Banha University
Faculty of Engineering - Shoubra
Civil Engineering Department

REINFORCED CONCRETE 1 - B

For 2nd Year Civil – 2nd Term

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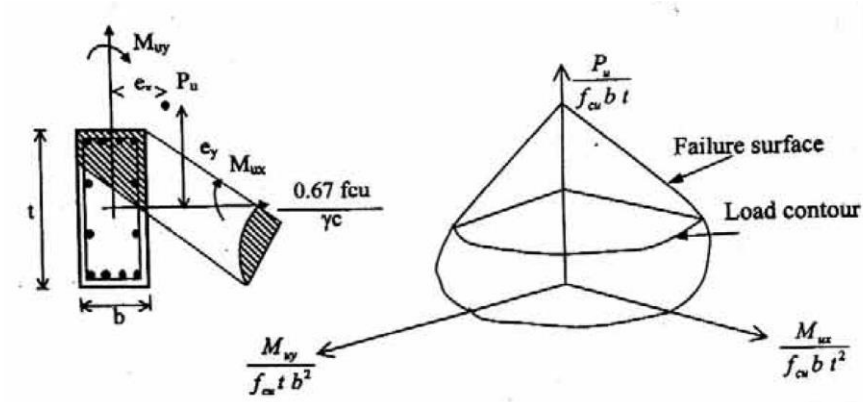
Chapter (4)

Column Sections Under Biaxial Bending

Chapter 4 Column Sections Under Biaxial Bending

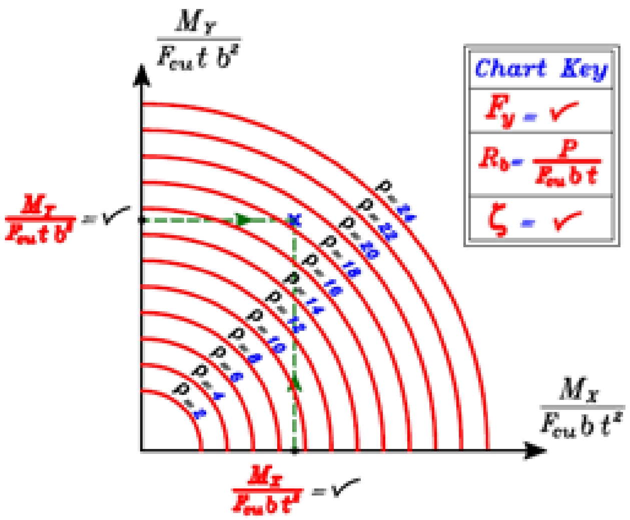
1- Biaxially Loaded Columns- Biaxial Interaction Diagram Method

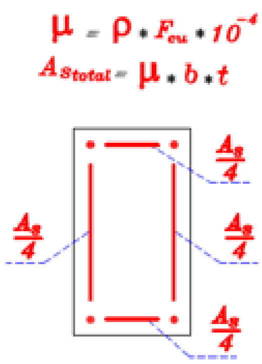
1- Using numerical integration, the force and moment in the concrete zone are determined by integrating the nonlinear idealized stress-strain curve for concrete in compression. 3-D failure surfaces are drawn for the column. The biaxial interaction diagrams (curves) are produced by cutting a horizontal plan R_b (load contour) through the failure surface as shown in the figure.



2- The use of these interaction curves is as follows:

- Determine the curve using the calculated of $\{f_y, R_b, (M_y / f_{cu}\, tb^2), (M_x / f_{cu}\, bt^2), \xi\}$
- From the design ID, get μ, ρ and calculate $A_{s\ total} = \mu * b * t$
- $A_{s\ total}$ (**$\geq A_{smin}$ = 0.006 bt**) is distributed equally on the four sides.





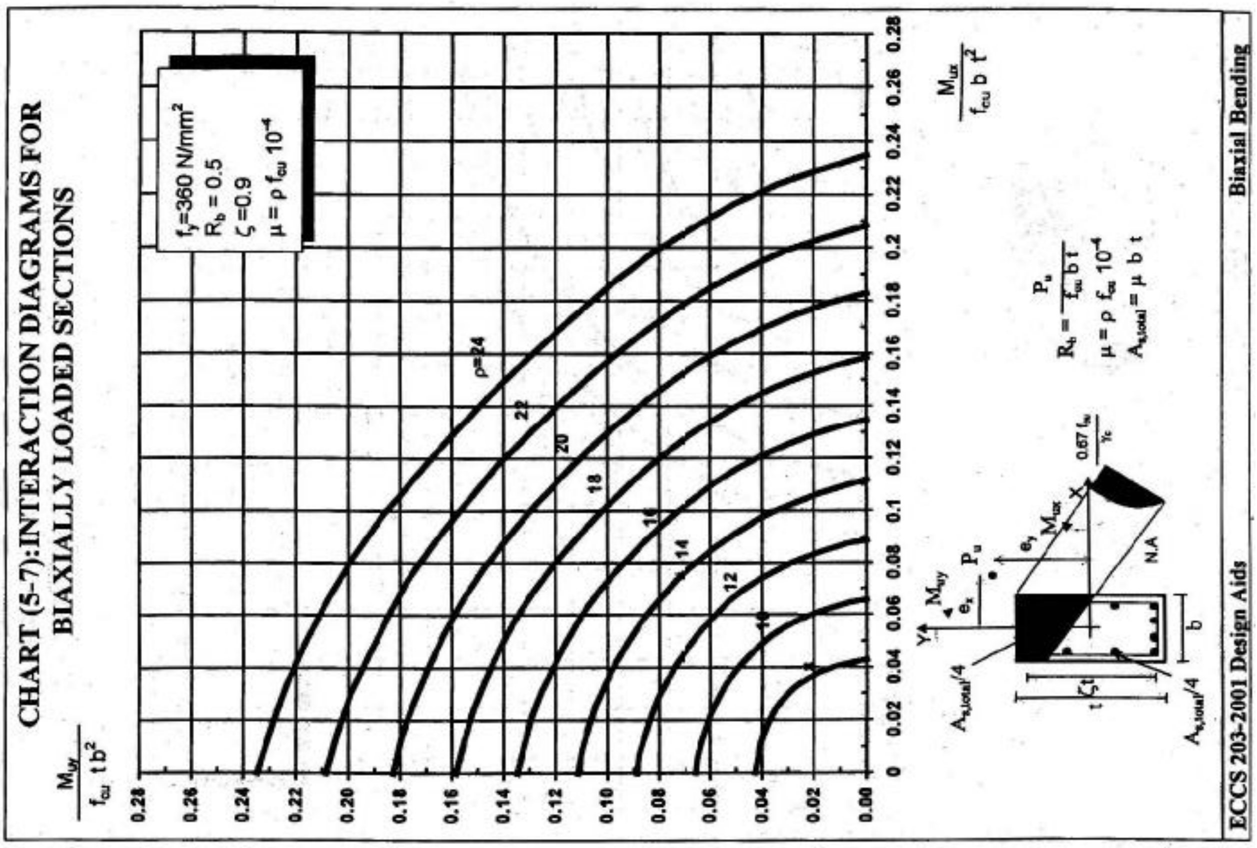


CHART (5-7):INTERACTION DIAGRAMS FOR BIAXIALLY LOADED SECTIONS
f_y=360 N/mm^2
R_b = 0.5
ζ =0.9
$\mu = \rho\ f_{cu}\ 10^{-4}$
$\frac{M_{uy}}{f_{cu}\ t\ b^2}$
$\frac{M_{ux}}{f_{cu}\ b\ t^2}$
$R_b = \frac{P_u}{f_{cu}\ b\ t}$
$\mu = \rho\ f_{cu}\ 10^{-4}$
$A_{s,total} = \mu\ b\ t$
ρ=24
22
20
18
14
12
0.67 f_{cu} / γ_c
N.A
$A_{s,total}/4$
ECCS 203-2001 Design Aids
Biaxial Bending

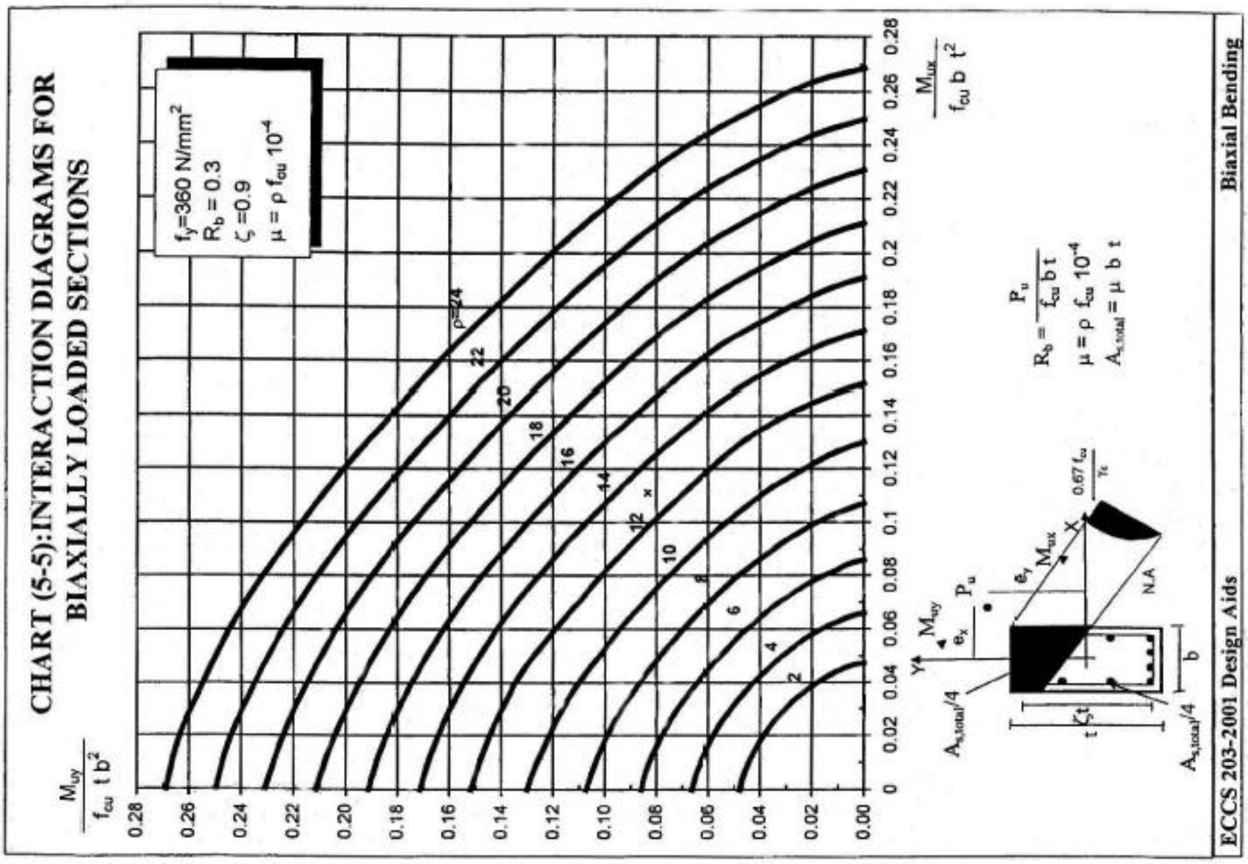


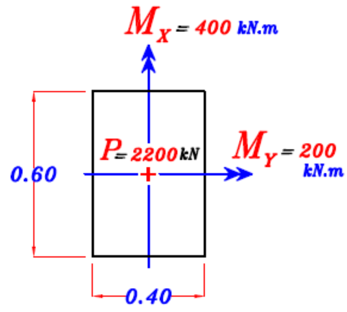
CHART (5-5):INTERACTION DIAGRAMS FOR BIAXIALLY LOADED SECTIONS
f_y=360 N/mm^2
R_b = 0.3
ζ =0.9
$\mu = \rho\ f_{cu}\ 10^{-4}$
$\frac{M_{uy}}{f_{cu}\ t\ b^2}$
$\frac{M_{ux}}{f_{cu}\ b\ t^2}$
$R_b = \frac{P_u}{f_{cu}\ b\ t}$
$\mu = \rho\ f_{cu}\ 10^{-4}$
$A_{s,total} = \mu\ b\ t$
ρ=24
22
20
18
16
14
12
10
6
4
2
0.67 f_{cu} / γ_c
N.A
$A_{s,total}/4$
ECCS 203-2001 Design Aids
Biaxial Bending

2- Biaxial Design Example for the Biaxial Interaction Diagrams

Design the shown rectangular section if

f_{cu}= 25 MPa & f_y= 360 MPa, P_u = 2200 kN,

M_{xu} = 400 m.kN, My = 200 m.kN



assume $\zeta = 0.90$ --------- ECCS لا توجد قيمه غيرها فى ال

$$R_b = \frac{P}{F_{cu}\, b\, t} = \frac{2200 * 10^3}{25 * 400 * 600} = 0.366 \longrightarrow \text{Not in ECCS}$$

لانه لا توجد قيمه ل R_b=0.366 فى كتاب ECCS فيتم حساب قيمتين ل ρ

مره عند R_b= 0.30 و مره عند R_b= 0.40 ثم أخذ قيمه لل ρ بينهم

For $R_b = 0.30 \longrightarrow$ ECCS Page (5-13)

$$\frac{M_X}{F_{cu}\, b\, t^2} = \frac{400 * 10^6}{25 * 400 * 600^2} = 0.111$$

$$\frac{M_Y}{F_{cu}\, t\, b^2} = \frac{200 * 10^6}{25 * 600 * 400^2} = 0.083$$

$\Big\}\ \rho = 11.8$

For $R_b = 0.40 \longrightarrow$ ECCS Page (5-14)

$$\frac{M_X}{F_{cu}\, b\, t^2} = \frac{400 * 10^6}{25 * 400 * 600^2} = 0.111$$

$$\frac{M_Y}{F_{cu}\, t\, b^2} = \frac{200 * 10^6}{25 * 600 * 400^2} = 0.083$$

$\Big\}\ \rho = 15$

نأخذ ρ قيمه بينهم

To get value of ρ For $R_b = 0.366$

$R_b = 0.30 \longrightarrow \rho = 11.8$

$R_b = 0.40 \longrightarrow \rho = 15$

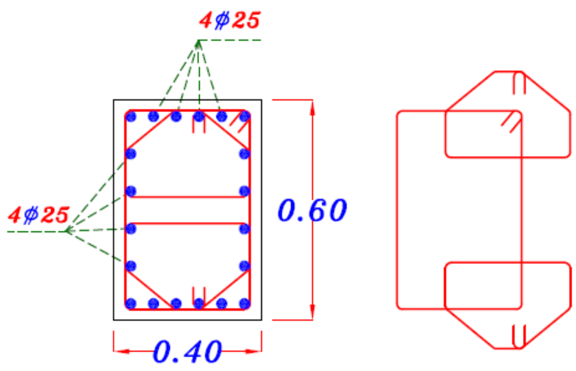
$\rho = 13.4$ نأخذ قيمه بينهم

$$\mu = \rho * F_{cu} * 10^{-4} = 13.4 * 25 * 10^{-4} = 0.0335$$

$$A_{S\,total} = \mu * b * t = 0.0335 * 400 * 600 = 8040\ mm^2$$

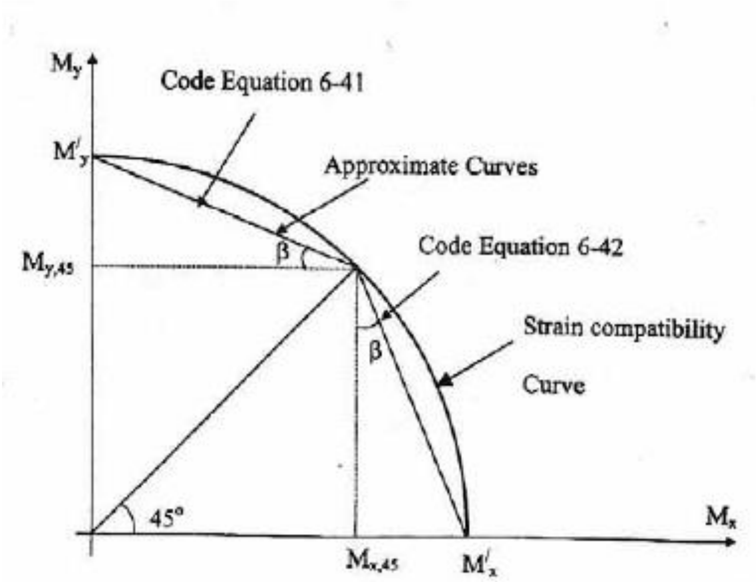
$$-\ \text{Check } A_{s_{min.}} = \frac{0.6}{100} * b * t = \frac{0.6}{100} * 400 * 600 = 1440\ mm^2$$

$$A_S = A_{S\,total} = 8040\ mm^2 \quad 20\phi25$$



3- Biaxially Loaded Columns- ECP Code Method

1- ECP offers a simplified method for the case of a R-section with symmetrical reinforcement by approximating the curved shape of biaxial I.D. by two straight lines as shown in the figure. The biaxial state is transferred to a case of uniaxial eccentric compression.



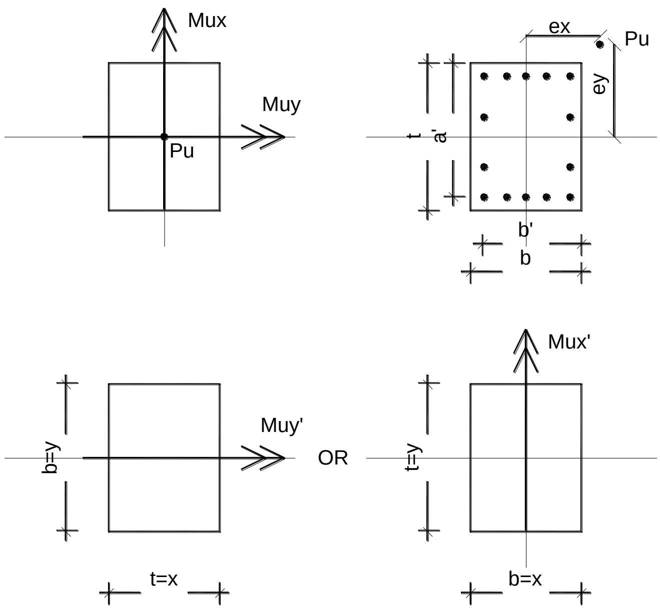
2- If the column section under P_u, M_{ux} & M_{uy} not given, assume the section as follows:

$e_y = M_{ux} * 10^6 / (P_u * 10^3)$ $\qquad$ $e_x = M_{uy} * 10^6 / (P_u * 10^3)$

If $e_x = e_y$ take $x = y$ square sec.

If $e_x > e_y$ take $x > y$ R-sec.

If $e_y > e_x$ take $y > x$ R-sec.



Case (2)   Case (1)

3- In case of rectangular or square columns sections with equal steel on its faces (uniform steel arrangement), then design moments can be reduced into an equivalent uniaxial moment as given below. (Consider **$a' = y - 50$ mm, $b' = x - 50$ mm** as shown in the figure)

4- Case (1): If $M_{ux} / a' > M_{uy} / b'$

then design the section for P_u & $M'_{ux} = (M_{ux} + \beta\,(a'/b')\,M_{uy})$ using I.D. of uniaxial bending

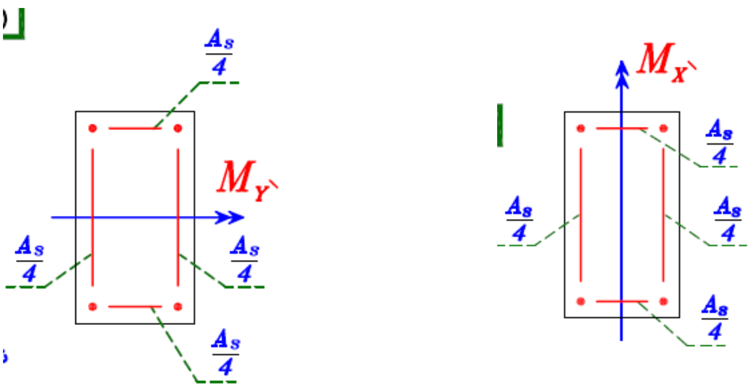
5- Case (2): If $M_{ux} / a' \leq M_{uy} / b'$

then design the section for P_u & $M'_{uy} = (M_{uy} + \beta\,(b'/a')\,M_{ux})$ using I.D. of uniaxial bending.

<u>Table for values of the coefficient β :-</u>

$P_u*10^3/(f_{cu}\,bt)$	≤ 0.2	0.3	0.4	0.5	≥ 0.6
β	0.80	0.75	0.70	0.65	0.60

6- The calculated steel area from I.D. **$A_{s\ total} \geq A_{s\ min}$ (= 0.006 bt)**



<u>4- Biaxial Design Example ECP Code Method (Case 1)</u>

<u>Given:</u> f_{cu} = 25 MPa , f_y = 360 MPa , d` = 50 mm

$P_{D.L.}$ = 1000 kN , $P_{L.L.}$ = 1500 kN

$M_{X\ D.L.}$ = 400 kN.m , $M_{X\ L.L}$ = 500 kN.m

$M_{Y\ D.L.}$ = 200 kN.m , $M_{Y\ L.L}$ = 300 kN.m

<u>Required:</u> Design the column section

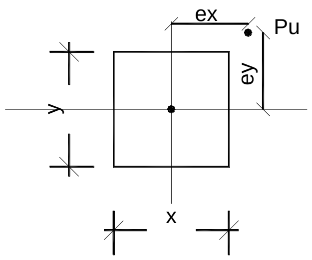
$P_u = 1.4\,P_{D.L} + 1.6\,P_{L.L} = 3800$ kN   where $P_{L.L} > 0.75\,P_{D.L}$

$M_{ux} = 1.4\,M_{X\ D.L} + 1.6\,M_{X\ L.L} = 1360$ kN.m   where $M_{X\ L.L} > 0.75\,M_{X\ D.L}$

M_{uy} = 1.4 $M_{Y\,D.L}$ + 1.6 $M_{Y\,L.L}$ = 760 kN.m where $M_{Y\,L.L}$ > 0.75 $M_{Y\,D.L}$

$e_y = M_{ux} * 10^6 / (P_u * 10^3)$ = 357.9 mm

$e_x = M_{uy} * 10^6 / (P_u * 10^3)$ = 200.0 mm



Assume square or rectangular section

If $e_x = e_y$ take x = y square sec.

If $e_x > e_y$ take x > y R-sec.

If $e_y > e_x$ take y > x R-sec.

Assume x = 800 mm , y = 1000 mm ($e_y > e_x$)

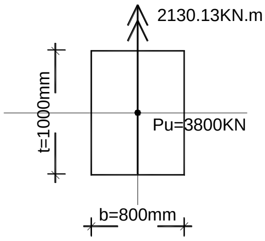
a` = t – d` = 1000 – 50 = 950 mm, b` = b – d` = 800 – 50 = 750 mm

M_{ux} / a` = 1.432, $M_{uy}$ / b` = 1.013

M_{ux} / a` > $M_{uy}$ / b` then $M`_{ux} = M_{ux} + \beta\, (a`/b`)\, M_{uy}$

$P_u*10^3/(f_{cu}\, bt)$ = 0.19 , then β = 0.8 from the previous table

$M`_{ux}$ = 1360 + 0.8 * (950 / 750) * 760 = 2130.13 kN.m



Then design a column as shown in the Figure

$e = M`_{ux} * 10^6 / (P_u * 10^3)$ = 560.6 mm

e / t = 0.561 (1)

$K = P_u * 10^3 / (f_{cu}\, b\, t)$ = 3800 * 10^3 / (25 * 800 * 1000) = 0.19 (2)

For f_y = 360 MPa (uniform steel arrangement)

and ξ = (t – 2d’) / t = (1000 – 2*50) / 1000 = 0.9 then use chart No. …..

From the chart get ρ = 5.2

$\mu = \rho\ f_{cu} * 10^{-4}$ = 0.013 = 1.3 %

A_s = μ b t = 10400 mm^2 (use 24 Φ 25)

Distribute the steel uniformly over the section