Design of Sections Subjected to M,N

Bending Moment & Compression Force.

Steps of Design :

1 – Get Dimensions of the section. $(b \times t)$

2 – Get Reinforcement $A_s , A_{s'}$

نسألكم الدعاء

Solution:

1 – Get Dimensions of the section. $(b \times t)$

Take $b = (25 \text{ cm} \longrightarrow 40 \text{ cm})$

To get t get the bigger value of t_1 (Bending) , t_2 (Normal)

– Get $d_1 = C_1 \sqrt{\dfrac{M_{U.L.}}{F_{cu}\, b}}$ take $C_1 = 3.5$, $J = 0.78$ (as R–Sec.)

$t_1 = d_1 + \text{cover}$ where cover $= 5.0$ cm IF $t \leqslant 100$ cm

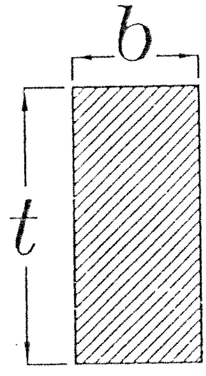
$= 10$ cm IF $t > 100$ cm

– Get $t_2 \xrightarrow{\text{Take}} \mu = \dfrac{A_s}{b\,t_2} = 1.0\,\% \longrightarrow A_s = \dfrac{b\,t_2}{100}$

From $P_{U.L.} = 0.35\, A_c\, F_{cu} + 0.67\, A_s\, F_y$

$\therefore P_{U.L.} = 0.35\; b\, t_2\, F_{cu} + 0.67\; \dfrac{b\,t_2}{100}\; F_y$

$\therefore \boxed{P_{U.L.} = \left(0.35\; b\; F_{cu} + 0.67\, \dfrac{b}{100}\, F_y\right) t_2}$



– t_o = The bigger value of t_1 & t_2

– $t = (1.1 \rightarrow 1.3)\; t_o$

Check:

√√ 1- IF $K = \frac{N_{U.L.}}{F_{cu}\, b\, t} \leqslant 0.04 \longrightarrow$ neglect $N_{U.L.}$

and Design the Sec. on B.M. only as Beams.

$\therefore\ d = d_1 = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}}$ take $C_1 = 3.5$, $J = 0.78$ (R-Sec.)

take $C_1 = 6.0$, $J = 0.826$ (T-Sec. , L-Sec.)

ملحوظة هامة :

فى بداية التصميم نعمل تصميم على M, N على أن القطاع R-sec.

و لكن اذا أهملنا الـ N فنعمل تصميم على M فقط فيجب مراعاه

اذا كان القطاع R-sec. or T-sec.

Then get $\boxed{e = \frac{M_{U.L.}}{N_{U.L.}}}$

2- IF $\frac{e}{t} \leqslant 0.05 \longrightarrow$ neglect $M_{U.L.}$

and Design the Sec. on N.F. only as Columns.

$P_{U.L.} = 0.35\, A_c\, F_{cu} + 0.67\, A_s\, F_y$ Take $\mu = 1.0\ \%$

$\therefore\ P_{U.L.} = 0.35\, A_c\, F_{cu} + 0.67\, \frac{A_c}{100}\, F_y$

Get A_c , A_s

2- Get Reinforcement A_s, A_s'

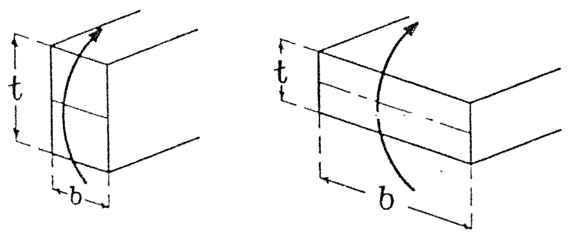
- IF $K = \frac{N_{U.L.}}{F_{cu}\, b\, t} > 0.04$ Design the Sec. on both N.F. , B.M.

Use Interaction Diagram

ECCS Page (4-20) → (4-63)

Interaction Diagram. (I.D.)

t هو العرض الموازى لل moment



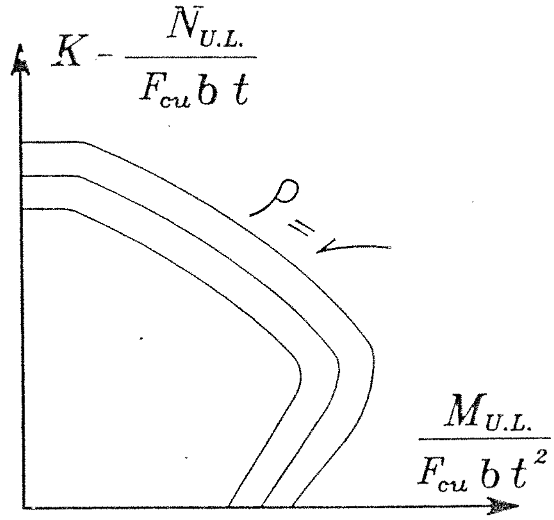


Chart Key مفتاح الجدول

يوجد فى كل صفحة من صفحات ال .I.D فى الجداول
مفتاح للجدول لتحديد أى جدول سوف نستخدمة

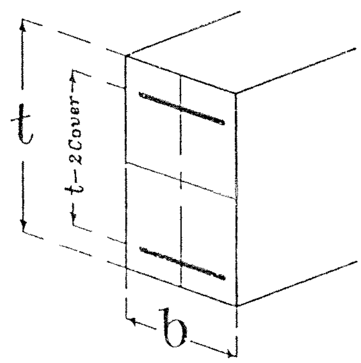
Chart Key

$F_y = \checkmark$
$\xi = \checkmark$
$\alpha = \frac{A_s'}{A_s} = 1$

- F_y = Type of Steel: 240, 280, 360, 400

- $\alpha = \frac{A_s'}{A_s}$: 0.8, 1.0 ✓✓ — نسبة تحدد قبل بدء ال Design و تؤخذ عاده تساوى ١

- $\xi = \frac{t - 2\,Cover}{t} = \frac{\text{المسافة بين الحديد}}{\text{التخانة الكلية}}$ و تقرب للرقم الأصغر



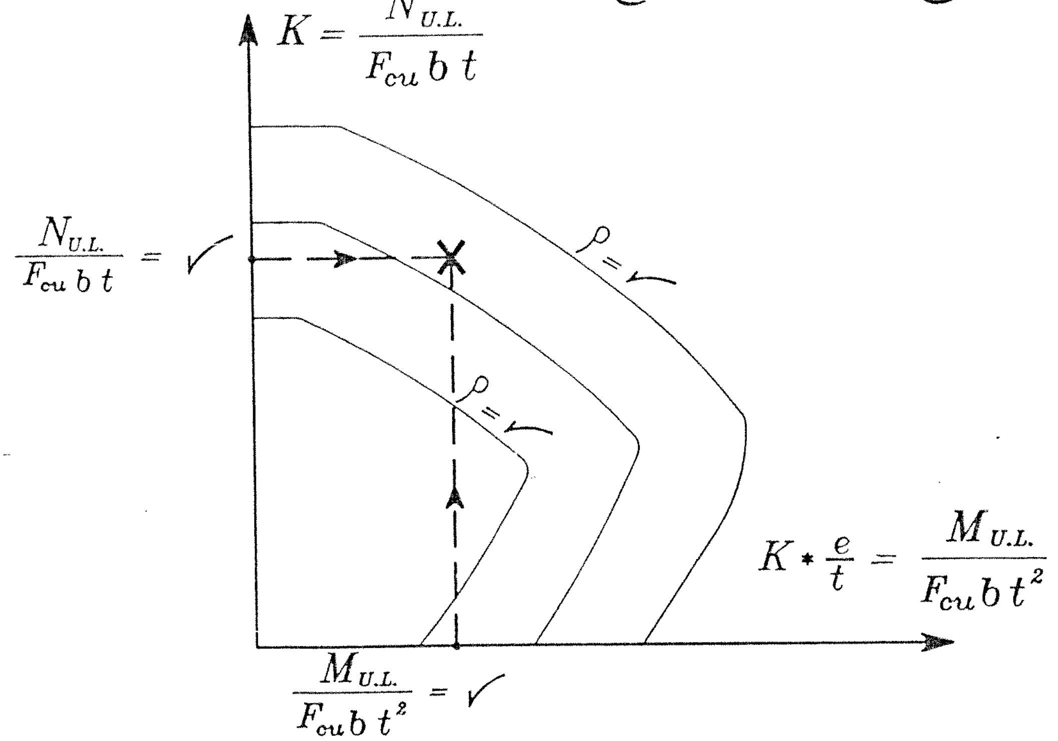
Example: $t = 80$ cm

$$\therefore \xi = \frac{80-10}{80} = \frac{70}{80} = 0.875 \xrightarrow{Take} \xi = 0.8$$

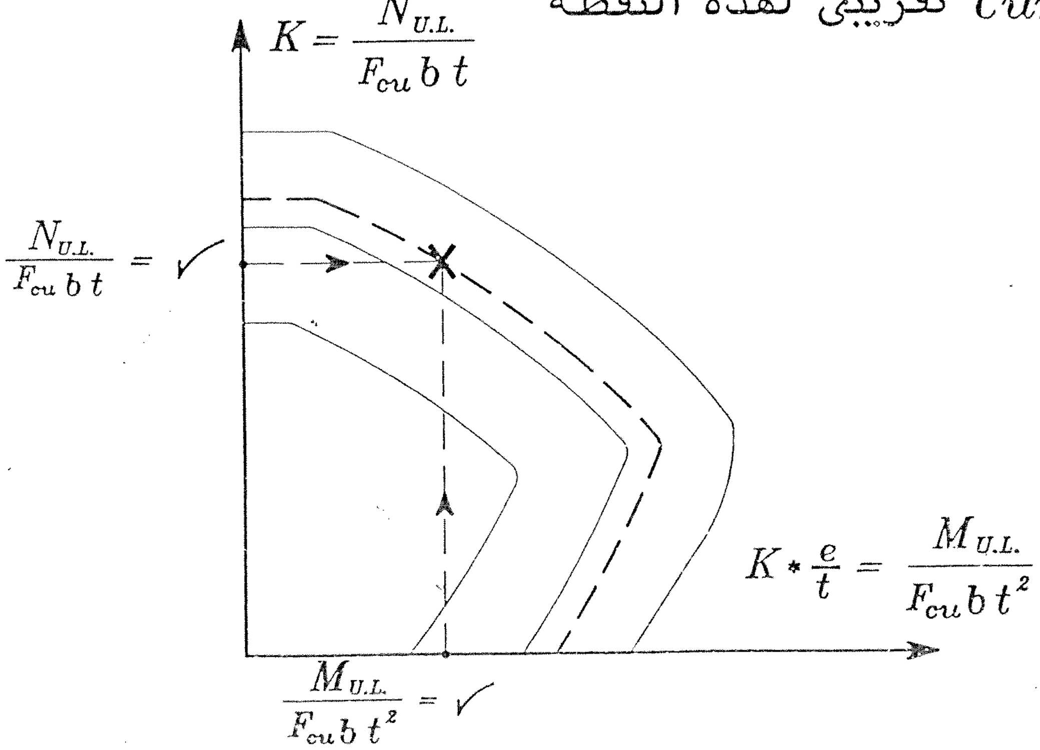
١- بعد تحديد الـ Curve بمعرفة كل من F_y , ξ , α

٢- نحدد قيمة كل من $K = \dfrac{N_{U.L.}}{F_{cu}\, b\, t}$, $K * \dfrac{e}{t} = \dfrac{M_{U.L.}}{F_{cu}\, b\, t^2}$

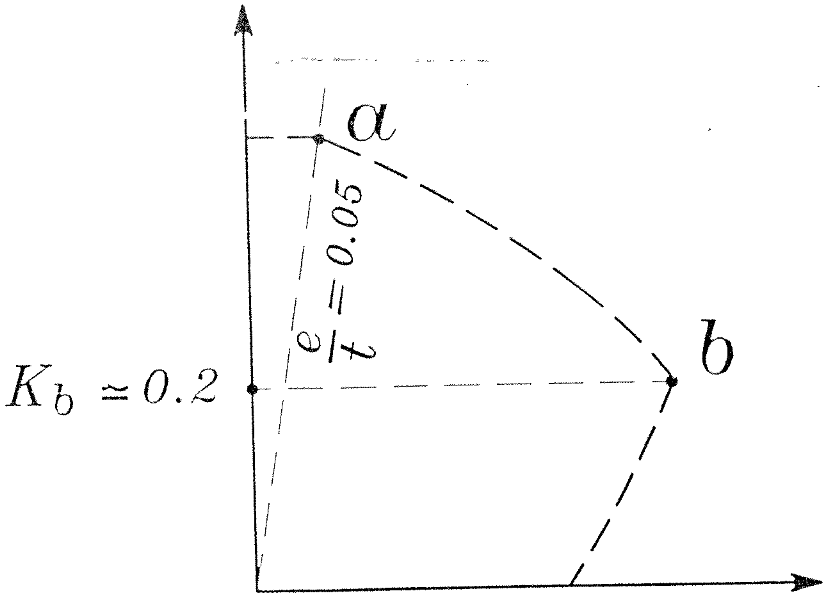
ثم نحدد نقطة التقاطع كما هو موضح



٣- ثم نرسم Curve تقريبى لهذه النقطة



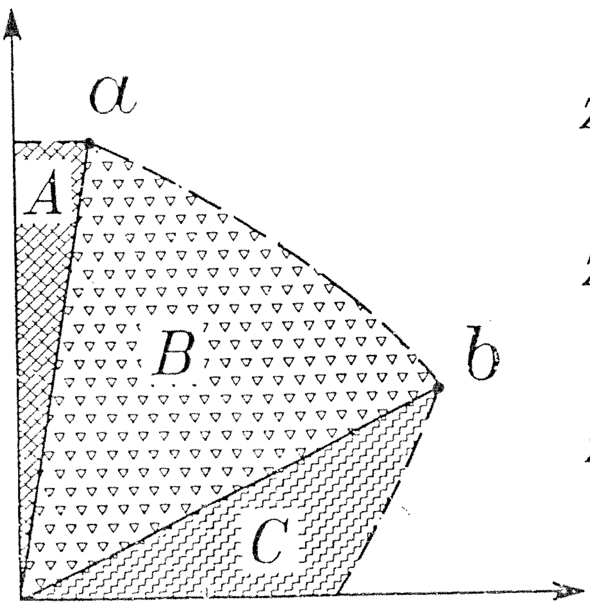
٤ـ نحدد النقطتين a , b على هذا الـ $Curve$
كما هو موضح بالشكل



$$K_b = K_{balanced}$$
$$K_b = \frac{N_b}{F_{cu}\, b\, t} \simeq 0.2$$

حيث a هى نقطة $min\ eccentricity$
و عند هذه النقطة تكون $\frac{e}{t} = 0.05$
و نقطة b هى نقطة الـ $Balanced\ Failure$

٥ـ من النقطتين a , b نوصل خطين الى نقطة الـ $origin\ (0,0)$
و نقسم المساحة الى $Zones$
و نحدد طريقة الـ $Design$

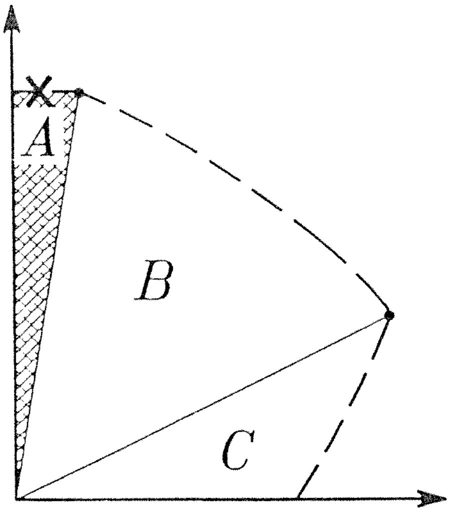


Zone A $\longrightarrow$ Design as Short Column

Zone B $\longrightarrow$ Design as Compression Failure

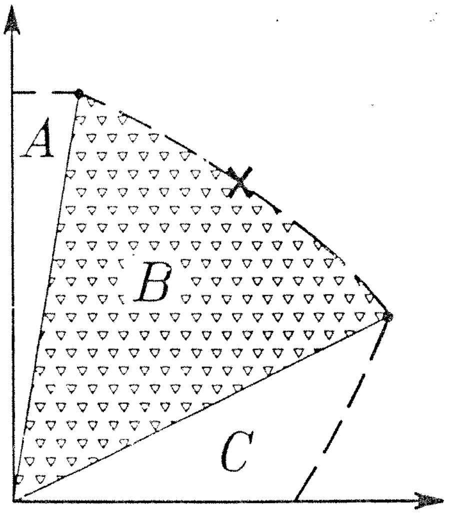
Zone C $\longrightarrow$ Design as Tension Failure

بعد تحديد نقطة تقاطع $K = \dfrac{N_{U.L.}}{F_{cu}\, b\, t}$, $K * \dfrac{e}{t} = \dfrac{M_{U.L.}}{F_{cu}\, b\, t^2}$



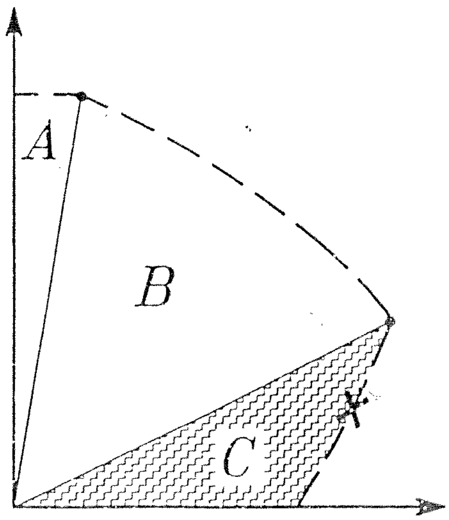
عند وجود نقطة التقاطع عند *Zone A*
ل وجود ال *moment* و نصمم على
ال *Normal* فقط

Design as Short Column using $P_{U.L.}$



عند وجود نقطة التقاطع عند *Zone B*
يكون أغلب القطاع علية *Compression*

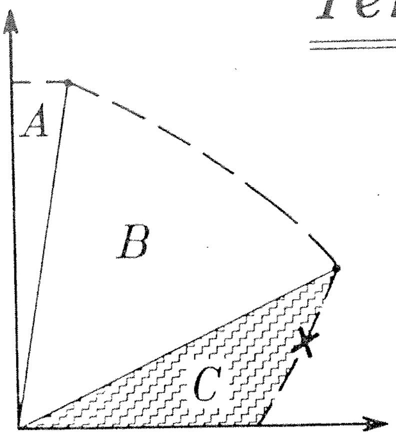
Design as Compression Failure using Interaction Diagram



عند وجود نقطة التقاطع عند *Zone C*
يكون أغلب القطاع علية *Tension*

Design as Tension Failure using e_s

Tension Failure (as Beams)



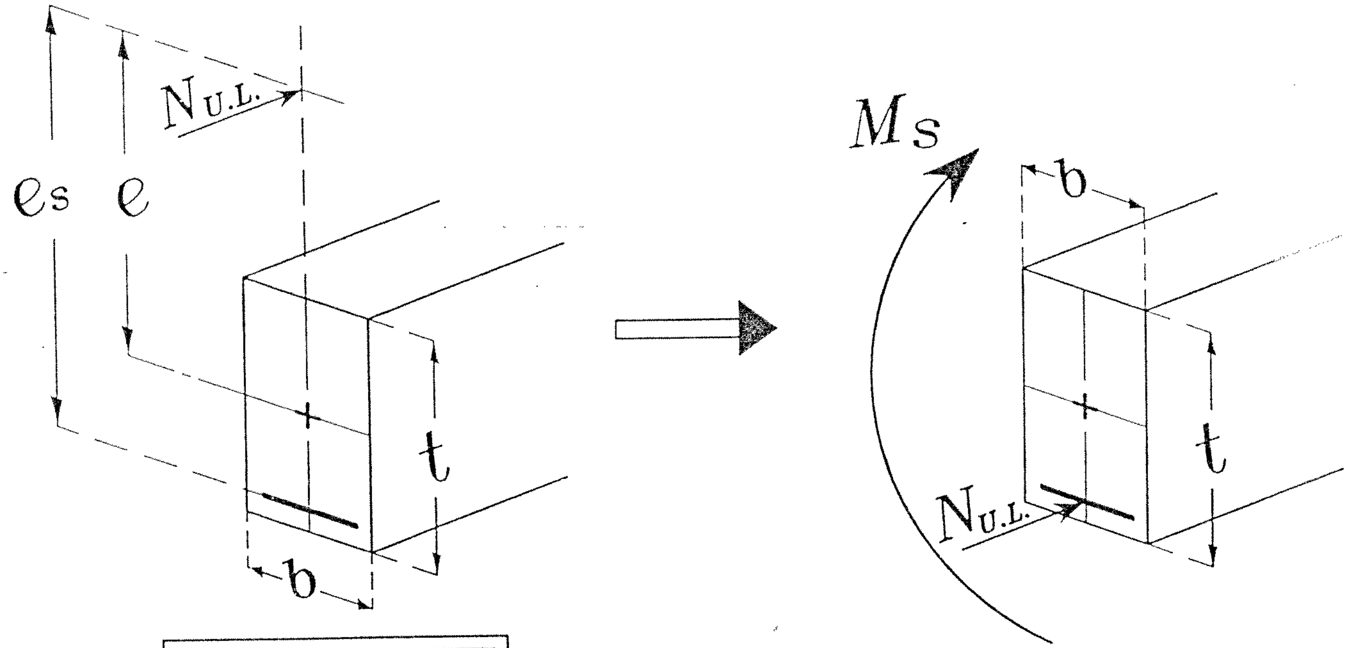
عند وجود نقطة التقاطع عند Zone C

يكون أغلب القطاع علية Tension

Design as Tension Failure

القطاع أقرب لقطاع الكمره منة لقطاع العمود .

أى أن جهة من الخرسانة عليها Compression و جهة عليها Tension .



Get $\boxed{e = \dfrac{M_{U.L.}}{N_{U.L.}}}$

Get $\boxed{e_s = e + \dfrac{t}{2} - c}$

حيث e هى بعد المحصلة عن ال C.G.

حيث e_s هى بعد المحصلة عن ال steel

Where: C is the Cover $\begin{cases} = 5 \text{ cm} & \text{IF } t \leqslant 100 \text{ cm} \\ = 10 \text{ cm} & \text{IF } t > 100 \text{ cm} \end{cases}$

– Get the moment about Tension steel

$$\boxed{M_s = N_{U.L.} * e_s}$$

– From $d = C_1 \sqrt{\dfrac{M_s}{F_{cu}\, b}}$ Get $C_1 = \checkmark \xrightarrow{get} J = \checkmark$

– Get A_s From

$$\boxed{A_s = \frac{M_s}{J\, F_y\, d} - \frac{N_{U.L.}}{(F_y/\gamma_s)}}$$

Stirrup Hangers.

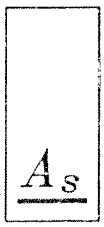
Stirrup Hangers = $\left.\begin{array}{l} (0.1 \rightarrow 0.2)\, A_s \\ 2\phi 13 \quad \text{Frames} \end{array}\right\}$ الأكبر

ملحوظة :
سواء كان الـ member أفقى أو رأسى يعامل معاملة الكمره
ولكن يفضل أن لا يقل الـ stirrup hangers فى الـ members
الرأسية عن $0.4\, A_s$ و هذا ليس شرط.

– Check $A_{s_{min.}}$

Compare with tension steel only

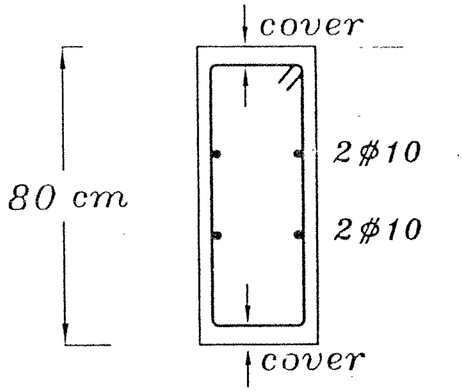
$$\left.\begin{array}{l} \left.\begin{array}{l} A_{s_{min.}} = \dfrac{11}{F_y}\, b\, d \\ 1.3\, A_{s_{req.}} \end{array}\right\} \text{الأقل} \\ \text{st. } 360/520 \quad \dfrac{0.15}{100}\, b\, d \\ \text{st. } 240/350 \quad \dfrac{0.25}{100}\, b\, d \end{array}\right\} \text{الأكبر}$$



Shrinkage Bars. (IF the sec. in Beam.)

- توضع ال Shrinkage Bars عندما تكون $t > 70$ cm
- قيمة ال Shrinkage Bars = $2\phi 10$ at every 30 cm

Example.



IF $t = 80$ cm

$\therefore$ No. of Spacings =

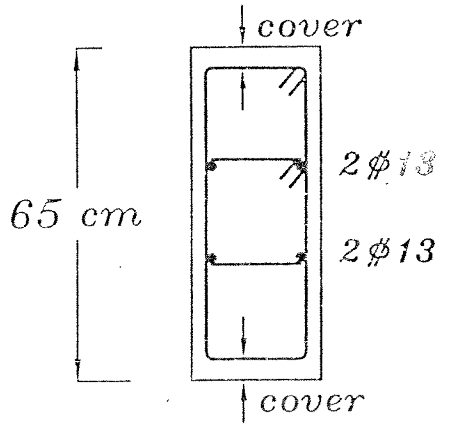
$$= \frac{80 - 10}{30} = 2.33 = 3.0 \text{ Spacing}$$

$$= 2.0 \text{ Bars}$$

Buckling Bars. (IF the sec. in Column.)

- فى الأعمده التى يؤثر عليها M & N.
يجب وضع أسياخ جانبية تسمى Buckling Bars.
- و توضع أيضاً عندما تكون $t < 70$ cm (ليس مثل ال Shrinkage Bars)
- و قيمة ال Buckling Bars = $2\phi 13$ at every 25 cm
- و توضع كانات داخلية
بحيث لا تزيد المسافة بين كل فرع كانة و الفرع الذى يلية عن ٣٠ سم

Example.



IF $t = 65$ cm

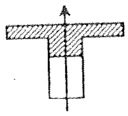
$\therefore$ No. of Spacings =

$$= \frac{65 - 10}{25} = 2.20 = 3.0 \text{ Spacing}$$

$$= 2.0 \text{ Bars}$$

Example.

$F_{cu} = 250\ kg\backslash cm^2$ st. 360/520

$M_{U.L.} = 30\ m.t.$  , $N_{U.L.} = 40\ t$, $b = 30\ cm$

Req. Design the Sec. (Beam.)

Solution.

$$- d_1 = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}} = 3.5 \sqrt{\frac{30 * 10^5}{250 * 30}} = 70\ cm \quad \text{(as R-Sec.)}$$

$$\therefore\ t_1 = 70 + 5 = 75\ cm$$

$$- P_{U.L.} = (0.35\, b\, F_{cu} + 0.67 \frac{b}{100} F_y)\, t_2$$

$$\therefore 40 * 10^3 = (0.35 * 30 * 250 + 0.67 * \frac{30}{100} * 3600)\, t_2 \rightarrow t_2 = 11.9\ cm$$

$$\therefore\ t_\circ = 75\ cm \longrightarrow t = (1.1 \rightarrow 1.3)\, t_\circ$$

$$= (82.5 \rightarrow 97.5)\ cm \quad \boxed{t = 85\ cm}$$

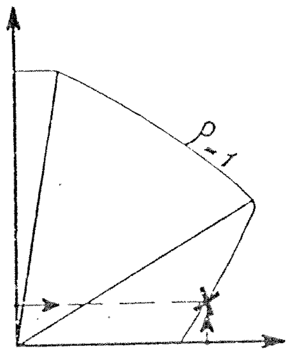
Check $\frac{N}{F_{cu}\, b t} = \frac{40 * 10^3}{250 * 30 * 85} = 0.063 > 0.04$ (Don't neglect N)

$\therefore$ Design the Sec. on both N.F. , B.M.

$\therefore$ Use Interaction Diagram

$\xi = \frac{85 - 10}{85} = 0.88 = 0.80 \xrightarrow{use}$ ECCS Design Aids Page 4–24

$$\left.\begin{array}{l} \frac{N_U}{F_{cu}\, b\, t} = \frac{40 * 10^3}{250 * 30 * 85} = 0.063 \\ \frac{M_U}{F_{cu}\, b\, t^2} = \frac{30 * 10^5}{250 * 30 * 85^2} = 0.055 \end{array}\right\}\ \rho = 1.0$$



Tension Zone $\therefore$ Use e_s

$$e = \frac{M}{N} = \frac{30}{40} = 0.75\ m$$

$$e_s = e + \frac{t}{2} - c = 0.75 + \frac{0.85}{2} - 0.05 = 1.125\ m$$

$$M_S = N * e_s = 40 * 1.125 = 45 \quad m.t.$$

$$\therefore d = C_1 \sqrt{\frac{M_S}{F_{cu}\, b}} \quad \therefore 80 = C_1 \sqrt{\frac{45 * 10^5}{250 * 30}} \rightarrow C_1 = 3.265 \rightarrow J = 0.766$$

$$\therefore A_S = \frac{M_S}{J\, F_y\, d} - \frac{N_{U.L.}}{(F_y \backslash \gamma_s)}$$

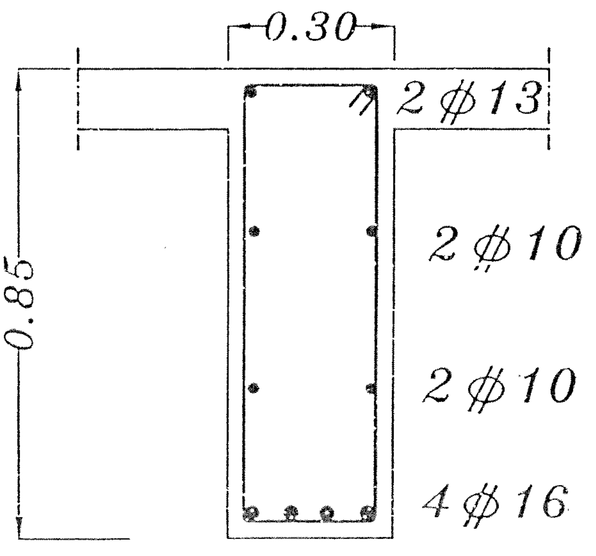
$$= \frac{45 * 10^5}{0.766 * 3600 * 80} - \frac{40 * 10^3}{(3600 \backslash 1.15)} = 7.62\ cm^2 \qquad 4\phi16$$

_ Check $A_{s_{min.}} = \frac{11}{F_y}\, b\, d = \frac{11}{360}\,(30)\,(80) = 7.33\ cm^2$

$$\therefore A_S > A_{s_{min.}} \quad \therefore o.k.$$

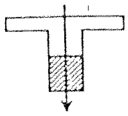
$$\therefore n = \frac{b - 2.5}{\phi + 2.5} = \frac{30 - 2.5}{1.6 + 2.5} = 6.70 = 6.0$$

Stirrup Hangers $= (0.1 \rightarrow 0.2)\, A_S = (0.1 \rightarrow 0.2)\ 7.62$ $2\phi13$



Example.

$F_{cu} = 300 \ kg\backslash cm^2$ st. 360/520

$M_{U.L.} = 50 \ m.t.$  , $N_{U.L.} = 20 \ t$, $b = 30 \ cm$

Req. Design the Sec. (Beam.)

Solution.

$$\therefore d_1 = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}} = 3.5 \sqrt{\frac{50 * 10^5}{300 * 30}} = 82.49 \ cm$$
$$= 85.0 \ cm$$

$$\therefore t_1 = 85 + 5 = 90 \ cm$$

$$- P_{U.L.} = \left(0.35\, b\, F_{cu} + 0.67 \frac{b}{100} F_y\right) t_2$$

$$\therefore 20 * 10^3 = \left(0.35 * 30 * 300 + 0.67 * \frac{30}{100} * 3600\right) t_2 \rightarrow t_2 = 5.16 \ cm$$

$$\therefore t_\circ = 90 \ cm \rightarrow t = (1.1 \rightarrow 1.3)\, t_\circ = (99 \rightarrow 117)\ mm \qquad \boxed{t = 100 \ cm}$$

$$\text{Check} \quad \frac{N}{F_{cu}\, b\, t} = \frac{20 * 10^3}{300 * 30 * 100} = 0.022 < 0.04 \quad \therefore (\text{neglect } N)$$

$$\therefore \text{Take} \quad d = d_1 = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}} \qquad \text{take } C_1 = 3.5 ,\ J = 0.78$$

$$\therefore d = 82.49 \ cm \qquad \therefore \text{Take} \quad \boxed{d = 85 \ cm} , \quad \boxed{t = 90 \ cm}$$

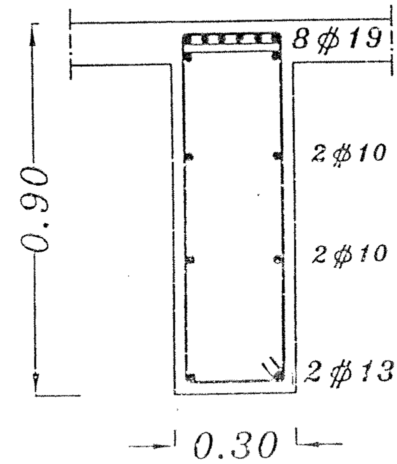
$$\therefore A_S = \frac{M_{U.L.}}{J\, F_y\, d} = \frac{50 * 10^5}{0.78 * 3600 * 82.49} = 21.60 \ cm^2 \qquad 8 \phi 19$$

$$- \text{Check } A_{s_{min.}} = \frac{11}{F_y}\, b\, d = \frac{11}{3600}(30)(85) = 7.79 \ cm^2$$

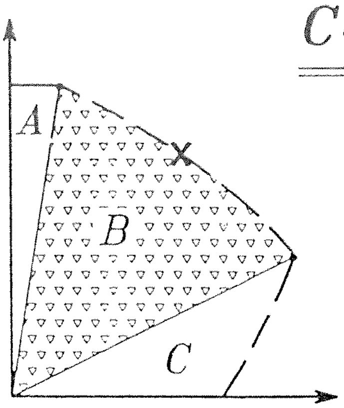
$$\therefore n = \frac{b - 2.5}{\phi + 2.5} = \frac{30 - 2.5}{1.9 + 2.5} = 6.25 = 6.0$$

$$\text{Stirrup Hangers} = (0.1 \rightarrow 0.2)\, A_S$$

$$= (0.1 \rightarrow 0.2)\ 21.60 \qquad 2 \phi 13$$



Compression Failure



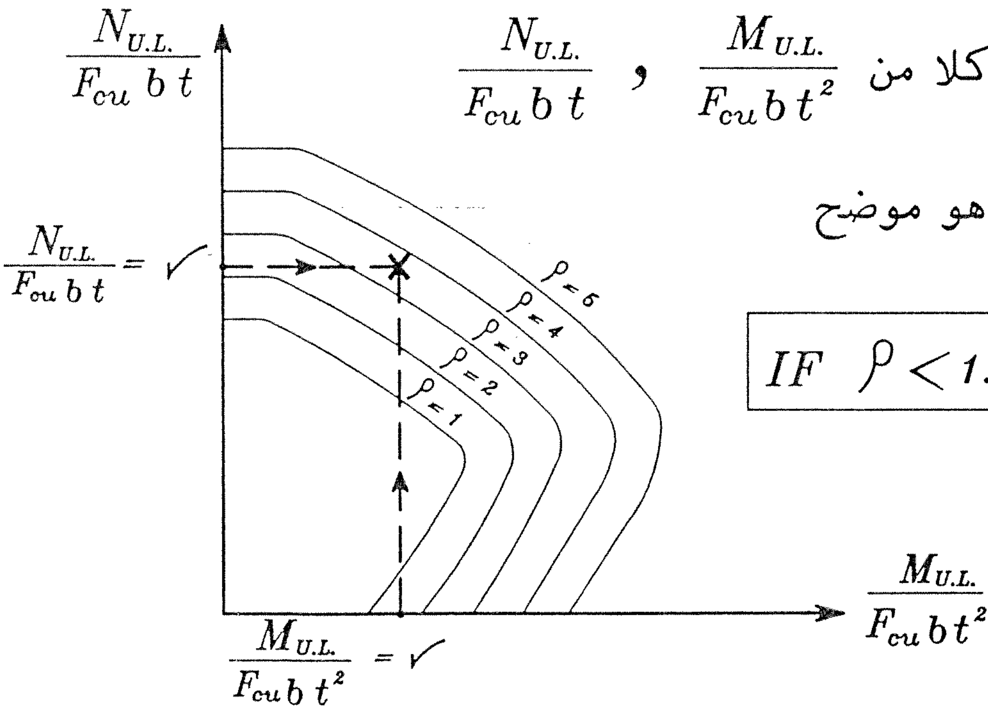
عند وجود نقطة التقاطع عند Zone B
يكون أغلب القطاع علية Compression

Design as Compression Failure

How to Design by using I.D. ??

بعد تحديد نقطة تقاطع كلا من $\frac{M_{U.L.}}{F_{cu}\,b\,t^2}$, $\frac{N_{U.L.}}{F_{cu}\,b\,t}$

نحدد قيمة ρ كما هو موضح



$$\boxed{IF\ \rho < 1.0 \xrightarrow{Take} \rho = 1.0}$$

ثم نعوض فى المعادلات الأتية لتحديد قيمة As , As\`

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

$$A_s = \mu * b * t$$

$$A_s' = \alpha * A_s$$

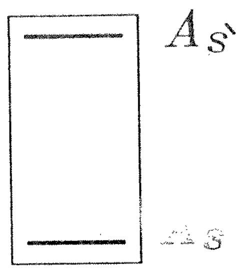
سوف نعوض بقيمه 10^{-5} بدلا من 10^{-4}
حتى تكون الوحدات بال kg & cm

ملحوظة :

ممكن التصميم بال I.D. فى الحالتين Comp. & Ten. Failure
و لكن القيم تكون غير دقيقة عندما تكون Ten. Failure

- Check $A_{s_{min.}}$

Calculate $A_{s_{Total}} = A_s + A_{s`}$



Calculate $A_{s_{min.}} = \frac{0.6}{100} * b * t$

IF $A_{s_{Total}} \geqslant A_{s_{min.}} \quad \therefore$ o.k.

IF $A_{s_{Total}} < A_{s_{min.}} \xrightarrow{take} A_s = A_{s`} = \frac{A_{s_{min.}}}{2}$

Shrinkage Bars. (IF the sec. in Beam.)

توضع ال Shrinkage Bars عندما تكون $t > 70$ cm

- و قيمة ال Shrinkage Bars = $2 \phi 10$ at every 30 cm

Buckling Bars. (IF the sec. in Column.)

فى الأعمده التى يؤثر عليها M & N .

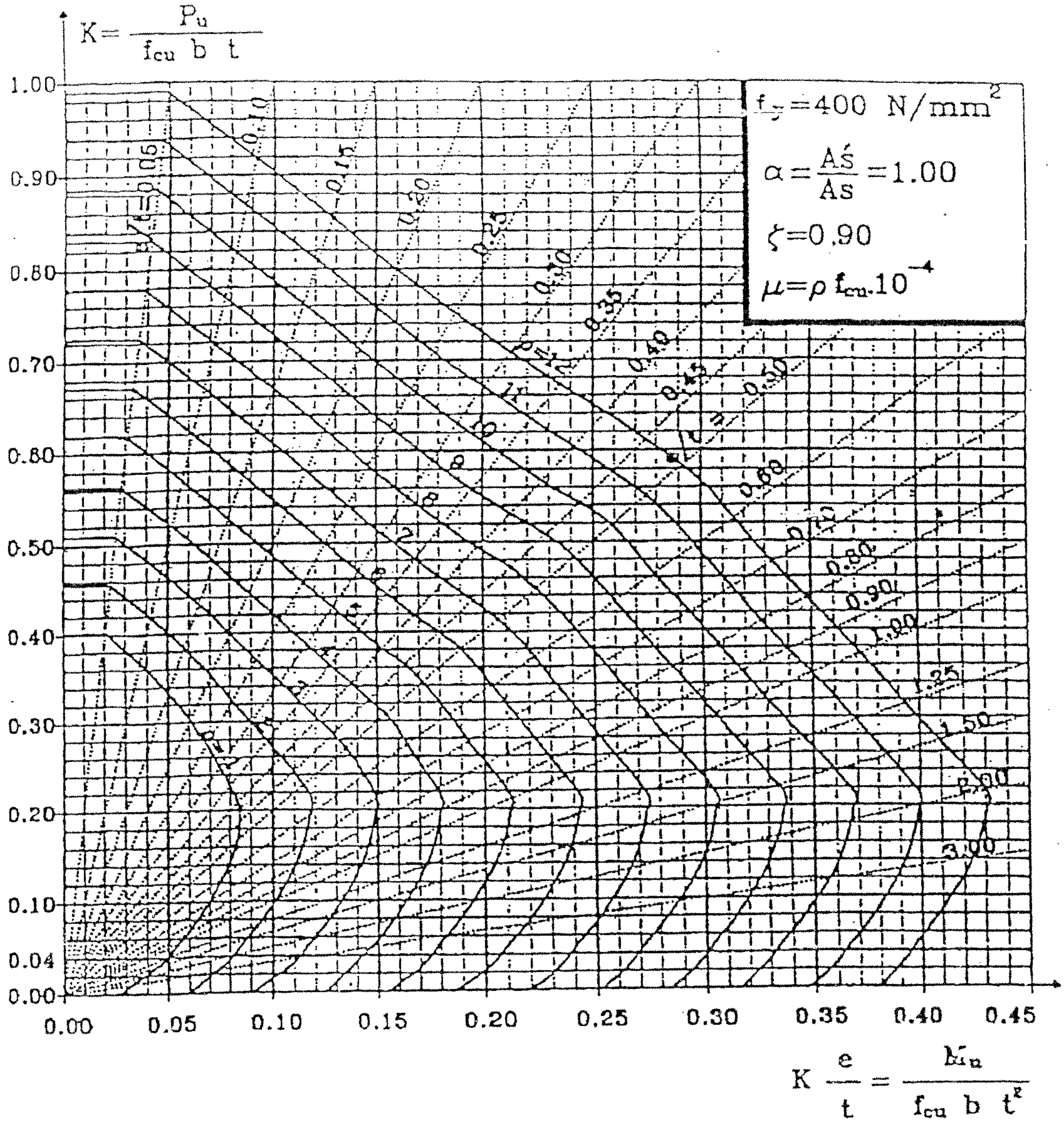
يجب وضع أسياخ جانبية تسمى Buckling Bars .

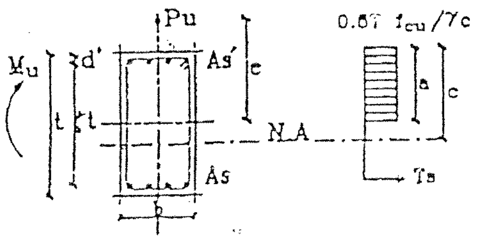
- و توضع أيضاً عندما تكون $t < 70$ cm (ليس مثل ال Shrinkage Bars)
- و قيمة ال Buckling Bars = $2 \phi 13$ at every 25 cm
- و توضع كانات داخلية

بحيث لا تزيد المسافة بين كل فرع كانة و الفرع الذى يلية عن ٣٠ سم

Chart (4-1) : INTERACTION DIAGRAMS

FOR DESIGN OF SECTIONS SUBJECTED TO ECCENTRIC COMP. FORCES





$\mu = \rho \, f_{cu} . 10^{-4}$

$A_s = \mu \; b \; t$

$A_s' = \alpha \; A_s$

$\zeta = \dfrac{d - d'}{t}$

R–Sec.

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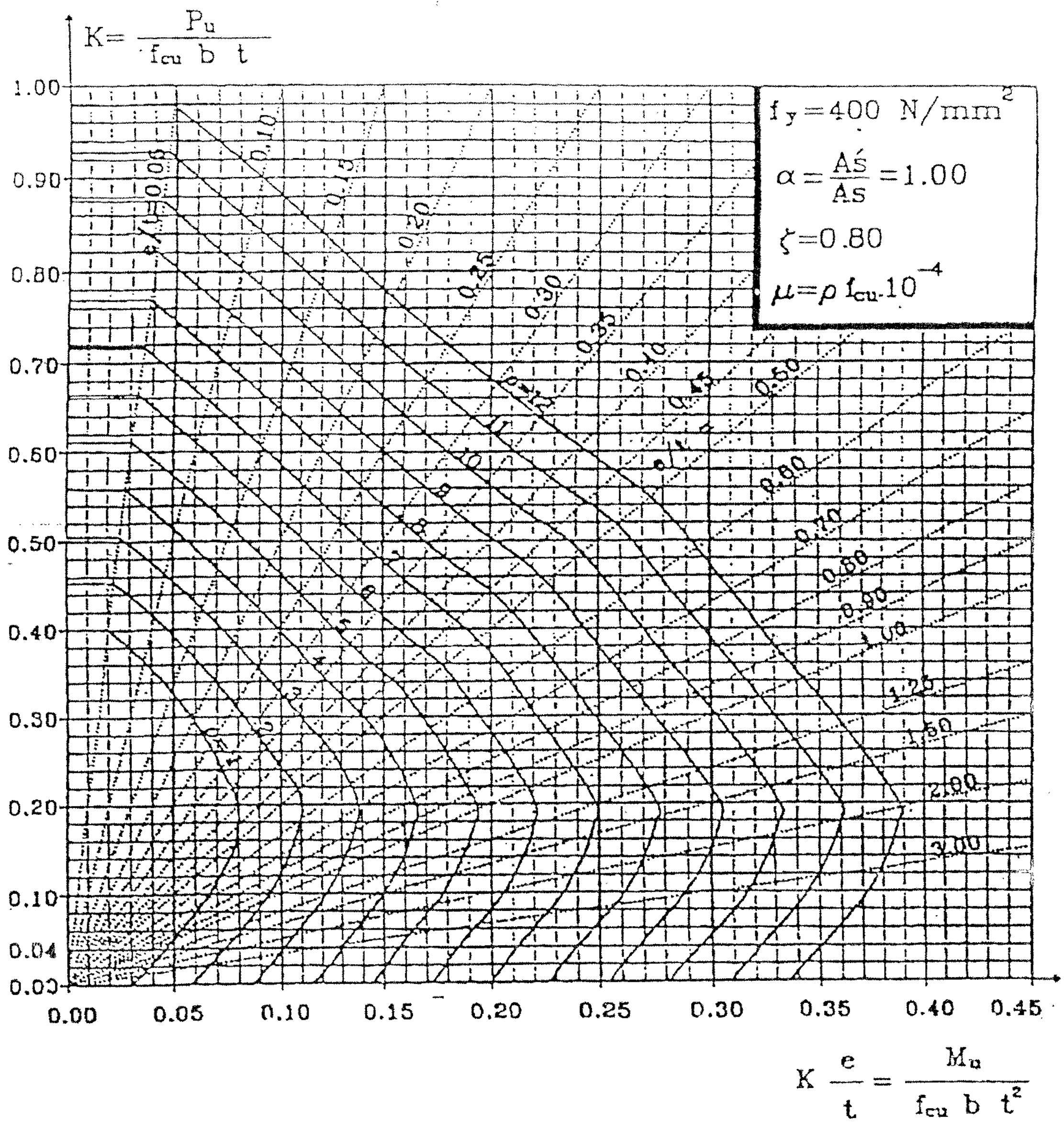
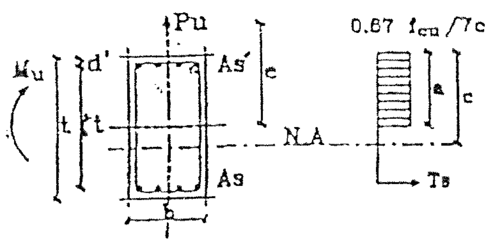
Chart (4-2) : INTERACTION DIAGRAMS

FOR DESIGN OF SECTIONS SUBJECTED TO ECCENTRIC COMP. FORCES





$\mu = \rho\ f_{cu} \cdot 10^{-4}$

$A_s = \mu\ b\ t$

$A_s' = \alpha\ A_s$

$\zeta = \frac{d - d'}{t}$

R–Sec.

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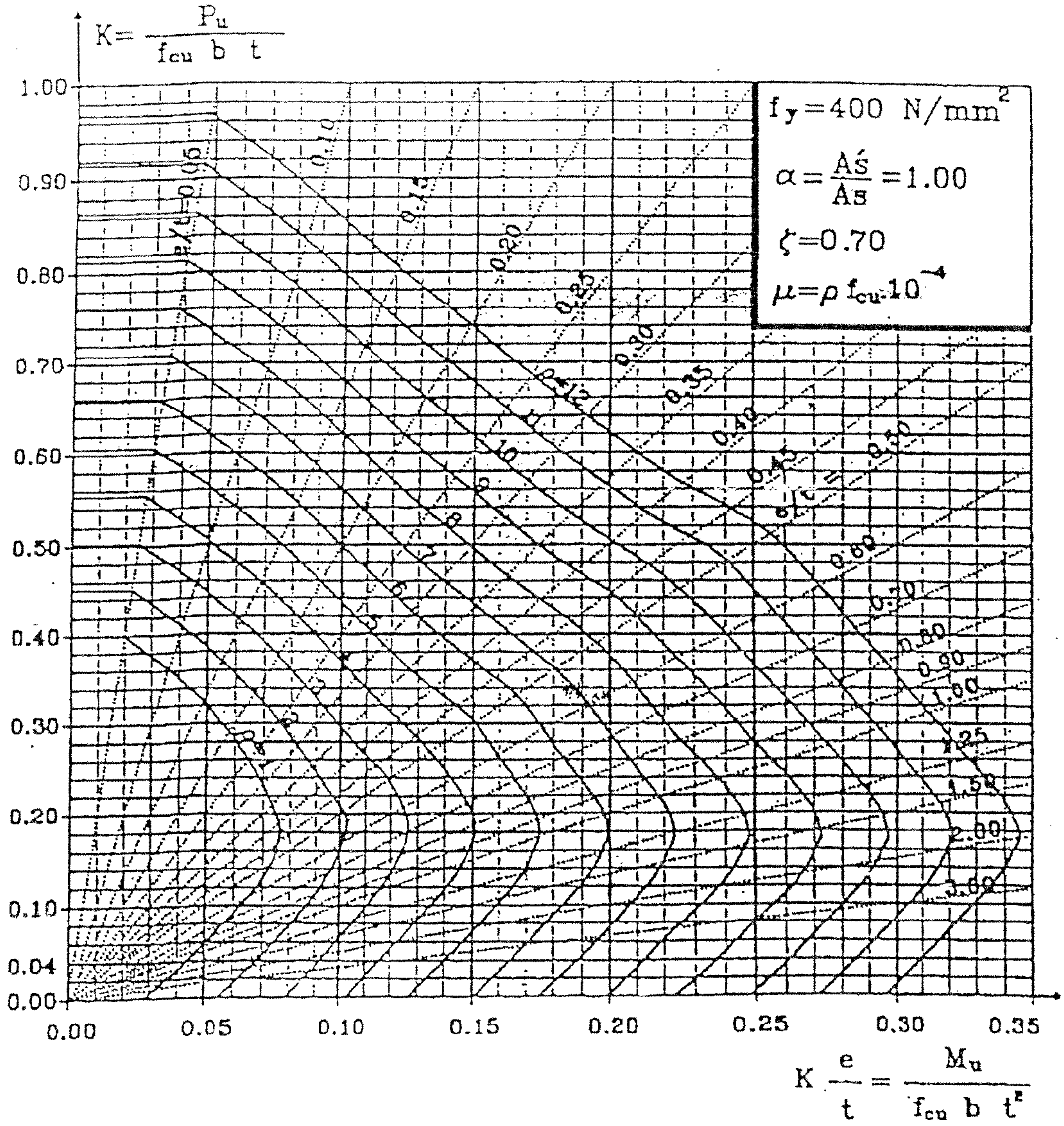
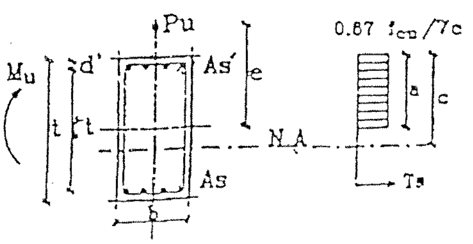
ECCS 203-2001 Interaction Diagrams

Chart (4-3) : INTERACTION DIAGRAMS

FOR DESIGN OF SECTIONS SUBJECTED TO ECCENTRIC COMP. FORCES





$\mu = \rho\ f_{cu} \cdot 10^{-4}$

$As = \mu\ b\ t$

$As' = \alpha\ As$

$\zeta = \frac{d-d'}{t}$

R–Sec.

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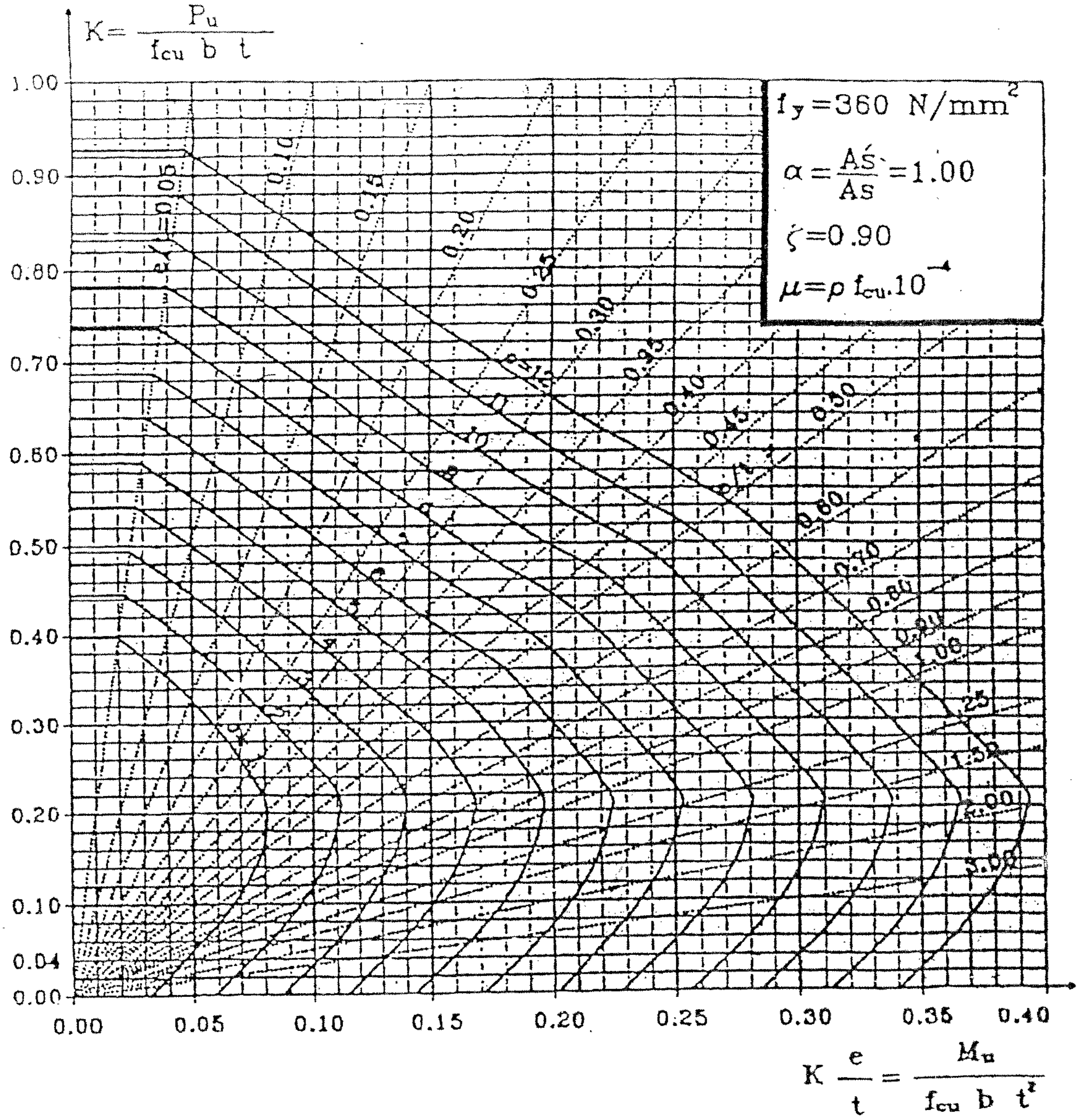
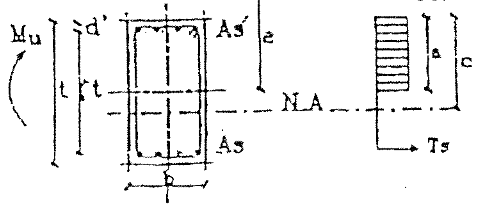
Chart (4-4) : INTERACTION DIAGRAMS

FOR DESIGN OF SECTIONS SUBJECTED TO ECCENTRIC COMP. FORCES





$\mu = \rho\ f_{cu}.10^{-4}$

$As = \mu\ b\ t$

$A\acute{s} = \alpha\ As$

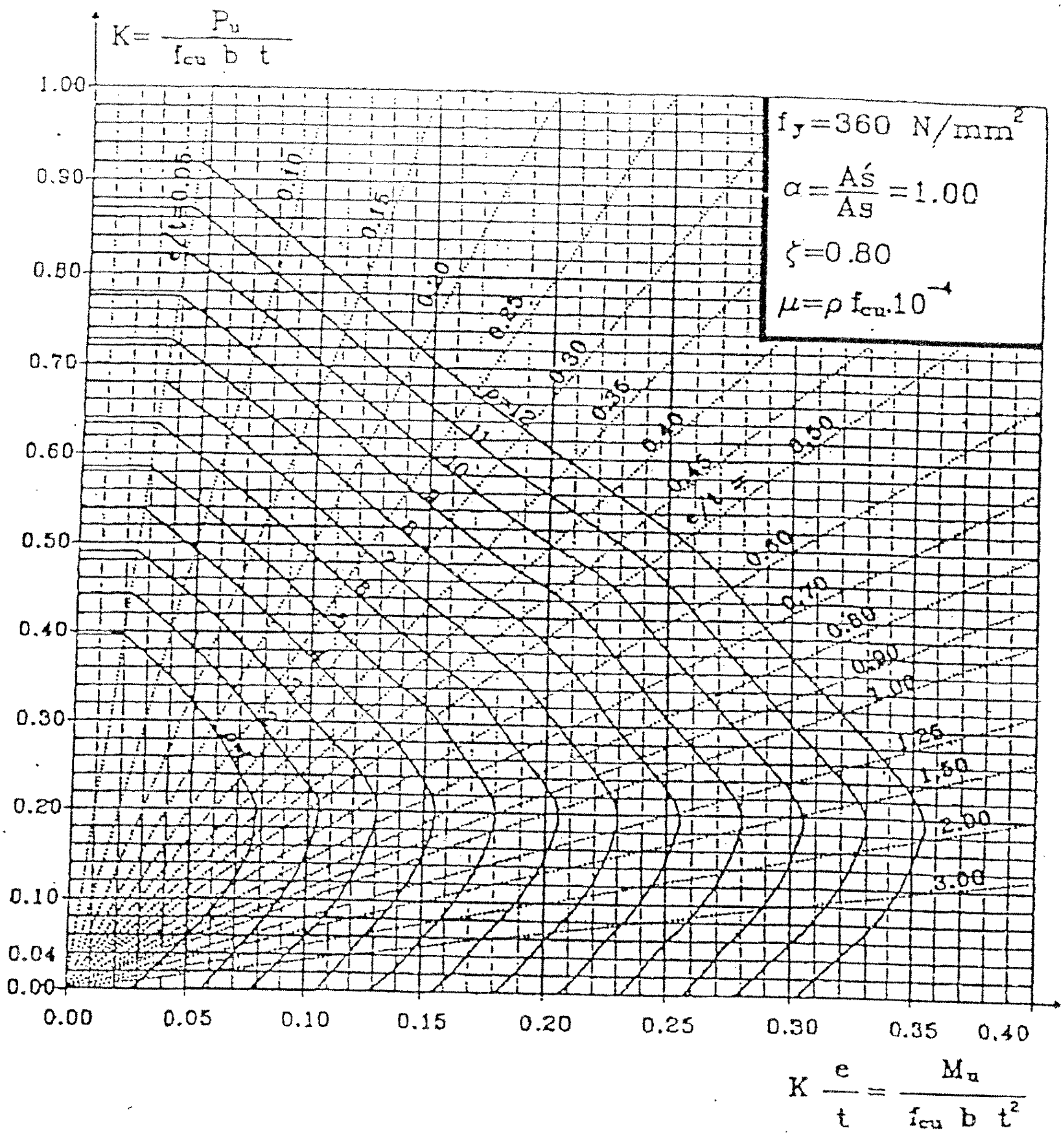
$\zeta = \frac{d - d'}{t}$

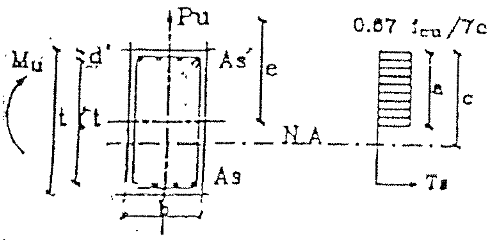
R–Sec.

4/24

Chart (4-5) : INTERACTION DIAGRAMS

FOR DESIGN OF SECTIONS SUBJECTED TO ECCENTRIC COMP. FORCES





$\mu = \rho\ f_{cu}.10^{-4}$

$As = \mu\ b\ t$

$A\acute{s} = \alpha\ As$

$\zeta = \frac{d - d'}{t}$

R–Sec.

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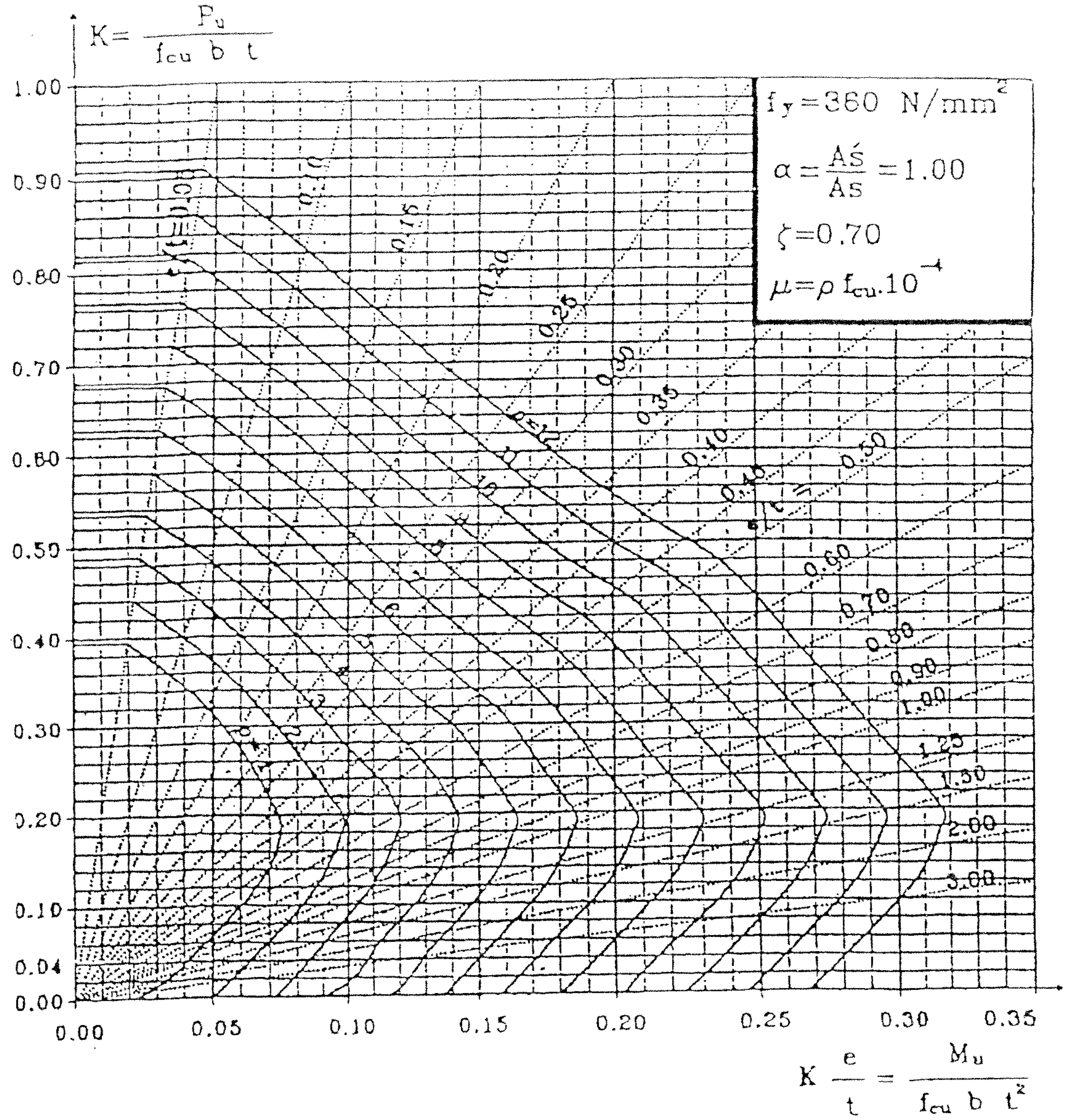
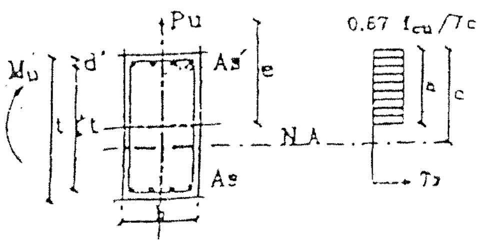
Chart (4-6) : INTERACTION DIAGRAMS

FOR DESIGN OF SECTIONS SUBJECTED TO ECCENTRIC COMP. FORCES





$\mu = \rho\ f_{cu}.10^{-4}$

$As = \mu\ b\ t$

$A\acute{s} = \alpha\ As$

$\zeta = \frac{d-d'}{t}$

R-Sec.

6/24

Example.

$F_{cu} = 250\ kg\backslash cm^2$ st. 360/520

$M_{U.L.} = 30\ m.t.$, $N_{U.L.} = 300\ t$, $b = 30\ cm$

Req. Design the Sec. (Column)

Solution.

$$- d_1 = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}} = 3.5 \sqrt{\frac{30 * 10^5}{250 * 30}} = 70\ cm$$

$$\therefore t_1 = 70 + 5 = 75\ cm$$

$$- P_{U.L.} = \left(0.35\, b\, F_{cu} + 0.67 \frac{b}{100} F_y\right) t_2$$

$$\therefore 300 * 10^3 = \left(0.35 * 30 * 250 + 0.67 * \frac{30}{100} * 3600\right) t_2 \rightarrow t_2 = 89.5\ cm$$

$$\therefore t_\circ = 90.0\ cm \longrightarrow t = (1.1 \rightarrow 1.3)\, t_\circ$$

$$= (99.0 \longrightarrow 117.0)\ mm \qquad \boxed{t = 100\ cm}$$

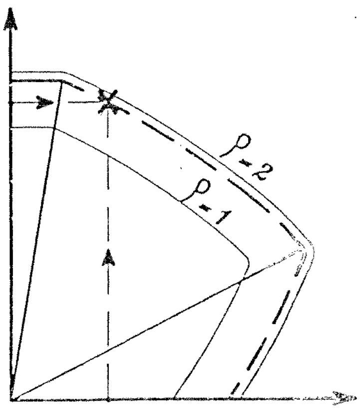
Check $\frac{N}{F_{cu}\, b\, t} = \frac{300 * 10^3}{250 * 30 * 100} = 0.40 > 0.04$ (Don't neglect N)

$\therefore$ Design the Sec. on both N.F. , B.M.

$\therefore$ Use Interaction Diagram

$\xi = \frac{100 - 10}{100} = 0.90 \xrightarrow{use}$ ECCS Design Aids Page 4–23

$$\left.\begin{aligned} \frac{N_U}{F_{cu}\, b\, t} &= \frac{300 * 10^3}{250 * 30 * 100} = 0.40 \\ \frac{M_U}{F_{cu}\, b\, t^2} &= \frac{30 * 10^5}{250 * 30 * 100^2} = 0.04 \end{aligned}\right\} \rho = 1.90$$



Compression Zone

$\therefore$ Use Interaction Diagram

$$\mu = \rho * F_{cu} * 10^{-5} = 1.9 * 25 * 10^{-5} = 4.75 * 10^{-3}$$

$$A_s = A_{s`} = \mu * b * t = 4.75 * 10^{-3} * 30 * 100$$

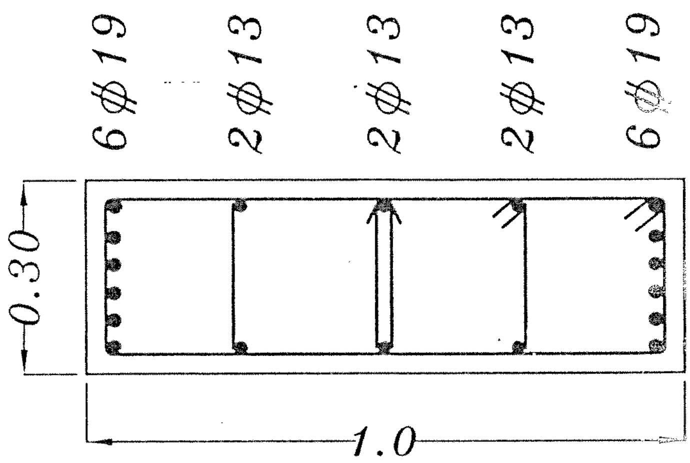
$$= 14.25 \ cm^2 \qquad 6\phi 19$$

$$A_{s_{Total}} = A_s + A_{s`} = 2 * 14.25 = 28.5 \ cm^2$$

$$- \text{ Check } A_{s_{min.}} = \frac{0.6}{100} * b * t = \frac{0.6}{100} * 30 * 100 = 18.0 \ cm^2$$

$$\therefore A_{s_{Total}} > A_{s_{min.}} \quad \therefore o.k.$$

$$- \quad n = \frac{b - 2.5}{\phi + 2.5} = \frac{30 - 2.5}{1.9 + 2.5} = 6.25 = 6.0$$



Example.

$F_{cu} = 250 \ kg\backslash cm^2$ st. 360/520

$M_{U.L.} = 20$ m.t. , $N_{U.L.} = 120$ t , $b = 30$ cm , $d = 75$ cm

Req. Design the Sec. (Column)

Solution.

Check $\dfrac{N}{F_{cu}\, b\, t} = \dfrac{120 * 10^3}{250 * 30 * 80} = 0.20 > 0.04$ (Don't neglect N)

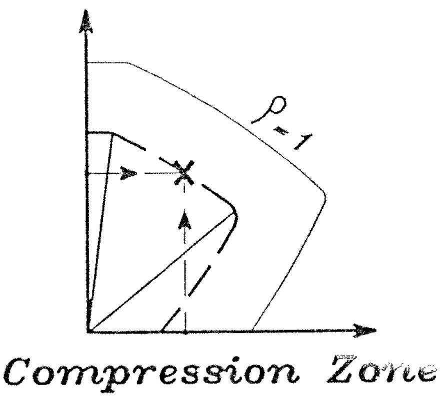
$\therefore$ Design the Sec. on both N.F. , B.M.

$\therefore$ Use Interaction Diagram

$\xi = \dfrac{80 - 10}{80} = 0.875 \xrightarrow{Take} \xi = 0.8$

$\xrightarrow{use}$ ECCS Design Aids Page 4–24

$$\left.\begin{aligned} \frac{N_U}{F_{cu}\, b\, t} &= \frac{120 * 10^3}{250 * 30 * 80} = 0.20 \\ \frac{M_U}{F_{cu}\, b\, t^2} &= \frac{20 * 10^5}{250 * 30 * 80^2} = 0.0416 \end{aligned}\right\} \rho < 1.0$$



$$\boxed{\because \rho < 1.0 \quad \therefore \text{Take } \rho = 1.0}$$

$\mu = \rho * F_{cu} * 10^{-5} = 1.0 * 250 * 10^{-5} = 2.5 * 10^{-3}$

$A_s = A_s' = \mu * b * t = 2.5 * 10^{-3} * 30 * 80 = 6.0 \ cm^2$

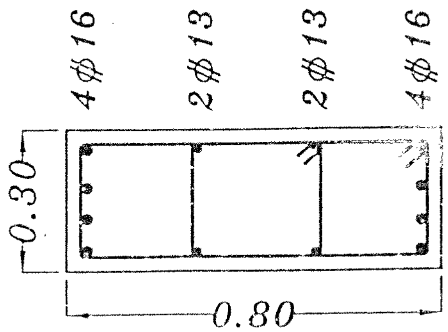
$A_{s_{Total}} = A_s + A_s' = 2 * 6.0 = 12.0 \ cm^2$

– Check $A_{s_{min}} = \dfrac{0.6}{100} * b * t = \dfrac{0.6}{100} * 30 * 80 = 14.4 \ cm^2$

$\therefore A_{s_{Total}} < A_{s_{min}}$

$\therefore$ take $A_s = A_s' = \dfrac{A_{s_{min}}}{2} = \dfrac{14.4}{2} = 7.2 \ cm^2$

4φ16



– $n = \dfrac{b - 2.5}{\phi + 2.5} = \dfrac{30 - 2.5}{1.6 + 2.5} = 6.70 = 6.0$