ_c	1.20	1.20	-	*Refer Cl.2.4.2.4,BS EN 1992-1-1:2004 + MS NA*	1.5 for DL and LL & 1.2 for Eq or Wind
Partial Factor of Safety for Material Steel	γ_s	1.00	1.00	-	*Refer Cl.2.4.2.4,BS EN 1992-1-1:2004 + MS NA*	1.15 for DL and LL & 1.0 for Eq or Wind
Co-efficient	α_{cc}	1.00	1.00	-	*Refer Cl.3.1.6,BS EN 1992-1-1:2004 + MS NA*	1.0 for BS EN and 0.85 for All other annex
Design value of concrete compressive strength	f_{cd}	50.00	41.67	N/mm^2	*Refer Cl .3.1.6,BS EN 1992-1-1:2004.*	
Design value of Steel yeild strength	f_{yd}	485.00	485.00	N/mm^2	*Refer Cl .3.2.7,BS EN 1992-1-1:2004.*	
Width of Column	B	-	400.00	mm	*from staad results/ user input*	
Overall Depth of Column	D	-	600.00	mm	*from staad results/ user input*	
Nominal Cover to Column	c_{nom}	50.00	50.00	mm	*Refer Cl. 4.4.1.2,BS EN 1992-1-1:2004.OR as per design brief*	
Longitudinal Bar dia	Ø	-	32.00	mm	*user input*	
Shear Reinforcement Bar dia	$Ø_{link}$	10.00	8.00	mm	*user input*	
Mean value of axial tensile strength of Concrete	f_{ctm}	-	4.07	N/mm^2	*Refer Table 3.1,BS EN 1992-1-1:2004.*	
Aggregate Size			25.00	mm	*user input (Aggregate size for minimum spacing between bars)*	
Modulus elasticity of concrete	Ecm		33,000	N/mm^2	*Refer table 3.1,BS EN 1992-1-1:2004.*	
Modulus elasticity of steel	Es		200,000	N/mm^2	*Refer CL 3.2.7,BS EN 1992-1-1:2004.*	

Step-2-- **Effective length factor**

Along D		leffD	0.59		*user input*
Along B		leffB	1.25		*user input*
Determine the effective length(lo)					
Along D	=MIN((leffD*(H-db1)),(leffD*(H-db2)))	loD	5,015.00	mm	
Along B	=MIN((leffB*(H-bb1)),(leffB*(H-bb2)))	loB	10,625.00	mm	



Column Cross Section

Step-3-- **Determine first order moments**

Minimum eccentricity (eo)				
Along D (eoD)	=max (D/30,20)	20.00	mm	*Refer Cl.6.1 (4) ,BS EN 1992-1-1:2004*
along B (eoB)	=max (B/30,20)	20.00	mm	*Refer Cl.6.1 (4) ,BS EN 1992-1-1:2004*
Moment due to geometric imperfections				
θ1		0.00354	radian	*Refer Cl.5.2 (5) ,BS EN 1992-1-1:2004*
θ0	=1/200	0.005		*Refer Cl.5.2 (5) ,BS EN 1992-1-1:2004*
αn	= 2/sqrt(h) and 2/3 <= αn <= 1	0.707		*Refer Cl.5.2 (5) ,BS EN 1992-1-1:2004*
αm	=1 effect on isolated member	1.00		*Refer Cl.5.2 (6) ,BS EN 1992-1-1:2004*
Eccentricity ,(ei) (along both the directions)		8.87	mm	*lo is effective length of the column*

		Mgeo	Mdesign		
M01D at top node	=max((MtopD+ei*Ned),eoD*Ned)	21.637	-354.82	69.98	kNm
M02D at bottom node	=max((MbotD+ei*Ned),eoD*Ned)	23.322	71.66	-356.50	kNm
M01B at top node	=max((MtopB+ei*Ned),eo**B***Ned)	21.637	-318.39	-318.39	kNm
M02B at bottom node	=max((MbotB+ei*Ned),eoB*Ned)	23.322	-528.90	-528.90	kNm

Step-4 -- **Check for slenderness**

slenderness ratio (λ)					
Effective Length of colui	=(leffD*(Hd-min(Db1,Db2)))		5015	mm	
Effective Length of colui	=(leffB*(Hb-min(Bb1,Bb2)))		10875	mm	
i along D			173.41	mm	*radius of Gyratio of sectio Along D*
i along B			115.61	mm	*radius of Gyratio of sectio Along B*
along D	=3.46*loD/D	λD	28.92		*Refer Cl.5.8.3.2 ,BS EN 1992-1-1:2004*
along B	=3.46*loB/B	λB	94.069		*Refer Cl.5.8.3.2 ,BS EN 1992-1-1:2004*
					for circular column constant would be 4
Permissible limit for slenderness					
Along D					
ϕef	constant User Input		2.142		*Refer Eq.5.37 and CL 5.8.4,BS EN 1992-1-1:2004*
As est	for first iteration Ast of 0.8*B*D shall be considered		12,867.96	sqmm	*Ast provided in Column*
ω	=As est*fyd / (B*D*fcd)		0.62		
Mo1			48.34	kNm	
Mo2			333.18	kNm	
rm	ratio of Mo2/Mo1 |M02| >= |M01|		-0.15		
n			0.26		

A	constant		0.70			*Refer Cl.5.3.8.1 ,BS EN 1992-1-1:2004*
B	constant		1.499			*Refer Cl.5.3.8.1 ,BS EN 1992-1-1:2004*
C	=1.7-rm		1.85			
Along B						
ϕef	constant User Input		2.142			*Refer Eq.5.37 and CL 5.8.4,BS EN 1992-1-1:2004*
As est	for first iteration Ast of 0.8*B*D shall be considered		12,867.96		sqmm	*Ast provided in Column*
ω	=As est*fyd / (B*D*fcd)		0.6241			
Mo1			296.75		kNm	
Mo2			505.58		kNm	
rm	ratio of Mo2/Mo1 |M02| >= |M01|		-0.59			
n			0.2631			
A	constant		0.7001			*Refer Cl.5.3.8.1 ,BS EN 1992-1-1:2004*
B	constant		1.4994			*Refer Cl.5.3.8.1 ,BS EN 1992-1-1:2004*
C	=1.7-rm		2.2869			
along D	=20*A*B*C/sqrt(n)	ʎDlim	75.52			*Refer Cl.5.8.3.1 ,BS EN 1992-1-1:2004*
along B	=20*A*B*C/sqrt(n)	ʎBlim	93.61			*Refer Cl.5.8.3.1 ,BS EN 1992-1-1:2004*
along D	=IF(ʎD<ʎDlim,"non slender","slender")		**Non-slender**			
along B	=IF(ʎB<ʎBlim,"non slender","slender")		**Slender**			

<u>Step-4a--</u> Determine Kr

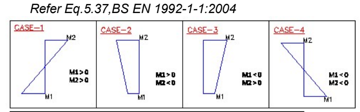
Deff for slenderness		d slender	1.00	mm	*User input (D/2+is) clause 5.8.8.3 (2)*
Beff for slenderness		b slender	206.32	mm	*User input (D/2+is) clause 5.8.8.3 (2)*
					Refer Cl.5.8.8.3,BS EN 1992-1-1:2004
As est	for first iteration Ast of 0.8*B*D shall be considered		12,867.96	sqmm	*Assumed value*
n	=Ned/(B*D*fcd)		0.26		*Refer Eq.5.36,BS EN 1992-1-1:2004*
ω	=As est*fyd / (B*D*fcd)		0.62		*Refer Eq.5.36,BS EN 1992-1-1:2004*
nu	=1+ω		1.62		*Refer Eq.5.36,BS EN 1992-1-1:2004*
nbal	constant		0.40		*Refer Eq.5.36,BS EN 1992-1-1:2004*
Kr	=min((nu-n)/(nu-nbal)),1)		1.00		*Refer Eq.5.36,BS EN 1992-1-1:2004*

Step-4b **Determine Kφ**

				Refer Eq.5.37,BS EN 1992-1-1:2004
ωef	constant - Along D	2.142		*Refer Eq.5.37 and CL 5.8.4,BS EN 1992-1-1:2004*
ωef	constant -Along B	2.142		*Refer Eq.5.37 and CL 5.8.4,BS EN 1992-1-1:2004*
βD	=0.35+fck/200-ʎD/150	0.407		*Refer Eq.5.37,BS EN 1992-1-1:2004*
βB	=0.35+fck/200-ʎB/150	-0.027		*Refer Eq.5.37,BS EN 1992-1-1:2004*
KφD	=max((1+βD*ωef),1)	1.87		*Refer Eq.5.37,BS EN 1992-1-1:2004*
KφB	=max((1+βB*ωef),1)	1.00		*Refer Eq.5.37,BS EN 1992-1-1:2004*

Step-4c

1/r0 along D	fyd/(0.45*(Deff slender)*Es	0.01		
1/r0 along B	fyd/(0.45*(Beff slender)*Es	2.61191E-05		
1/r along D	Kr x kφ Dx (1/r0) along D	0.010089211		
1/r along B	Kr x kφB x (1/r0) along B	2.61191E-05		
Determine e2D	=0.1*(Kr*KφD*fyd/(0.45*(Deff slender)*Es))*lo^2 -	25374.593	mm	*Refer Eq.5.33,BS EN 1992-1-1:2004*
Determine e2B	=0.1*(Kr*KφB*fyd/(0.45*(Beff slender)*Es))*lo^2	308.899	mm	*Refer Eq.5.37,BS EN 1992-1-1:2004*

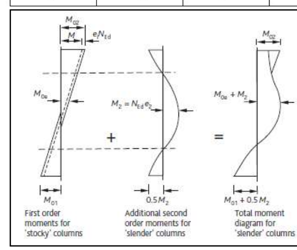


Step-4d-- **Determine final design moments for slenderness effect:**

Along B

MoeB	= 0.6 x M02 + 0.4 x M01 >= 0.4 x M02	moment due to 1st oredr	-211.56	kNm
M2B	= e2B x Ned	moment due to 2nd order	812.60	kNm
total mid moment,along B	=MoeB + M2B		-1,024.16	kNm

along B		
along B (top)	**724.69**	kNm
along B (Bottom)	**935.20**	kNm



slenderness moments shall be replaced to moments calculated in flexure design if column is slender

Med= max (M02,Moe+M2, M01+0.5M2) i.e. max top,mid and bottom section (refer sketch 02)
note: design of column shall be at three section. i.e. top,mid and bottom
at each section combination of moment along D and B shall be considered and Ast shall be find out
critical of three sections shall be considered for design

Step-5
Final Moments

along D (top)	354.82	kNm	*A member shall be designed for top and bottom moments along B and D*
along D (bottom)	71.66	kNm	*Combination of moment along B and D at respetive end shall be considered for design*
along B (top)	724.69	kNm	*and critical moments of the top and bottom shall be considred as final desgn moments*
along B (Bottom)	935.20	kNm	

Step-6 **Bia-axial bending**

ʎD/ʎB		0.30743		*Refer Cl.5.8.9 Eq 5.38a ,BS EN 1992-1-1:2004*
ʎB/ʎD		3.2527		*Refer Cl.5.8.9 Eq 5.38a ,BS EN 1992-1-1:2004*
eD (top)	= M-design_D / Ned (top)	134.878	mm	
eD (bot)	= M-design_D / Ned (bottom)	27.241	mm	
eB (top)	= M-design_B / Ned (top)	275.480	mm	
eB (bot)	= M-design_B / Ned (bottom)	355.504	mm	
(eD top/D)/(eB top/B)		0.33		*Refer Cl.5.8.9 Eq 5.38b ,BS EN 1992-1-1:2004*
(eB top/B)/(eD top/D)		3.06		*Refer Cl.5.8.9 Eq 5.38b ,BS EN 1992-1-1:2004*
(eD bot/D)/(eB bot/B)		0.05		*Refer Cl.5.8.9 Eq 5.38b ,BS EN 1992-1-1:2004*
(eB bot/B)/(eD bot/D)		19.58		*Refer Cl.5.8.9 Eq 5.38b ,BS EN 1992-1-1:2004*
Check for Bi-axial bending		Consider Biaxial		*Refer Cl.5.8.9 ,BS EN 1992-1-1:2004*

Step-8

Detailing Requirements

Longitudinal reinforcement

Minimum diameter of longitudinal reinforcement	Ø min	10	mm	*Refer Cl.9.5.2 (1) ,BS EN 1992-1-1:2004 + MS NA*
Minimum area of longitudinal reinforcement		542.4	sqmm	*Refer Cl.9.5.2 (2) ,BS EN 1992-1-1:2004 + MS NA*
Maximum area of longitudinal reinforcement		9600	sqmm	*Refer Cl.9.5.2 (3) ,BS EN 1992-1-1:2004 + MS NA*
Maximum spacing of longitudinal reinforcement		150	mm	*Refer Cl.9.5.3 (6) ,BS EN 1992-1-1:2004 + MS NA*
Transverse reinforcement				
Minimum diameter of transverse reinforcement		8	mm	*Refer Cl.9.5.3 (1) ,BS EN 1992-1-1:2004 + MS NA*
maximum Spacing of transverse reinforcement	=MIN (20x dia of main bar,B, 400mm)	400	mm	*Refer Cl.9.5.3 (3) ,BS EN 1992-1-1:2004 + MS NA*
Maximum Spacing of transverse reinforcement in lap joint	=if main bar dia >14mm then spacing shall be multliplied with 0.6	240	mm	*Refer Cl.9.5.3 (4) ,BS EN 1992-1-1:2004 + MS NA*

Step-9

Ductility Class Medium (DCM)

Minimum concrete Grade		C25/30		*Refer Cl.5.4.1.1 (1),BS EN 1998-1:2004 (E)*
Seismic detailing				
Minimum % longitudinal reinforcement	ρ1	1	%	*Refer Cl.5.4.3.2.2 (1) ,BS EN 1998-1:2004 (E)*
Maximum % longitudinal reinforcement	ρ2	4	%	*Refer Cl.5.4.3.2.2 (1) ,BS EN 1998-1:2004 (E)*
Zone for ductile links				
Max of (D,Lo/6,450) and if (Lo/d<3, full height)	z1	835.8333333	mm	*Refer Cl.5.4.3.2.2 (4)(6) ,BS EN 1998-1:2004 (E)*
Volume of confining hoops				*Refer Cl.5.2.3.4 (3) ,BS EN 1998-1:2004 (E)*
diameter of link		8	mm	*(assumed for further calculations)*
dbL	(minimum dia of longitudinal reinf. After detailing)	12	mm	*Refer Cl.5.2.3.4 (11) Eq 5.18 ,BS EN 1998-1:2004 (E)*
Volume of confining link per m		1,649.48	sqmm/m	*Refer Cl.5.2.3.4 (8) ,BS EN 1998-1:2004 (E)*
ωwd	=(30*μΦ*Vd*εsyd*(bc/bo)-0.035)/α	0.080000		*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
Type of column		Rectangular		
α=αn * αs		0.75		*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
αn	for rec (1-bi^2/(6*bo*h*)) and for circular (1)	0.98		*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
αs	for rec (1-(s/(2*bo)/(1-(s/2*ho))	0.76		*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
bc	column width	400.00	mm	*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
hc	column depth	600.00	mm	
bo	(column width-2*cover+ dia. Of link)	308.00	mm	*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
s	=min(bo/2,175,8*dbL)	96.00	mm	*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
ho=Do		508.00	mm	*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
bi	(as per actual detailing of the longitudinal reinforcement)	150	mm	*Refer Cl.5.4.3.2.2 (8) ,BS EN 1998-1:2004 (E)*
μΦ	=value assumed	1.100		*Refer Cl.5.4.3.2.2 ,BS EN 1998-1:2004 (E)*
Vd	=Ned /(Ac*fcd)	0.26		*Refer Cl.5.4.3.2.2 ,BS EN 1998-1:2004 (E)*
εsyd	=value assumed (design of of tension steel strain)	0.0025		*Refer Cl.5.4.3.2.2 ,BS EN 1998-1:2004 (E)*