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2nd year civil Engineering

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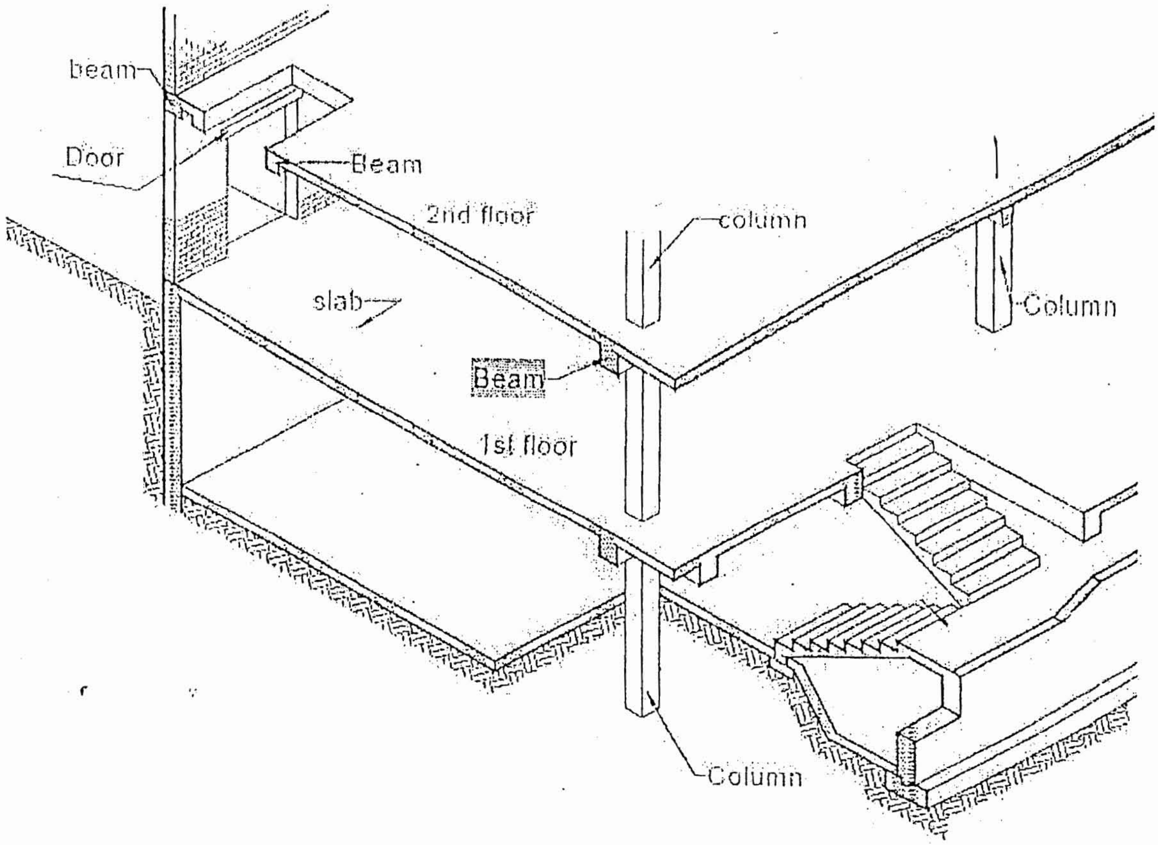


Reinforced concrete

Sheet 3

Ultimate Design الـ Sheet

Sheet (3)

Ultimate Limit State Method

- By Using Ultimate Limit State Method, design a rectangular section to resist factored bending moment (ultimate) of 400 kN.m , if the width of the section b=250 mm

f_{cu}	25	25
f_y	240	400

For steel 240/350 , $C_{max}/d = 0.5$ and $R_{max} = 0.214$

For steel 400/600 , $C_{max}/d = 0.42$ and $R_{max} = 0.187$

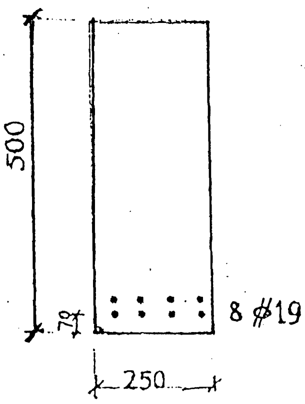
if the section designed is 250 * 650 mm calculate the required reinforcement.

2- By Using Ultimate Limit State Method, design a RC singly reinforced rectangular section with b = 300 mm and subjected to factored bending moment (ultimate) of 400 kN.m , if the steel ratio μ is required to be 0.5 μ_b

$f_{cu} = 25$ N/mm^2, $f_y = 360$ N/mm^2, $C_{max}/d = 0.44$ and $R_{max} = 0.194$, $\mu_{max} = 5*10^{-4} f_{cu}$

3 - For the RC singly reinforced rectangular section shown in figure, using the ultimate strength Design Method, determine what modifications should be done to the section reinforcement if it is subjected to an ultimate moment = 250 kN.m

$f_{cu} = 25$ N/mm^2, $f_y = 360$ N/mm^2, $C_{max}/d = 0.44$ and $R_{max} = 0.194$, $\mu_{max} = 5*10^{-4} f_{cu}$

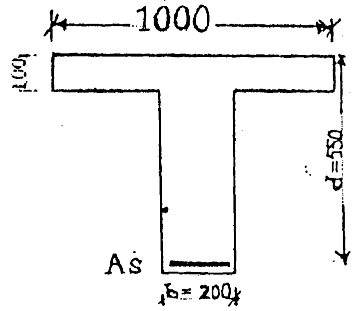


4 - For the RC T- section calculate the required area of steel reinforcement if the section is required to resist a factored bending moment

a- Mu = 300 kN.m

b- Mu = 700 kN.m

Materials are : Concrete f_{cu} = 25 N/mm^2, steel Grade 360/520

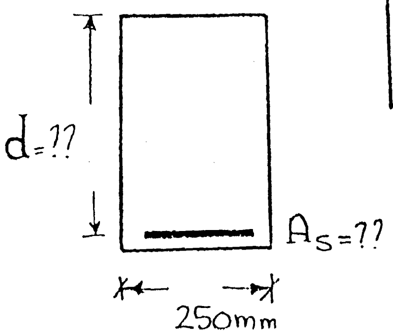


Problem No: 1

المسألة في ال Sheet عبارة عن 3 مسائل

1 الجزء الأول

$F_{cu} = 25\ N/mm^2$
$F_y = 240\ N/mm^2$



$M_{ult} = 400\ kN.m$

Find d, A_s

1 $$\boxed{M_{u\,max} = R_{max} * \frac{f_{cu}}{\gamma_c} * b * d^2}$$

$$400*10^6 = 0.214 * \frac{25}{1.5} * 250 * d^2$$

$$d = 669.77\ mm \xrightarrow[50\,mm]{\text{تقرب لأقرب}} \boxed{700\ mm}$$

$$\therefore h = d + d' = 700 + 50 = 750\ mm$$

2 $$\boxed{M_u = C\,[d - a/2]}$$

$$400*10^6 = 0.67 * f_{cu}/\gamma_c * (a)(b)\left[d - \frac{a}{2}\right]$$
$$= 0.67 * \frac{25}{1.5} * (a)(250)\left[700 - \frac{a}{2}\right]$$

$a = 248.96\,mm$ ✓
$a_{min} = 0.1d = 70\ mm$ $\quad\therefore a = 248.96\ mm$

3 $$\boxed{M_u = T\,[d - a/2]}$$

$$M_u = A_s * f_y/\gamma_s * [d - a/2]$$

$$400*10^6 = A_s * \frac{240}{1.15} * \left[700 - \frac{248.96}{2}\right]$$

$A_s = 3330.3\ mm^2 = 7\phi25$

$F_{cu} = 25\ N/mm^2$
$F_y = 400\ N/mm^2$

2 الجزء الثالث أعد حل المسألة اذا كان

$M_{ult} = 400\ kN.m$

1 $\boxed{M_{u_{max}} = R_{max} * \frac{F_{cu}}{\gamma_c} * b * d^2}$

$400 * 10^6 = 0.187 * \frac{25}{1.5} * 250 * d^2$

$d = 716.5\,mm \xrightarrow[50mm]{\text{تقرب لأقرب}} 750\,mm$

$h = d + d' = 750 + 50 = 800\,mm$

2 $\boxed{M_{u_{max}} = C\left[d - \frac{a}{2}\right]}$

$400 * 10^6 = 0.67 * \frac{25}{1.5} * (a) * (250)\left[750 - \frac{a}{2}\right]$

$a = 224\ mm$ ✓ الأكبر

$a_{min} = 0.1d = 75\,mm$

3 $\boxed{M_{u_{max}} = T\left[d - a/2\right]}$

$400 * 10^6 = A_s * \frac{400}{1.15} * \left[750 - \frac{224}{2}\right]$

$A_s = 1803\ mm^2$

$8\ \phi 18\ mm$

③ الجزء الثالث) قال لو كان القطاع $250 * 650^{mm}$ والعزم $400\ KN.m$

اوجد التسليح .

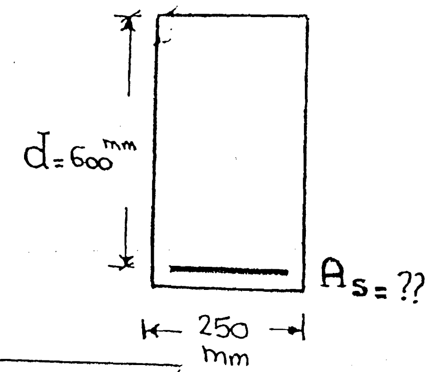
$F_{cu} = 25\ N/mm^2$

$F_y = 400\ N/mm^2$

* Given: $M = 400\ KN.m$

$d = 600\ mm$

* Req: A_s



① $$\boxed{M_{u_{max}} = R_{max} * \frac{F_{cu}}{\gamma_c} * b * d^2}$$

$$= 0.187 * \frac{25}{1.5} * 250 * (600)^2 = \underline{280.5}\ KN.m$$

• معنى ذلك انك يريد بتصميم القطاع على عزم = 400 ؟ وانت وجدت ان اقصى

عزم يتحمله القطاع = 280.5 "أى القطاع غير كافى Use Compression Steel

ويكون العزم الذى يتحمله حديد الضغط

② $$\boxed{M_1 = M_{u_{given}} - M_{u_{max}}} = 400 - 280.5 = 119.5\ KN.m$$

$$\therefore M_1 = C_s (d - d'')$$

$$119.5 * 10^6 = A_s' * \frac{F_y}{\gamma_s} (d - d'')$$

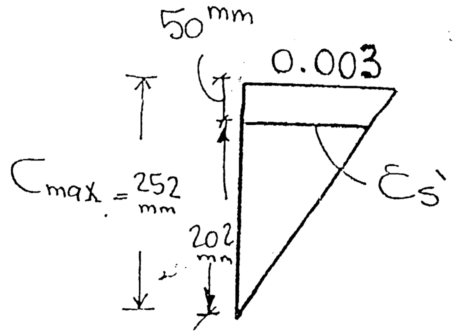
$$119.5 * 10^6 = A_s' * \frac{400}{1.15} * (600 - 50)$$

$$A_s' = 624.65\ mm^2$$

$$= 4 \phi 16_{mm}$$

{Check of yeilding for A_s'}

$\frac{C_{max}}{d} = 0.42$ من الجدول



$C_{max} = 252$ mm

$\therefore \frac{\varepsilon_s'}{0.003} = \frac{202}{252}$

$\therefore \varepsilon_s' = 0.0024 > \varepsilon_y = \frac{360}{1.15 * 2 * 10^5}$

$= 0.00156$

الحديد العلوي "حديد الضغط" تعدى ال "yeild" ok

$* \ a_{max} = 0.8 \ C_{max} = 201.6$ mm.

3 $\boxed{C_c + C_s = T}$

$$0.67 * \frac{F_{cu}}{\gamma_c} * a_{max} * b + A_s' * \frac{F_y}{\gamma_s} = A_s * \frac{F_y}{\gamma_s}$$

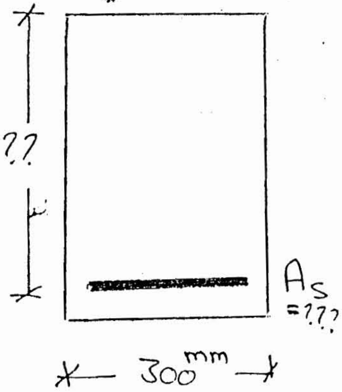
$$0.67 * \frac{25}{1.5} * 201.6 * 250 + 624.65 * \frac{400}{1.15} = A_s * \frac{400}{1.15}$$

$A_s = 2242.7 \ mm^2$

$6 \phi 22$

Problem NO: 2

if $\mu = 0.5\,\mu_b$



Given: $M_u = 400\ kN.m$

$\mu = 0.5\,\mu_b \leftarrow$ شرط.

Req: d , A_s

أعطاك في المسألة شرط ← استنبط

$$\boxed{\mu_b = 0.41 * \frac{F_{cu}}{F_y} * \frac{600}{600 + F_y/\gamma_s}}$$

$$= 0.41 * \frac{25}{360} * \frac{600}{600 + \frac{360}{1.15}} = 0.018$$

$$\boxed{\mu = 0.5\,\mu_b}$$

$$= 0.5 * 0.018 = 0.009$$

$$\boxed{\mu = \frac{A_s}{b * d}}$$

$$\therefore A_s = \mu * b * d = 0.009 * 300 * d$$

$$\boxed{A_s = 2.7\,d}$$

ثاني خطوة

② ادخل معادلة الاتزان

هو زايد جعل
" مسألتك عادى "

$$\boxed{C_c = T}$$

$$(0.67)\left(\frac{f_{cu}}{\gamma_c}\right)(a)(b) = (A_s)\left(\frac{F_y}{\gamma_s}\right)$$

عوض عن $A_s = 2.7\,d$

$$0.67\left(\frac{f_{cu}}{\gamma_c}\right)(a)(b) = \left[(2.7)(d)\right]\left(f_y/\gamma_s\right)$$

$$0.67\left(\frac{25}{1.5}\right)(a)(300) = 2.7 * d * \frac{360}{1.15}$$

هات علاقة بين (a,d)

$$\boxed{a = 0.25\,d}$$

ثالث خطوة

③ ادخل معادلة العزم

$$\boxed{M_u = C\left(d - a/2\right)}$$

فيها a, d مجاهيل

بالمعادلة السابقة كليم مجهول واحد

$$M_u = 0.67 * \frac{f_{cu}}{\gamma_c} * (a) * (b) * \left[d - \frac{a}{2}\right]$$

شيل كل a وحط مكانها $0.25d$

$$M_u = 0.67 * \frac{f_{cu}}{\gamma_c} * (0.25d)(b)\left[d - \frac{0.25d}{2}\right]$$

$$400 * 10^6 = 0.67 * \frac{25}{1.5} * 0.25 * d * 300 * \left[d - 0.125d\right]$$

$$d = 738.8 \xrightarrow{\text{تقرب}} 750 \text{ mm}$$

$$h = 800\text{mm}$$

من العلاقة الأولى :

$$A_s = 2.7 * d = 2.7 * 750 = 2025$$

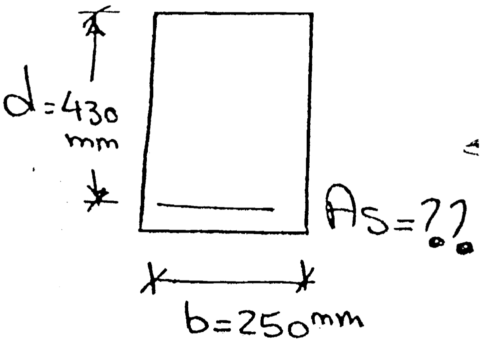
$8\phi 18$

problem NO: 3

معنى المسألة انه طلب "ماهى التعديلات التى يجب اجراؤها على حديد "حديد القطاع"

أى حل المسألة عادى بس أحنا الحديد "As" مجهول

* هنحسب $M_{u_{max}}$ ونقارنها بـ $M_{u_{given}}$ ونحل عادى جداً.



$$\boxed{① M_{u_{max}} = R_{max} * \frac{F_{cu}}{\gamma_c} * b * d^2}$$

$$= 0.194 * \frac{25}{1.5} * 250 * (430)^2$$

$$= 149.46 \text{ KN.m}$$

$$\boxed{M_{u_{max}} < M_{u_{given}}}$$

أى ان القطاع بلحظى أخره بيتحمل 149.46 KN.m وهو عايزك

تصممه على ان يتحمل 250 KN.m .

Use Comp. Steel

$$M_1 = Mu_{given} - Mu_{max}$$

$$= 250 - 149.46 = 100.5 \text{ KN.m}$$

$$\boxed{M_1 = C_s * (d - d'')}$$

$$100.5 * 10^6 = As' * \frac{Fy}{\gamma_s} * (d - d'')$$

غطاء = 50 mm حالة تغطية

$$100.5 * 10^6 = As' * \frac{360}{1.15} * (430 - 50)$$

$$\boxed{* \ As' = 844 \ mm^2 \rightarrow 4\phi 18}$$

$$\boxed{C_c + C_s = T}$$

$$0.67 * \frac{F_{cu}}{\gamma_c} * a_{max} * b + As' * \frac{Fy}{\gamma_s} = As * \frac{Fy}{\gamma_s}$$

$$\frac{C_{max}}{d} = 0.44$$

$C_{max} = 189.2$ mm

$a_{max} = 0.8 C_{max} = 151.3$ mm

$$0.67 * \frac{25}{1.5} * 151.3 * 250 + 844 * \frac{360}{1.15} = As * \frac{360}{1.15}$$

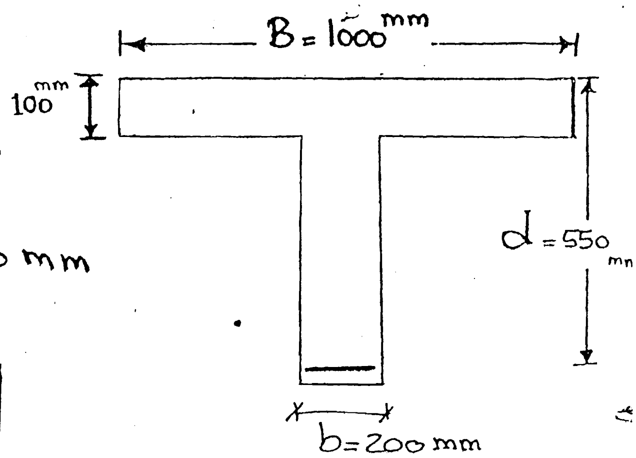
$$As = 2193.26 \ mm^2 \rightarrow 5\phi 22$$

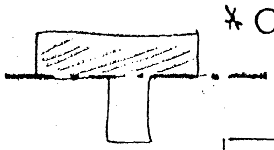
Problem No : 4

* المسألة عبارة عن مسألتين T_Sec.

طلب حل المسألة مرة لو $M_u = 300$ ومرة أخرى لو $M_u = 700$

Case a $M_u = 300$ kN.m





* assume $a = t_s = 100$ mm

[1] $$\boxed{M_{u\,max} = C\left[d - \frac{a}{2}\right]}$$

$$= 0.67 * \frac{F_{cu}}{\gamma_c} * a * B * \left[d - \frac{a}{2}\right]$$

$$= 0.67 * \frac{25}{1.5} * 100 * 1000 * \left[550 - \frac{100}{2}\right]$$

$$\therefore M_{u\,max} = 558.3 \text{ kN.m}$$

ونجد أن العزم الذى تتحمله الـ Flange وقدرها = 558 ويراد تصميم القطاع على $300^{kN.m}$

$$\therefore a < t_s$$

[2] $$\boxed{M_u = C\left[d - \frac{a}{2}\right]}$$

$$300 * 10^6 = 0.67 * \frac{F_{cu}}{\gamma_c} * (a) * (B) * \left[d - \frac{a}{2}\right]$$

$$300 * 10^6 = 0.67 * \frac{25}{1.5} * (a) * (1000) * \left[550 - \frac{a}{2}\right]$$

$a = 51.23$ mm

$a_{min} = 0.1d = 55$ mm ✓ الأكبر

$\boxed{3}$

$$\boxed{M_u = T\left[d - \frac{a}{2}\right]}$$

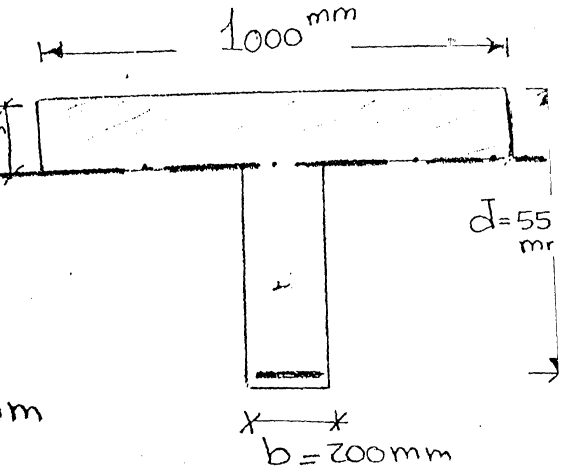
$$300 * 10^6 = A_s * \frac{f_y}{\gamma_s} * \left[d - \frac{a}{2}\right]$$

$$300 * 10^6 = A_s * \frac{360}{1.15} * \left[550 - \frac{55}{2}\right]$$

$$A_s = 1834 \text{ mm}^2$$

$$= 8 \phi 18 \text{ mm}$$

Case B



$M_u = 700$ kN.m

*assume $a = t_s = 100$ mm

$$\boxed{1} \quad \boxed{Mu_{max} = C\left[d - \frac{a}{2}\right]}$$

$$= 0.67 * \frac{f_{cu}}{\gamma_c} * (a) * B * \left[d - \frac{a}{2}\right]$$

$$= 0.67 * \frac{25}{1.5} * 100 * 1000 * \left[550 - \frac{100}{2}\right]$$

$$= 558.3 \text{ kN.m}$$

ولكن هنا انت بتريد تصميم القطاع على $700^{kN.m}$ ووجدنا ان ال Flange

وحدها تتحمل 558.3 فقط لاتكفي ، وتحتاج جزء من ال Web

$a > t_s$ ∴

$$\boxed{M_u = C_w\left(d - \frac{a}{2}\right) + C_F\left(d - \frac{t_s}{2}\right)}$$

$$700*10^6 = 0.67 * \frac{f_{cu}}{\gamma_c} * (a)(b)\left[d - \frac{a}{2}\right] + 0.67 * \frac{f_{cu}}{\gamma_c} * (ts)(B-b) * \left[d - a/2\right]$$

$$700*10^6 = 0.67 * \frac{25}{1.5} * a * 200 * \left[550 - \frac{a}{2}\right] + 0.67 * \frac{25}{1.5} * 100 * (1000-200) * \left[550 - \frac{100}{2}\right]$$

$a = 274.98$ mm ✓✓

$a_{min} = 55$ mm

$$\boxed{C_W + C_F = T}$$

$$0.67 * \frac{25}{1.5} * 274.98 * 200 + 0.67 * \frac{25}{1.5} * 100 * (1000 - 200)$$

$$= A_s * \frac{360}{1.15}$$

$$A_s = 4815.48\ mm^2$$

$$10 \phi 25$$

عزم كبير بيطلع حديد كتير