Alexandria University
Faculty of Engineering
Second year Civil Engineering (تخلفات)

Reinforced concrete-1
June 2009
time allowed: **3 hours**

Materials to be used: **concrete:** f_{cu}=25MPa
Steel: st.360/520 (for longitudinal reinforcement) & st.240/350 (for stirrups)

Working Stress Design Method:
$f_{c\ allowable}=9.5N/mm^2$, $f_{s\ allowable}$ (for st.360/520)$=200N/mm^2$, $f_{ctr}=3.0N/mm^2$

Ultimate Strength Design Method:
$c_{max}/d=0.44$, $\mu_{max}=5.0\times10^{-4}f_{cu}$, $R_{max}=0.194$
$q_{cu}=0.24(f_{cu}/\gamma_c)^{1/2}$, $q_{u\ max}=0.7(f_{cu}/\gamma_c)^{1/2}$
$L_d=55\varphi$ (for η=1.0)
η=1.0 (for bottom bars), η=1.3 (for top bars)

امتحان سهل جداً
اقرا الاسئلة فقط
لا تكله بإيدك

Question 1: (15% of max credit)
Define briefly (using sketches) the following:
a) Balanced section.
b) Under-reinforced section.
c) Over-reinforced section.

State the Egyptian Code requirements for the following:
d) Minimum reinforcement for sections subjected to flexure.
e) Minimum web reinforcement for beams.
f) Minimum longitudinal reinforcement for short columns.
g) Stirrups for tied columns.

Question 2: (20% of max credit)
For the reinforced concrete rectangular section shown in Fig.1, calculate the following:
a) Cracking moment.
b) Service moment capacity.
c) Ultimate moment capacity.

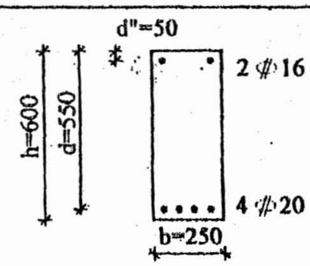


Fig.1

Question 3: (15% of max credit)
For a reinforced concrete rectangular beam section (b=300mm, d=730mm), calculate the following:
a) Maximum area of tensile reinforcement allowed in the section and the corresponding ultimate moment.
b) Reinforcement required to resist an ultimate moment (M_u=600 kN.m).

Question 4: (10% of max credit)
Calculate the ultimate moment capacity for the reinforced concrete T-section shown in Fig.2.

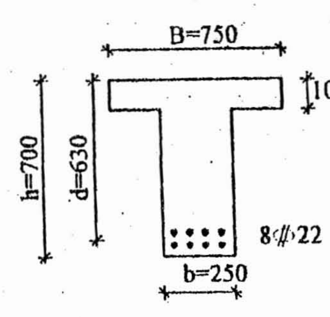


Fig.2

uestion 5: (40% of max credit)

ig.3 shows a reinforced concrete beam (span=6.00m) with two overhanging ends (length=2.00m) pported on two columns (0.30×0.30m). The spacing between the beams is 3.00m. The beam cross ction and the ultimate loads acting on the beam are shown in the figure. It is required to:

a) Draw the bending moment and the shearing force diagrams.
b) Design the reinforcement required for the positive and negative bending moments.
c) Design the web reinforcement using vertical stirrups only.
d) Draw a longitudinal section of the beam (scale 1:40) and a cross section at mid-span (scale 1:20) showing all reinforcement details using reasonable cutoff points.

نقط التوقيف

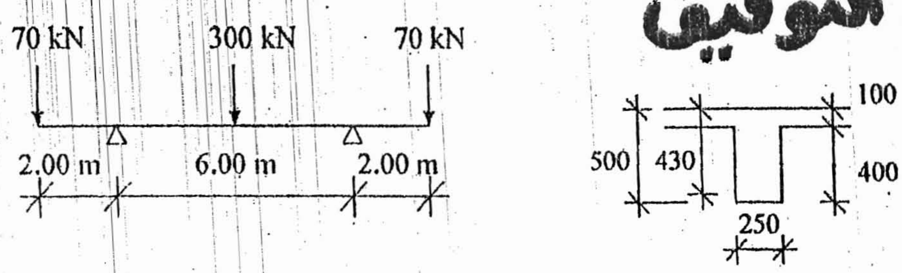


Fig.3

Best wishes...

Alexandria University
Faculty of Engineering
Structural Engineering Department

جامعة الإسكندرية
كلية الهندسة
قسم الهندسة الإنشائية

June 2008 — يونيو ٢٠٠٨

Course title: Reinforced Concrete-1 — اسم المقرر: الخرسانة المسلحة-١ CE271

2nd Year Civil — السنة الدراسية: الثانية مدني

Time allowed: 3 Hours — الزمن: ثلاثة ساعات

- **Materials:** Concrete f_{cu} = 30 N/mm² and Steel Grade 400/600 for longitudinal bars and Steel Grade 240/350 for stirrups
- **Load factors:** 1.4 for Dead Load and 1.6 for Live Load
- **Material factors:** $\gamma_c = 1.5$, $\gamma_s = 1.15$
- **Ultimate Limit State Design Method:**

Flexure: $c_{max} / d = 0.42$, $\mu_{max} = 4.31 \times 10^{-4} f_{cu}$ $R_{max} = 0.187$

Shear: $q_{cu} = 0.24 \sqrt{f_{cu}/\gamma_c}$ N/mm², $q_{umax} = 0.7 \sqrt{f_{cu}/\gamma_c}$ N/mm²

Torsion: $A_{str} = M_{tu} s / \left[1.7 x_1 y_1 (f_{yst}/\gamma_s)\right]$ $A_{sl} = \left[A_{str} p_h / s\right] f_{yst} / f_y$

Development length: $L_d = 50\,\phi$ for bottom bars in tension, $\eta = 1.3$ for top bars

- **Working Stress Design Method:**

$f_c = 10.5$ N/mm², $f_s = 220$ N/mm² for Steel 400/600, cracking stress = 3.3 N/mm²

Attempt All Questions: Total Marks = 70

1. For the RC section shown in Fig. 1, it is required to:
i. Calculate the ***positive*** **cracking** moment of the section; M_{cr}
ii. The **maximum working moment** that can be resisted by the section
iii. Check the stresses in concrete and steel if the section is subjected to a ***positive working moment*** M_w = 150 kN.m
iv. The **ultimate positive moment** that can be resisted by the section

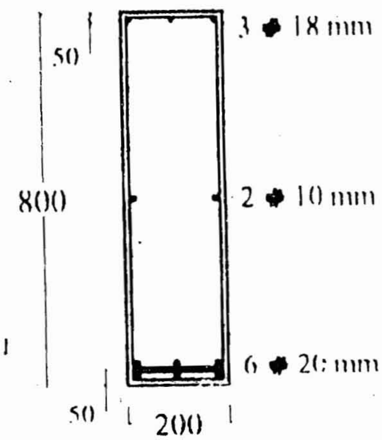


Figure 1

(22 marks)

2. Using **Ultimate Strength Design Method**, find the reinforcement required for a RC rectangular section to resist a **factored (ultimate)** moment = 125 kN.m. The section dimensions are: width b = 200 mm, overall depth h = 1050 mm, and effective depth d = 1000 mm.
For this problem only: f_{cu} = 20 N/mm², Steel 360/520.
What is the percentage of reinforcement increase if the overall depth of the beam; h is reduced to 550 mm.

(12 Marks)

3. Using the **Ultimate Strength Design Method**, design a *tied* RC short column of ***circular*** section to carry the following **working loads**: Dead load = 2500 kN and live load = 1750 kN.
Draw the cross section of the column showing longitudinal steel and stirrups with scale 1: 20.
For the same loads, design the reinforcement required for the column, if outside diameter of the column is 700 mm.

(16 Marks)

Exam Committee: Dr. M. E. Shoukry & Dr. A. E. Helba

4. Figure 2 shows the **ultimate (factored)** loads acting on beam ABC of span 8.0 m with an overhanging end of 2.0 m length. The cross section of the beam has a web width b = 200 mm and flange thickness t_s = 120 mm. The spacing of the beam = 3.5 m. Columns at supports have square cross section with side length = 400 mm. It is required to:

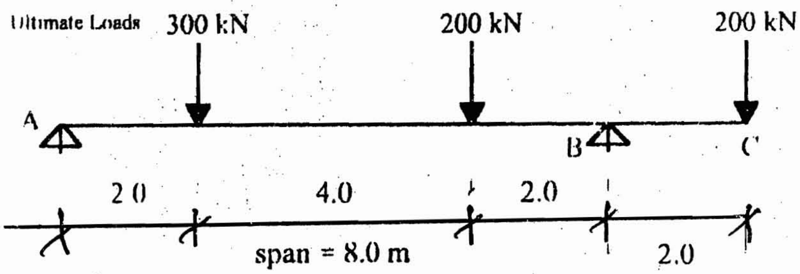
a. Design the beam section and calculate the longitudinal reinforcement required for positive and negative moments. Use concrete cover ≈ 70 mm.

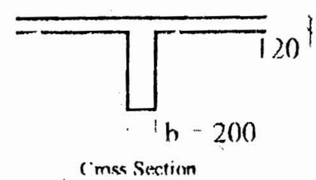
b. Design the shear reinforcement of the beam using ***vertical stirrups only***

c. Draw the longitudinal and cross sections (**scale 1:25**) showing reinforcement details. **Show the curtailment of longitudinal bars توقف صلب التسليح according to bending moment diagram (Draw moment of resistance diagram; Mr – diag.)**

d. If shear is resisted by bent-up bars & vertical stirrups, calculate the required bent-up bars at the left side of support B, and fix their position in a sketch

(25 Marks)





5. A Reinforced Concrete rectangular section with width b = 450 mm, height h = 700 mm, effective depth d = 650 mm, concrete cover = 25 mm (giving x_1 = 400 mm and y_1 = 650 mm). The section is subjected to an ultimate torsion moment M_{tu} = 70 kN.m and a factored shear force Q_u = 300 kN. The flexural reinforcement is 6 bars, 16 mm diameter. It is required to:

i. Calculate the required torsion and shear reinforcement

ii. Draw, to scale 1:20, the cross section showing longitudinal steel and stirrups.

(15 Marks)

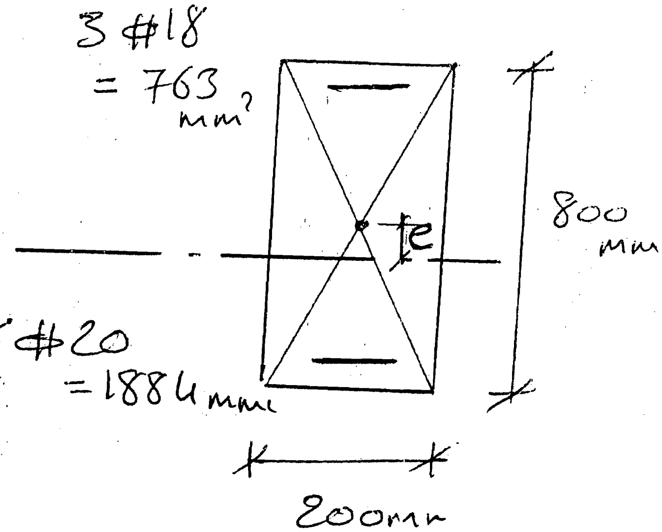
Area of reinforcing bars

φ, mm	8	10	12	16	18	20	22	25
Area, mm^2	50	79	113	201	254	314	380	491

Qu 1 :

(i) Calculate the +ve cracking Moment:

$*\sum M$ @ c.g. **عزوم مساحة**



$$10(1884)\left(\frac{800}{2}-50\right)$$

$$-10(763)\left(\frac{800}{2}-50\right)$$

$$=\left[800\times200+10(1884)+10(763)\right]e$$

$$\therefore e = 21.04\ mm$$

$$* I_{N.A} = \frac{200\times800^3}{12}+200(800)(21.04)^2$$

$$+10(1884)\left(\frac{800}{2}-21.04-50\right)^2$$

$$+10(763)\left(\frac{800}{2}+21.04-50\right)^2$$

$$I_{N.A} = 1.169 * 10^{10}\ mm^4$$

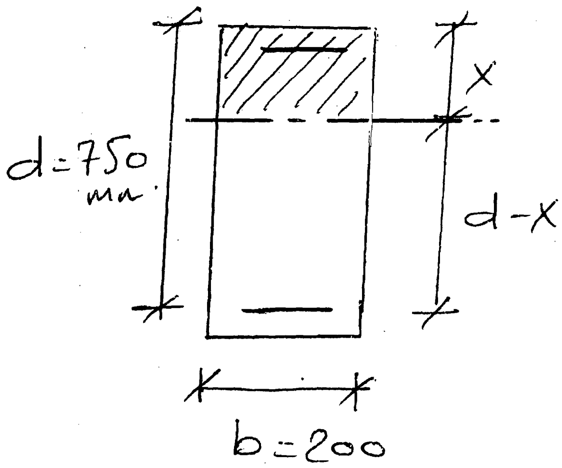
$$f_{cr} = 0.6\sqrt{f_{cu}} = 0.6\sqrt{30} = 3.3\ N/mm^2$$

$$f_{cr} = \frac{M_{cr}}{I_{N.A}} \left(h/2 - e \right)$$

$$3.3 = \frac{M_{cr} * 10^6}{1.169 \times 10^{10}} \left(\frac{800}{2} - 21.04 \right)$$

$$\boxed{M_{cr} = 101.8 \ KN.m}$$

(ii) **The maximum working mom.: (M^{w}_{max})**



* $\Sigma M @ N.A = 0.0$

$$200 \frac{X^2}{2} + 15 (763) (X - 50) = 15 (1884) (750 - X)$$

$$\longrightarrow \boxed{X = 308.51 \ mm}$$

* $$I_{N.A} = \frac{200 (308.51)^3}{3} + 15 (763) (308.51 - 50)^2 + 15 (1884) (750 - 308.51)^2$$

$$\boxed{I_{N.A} = 8.23 \times 10^9 \ mm^4}$$

* $$f_c = f_{call} = 10.5 = \frac{M_1 \times 10^6}{8.23 \times 10^9} (308.51)$$

$$\boxed{M_1 = 280.1 \ KN.m}$$

$$* \quad \frac{f_s}{n} = \frac{f_{s\,all}}{n} = \frac{220}{15} = \frac{M_2 \times 10^6}{8.23 \times 10^9} (750 - 308.$$

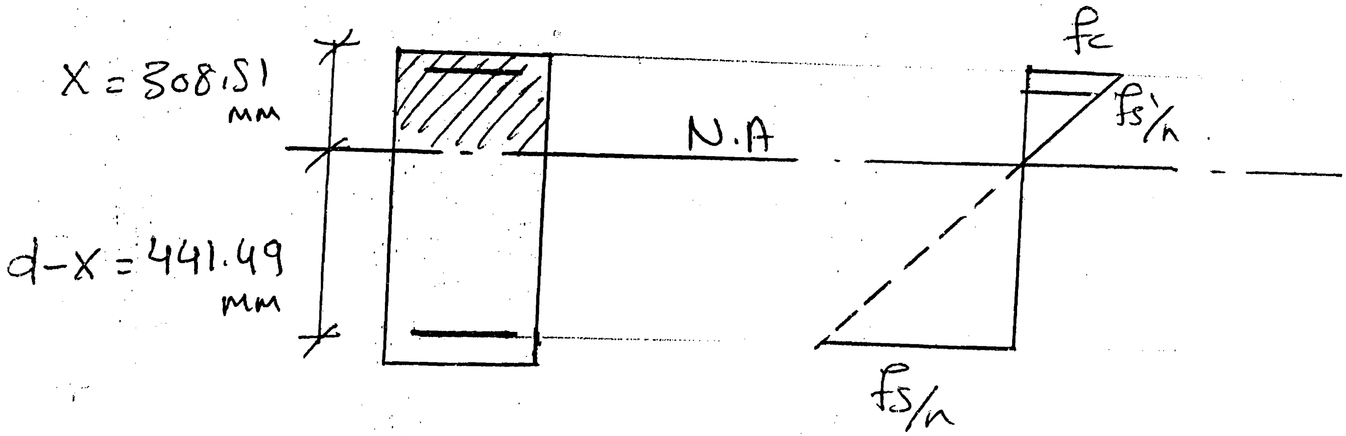
$$\boxed{M_2 = 273.4 \ KN.m}$$

$$M^{w}_{max} = 273.4 \ KN.m \longrightarrow$$ أقل من الاثنين

(iii) Check the stresses in steel & Conc. if subjected $M_w = 150 \ KN.m$.

$$M_w = 150 \ KN.m > M_{cr} = 101.8 \ KN.m$$

$\hookrightarrow$ stage (II) $\boxed{n = 15}$



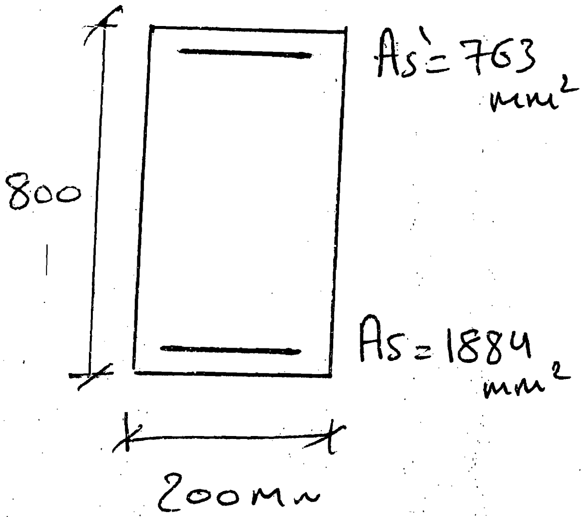
$$f_c = \frac{150 * 10^6}{8.23 \times 10^9} (308.51) = 5.62 \ N/mm^2 < f_c \longrightarrow ok$$

$$f_s' = 15 * \frac{150 \times 10^6}{8.23 \times 10^9} (308.51 - 50) = 70.67 \ N/mm^2 < f_s \longrightarrow ok$$

(n) ↗

$$f_s = 15 * \frac{150 \times 10^6}{8.23 \times 10^9} (441.49) = 120.698 \ N/mm^2 < f_s \longrightarrow ok.$$

(IV) The ultimate positive moment (M_u):



ass $\varepsilon_s > \varepsilon_y \longrightarrow T = f_y/\gamma_s \, A_s$.

$$\frac{A_s'}{A_s} = 40\% < 60\%$$

ass $\varepsilon_s' > \varepsilon_y \longrightarrow C_s = f_y/\gamma_s \, A_s'$

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

$$0.67 * \frac{30}{1.5} * a * 200 + \frac{400}{1.15}(763) = \frac{400}{1.15}(1884)$$

$$\longrightarrow a = 145.49 \text{ mm}$$

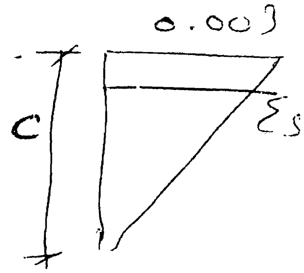
$$c = a/0.8 = 181.86 \text{ mm}.$$

check:

$$c_b = \frac{600}{600 + f_y/\gamma_s}(d) = \frac{600}{600 + \frac{400}{1.15}}(750)$$

$$c < c_b = 474.77 \text{mm} \longrightarrow$$ الفرض الأول صحيح

$$\varepsilon_s' = 0.003\left(\frac{181.86 - 50}{181.86}\right) = 0.00217.$$



$$\varepsilon_y = \frac{f_y}{\gamma_s E_s} = \frac{400}{1.15(2 \times 10^5)} = 0.00174$$

$$\boxed{\varepsilon_s' > \varepsilon_y} \longrightarrow$$ الفرض الثاني صحيح

$$M_u = C_c(d - a/2) + C_s(d - d'')$$

$$M_u = 0.67 \times \frac{30}{1.5} * 145.49 \times 200 \left(750 - \frac{145.49}{2}\right)$$

$$+ \frac{400}{1.15} \times 763 (750 - 50) / 10^6$$

$$M_u = 449.84 \text{ KN.m}$$

Qu 2

<u>Given:</u> $M_u = 125$ KN.m.

$d = 1000$ mm. $b = 200$ mm.

$f_{cu} = 20$ N/mm² $F_y = 360$ N/mm²

$R_{max} = 0.194$

$$d_{min} = \sqrt{\frac{1}{R_{max} \frac{f_{cu}}{\gamma_c}}} * \sqrt{\frac{M_u}{b}}$$

$$d_{min} = \sqrt{\frac{1}{0.194 \times \frac{20}{1.5}}} * \sqrt{\frac{125 \times 10^6}{200}} = 491.55 \text{mm}$$

$d_{giv} = 1000$ mm $> d_{min} = 491.55$ mm

→ use T.S only

* **KFT:**

$$M_u = C_c \left(d - \frac{a}{2}\right)$$

$$125 \times 10^6 = 0.67 \times \frac{20}{1.5} \times a \times 200 \left(1000 - \frac{a}{2}\right)$$

$$\longrightarrow a = 72.597 \text{ mm}$$

$$a_{min} = 0.1 d = 100 \text{ mm}$$

اكبر

$$A_s = \frac{M_u}{\frac{f_y}{\gamma_s} \left(d - \frac{a}{2}\right)}$$

$$A_s = \frac{125 \times 10^6}{\frac{360}{1.15} \left(1000 - \frac{100}{2}\right)} = 420.32 \text{ mm}^2$$

$$A_{s\,min} = 0.15\% \; bd$$

$$= \frac{0.15}{100} \times 200 \times 1000 = 300 \text{ mm}^2$$

$$A_{s\,min} = \frac{1.1}{f_y} bd$$

$$= \frac{1.1}{360} \times 200 \times 1000 = 611.11 \text{ mm}^2$$

اكبر

$$A_s = 611.11 \text{ mm}^2 \longrightarrow 3 \# 18$$

if the (h) is reduced to 550 mm:

$h = 550\ mm$

$d = 500\ mm > d_{min} = 491.55\ mm$

→ use tension steel only

RFT:

$$M_u = C_c (d - a/2)$$

$$125 \times 10^6 = 0.67 \times \frac{20}{1.5} \times a \times 200 (500 - a/2)$$

→ $a = 168.285\ mm$

$a_{min} = 0.1 d = 50\ mm$

} $\checkmark$

$$A_s = \frac{M_u}{f_y/\gamma_s\ (d - a/2)}$$

$$A_s = \frac{125 \times 10^6}{\frac{360}{1.15}\left(500 - \frac{168.285}{2}\right)} = 960.19\ mm^2$$

3 #22

$$\text{\% of RFT increased} = \frac{960.19 - 611.11}{611.11}$$

% of RFT increased = 57.12 %

Qu 3

$$P_u = 1.5\,(P_{DL} + P_{LL})$$

$$P_u = 1.5\,(2500 + 1750) = 6375\ \text{KN}$$

$$P_u = 0.35\,f_{cu}\,A_{creq} + 0.67\,f_y\,A_s$$

assume: $\mu = 1\% = \dfrac{A_s}{A_{creq}}$

$$6375 \times 10^3 = A_{creq}\,(0.35 \times 30 + 0.67 \times 400 \times 0.01)$$

$$A_{creq} = 483687.4\ \text{mm}^2 = \frac{\pi}{4} D^2$$

$$D = 784.76\ \text{mm}$$

$$D_{act} = 800\ \text{mm}$$

$$A_{cact} = \frac{\pi}{4}(800^2) = 502654.82\ \text{mm}^2$$

$$A_s = 0.01\,(A_{creq}) = 4836.87\ \text{mm}^2$$

$$= 0.006\,(A_{cact}) = 3015.92\ \text{mm}^2$$

16 Φ20

ϕ_{st} → 8 mm, $\dfrac{\phi_{max}}{4}$ → **$\phi_{st} = 8$ mm**

$S \begin{cases} \rightarrow 15\,\phi_{min} \\ \rightarrow 200\,mm \end{cases} \rightarrow \boxed{S = 200\,mm}$

check: $\dfrac{\text{vol. of stirrups}}{\text{vol. of conc.}} \geq 0.25\,\%$

$$\frac{\pi/4\,(8^2)\,[\pi\,(750)]}{502654.82 * 200} = 0.11\,\% < 0.25\,\%$$

try: $\boxed{\phi_{st} = 12\,mm.}$

$$\frac{\pi/4\,(12^2)\,[\pi\,(750)]}{502654.82 \times 200.} = 0.265\,\% > 0.25\,\% \rightarrow ok.$$

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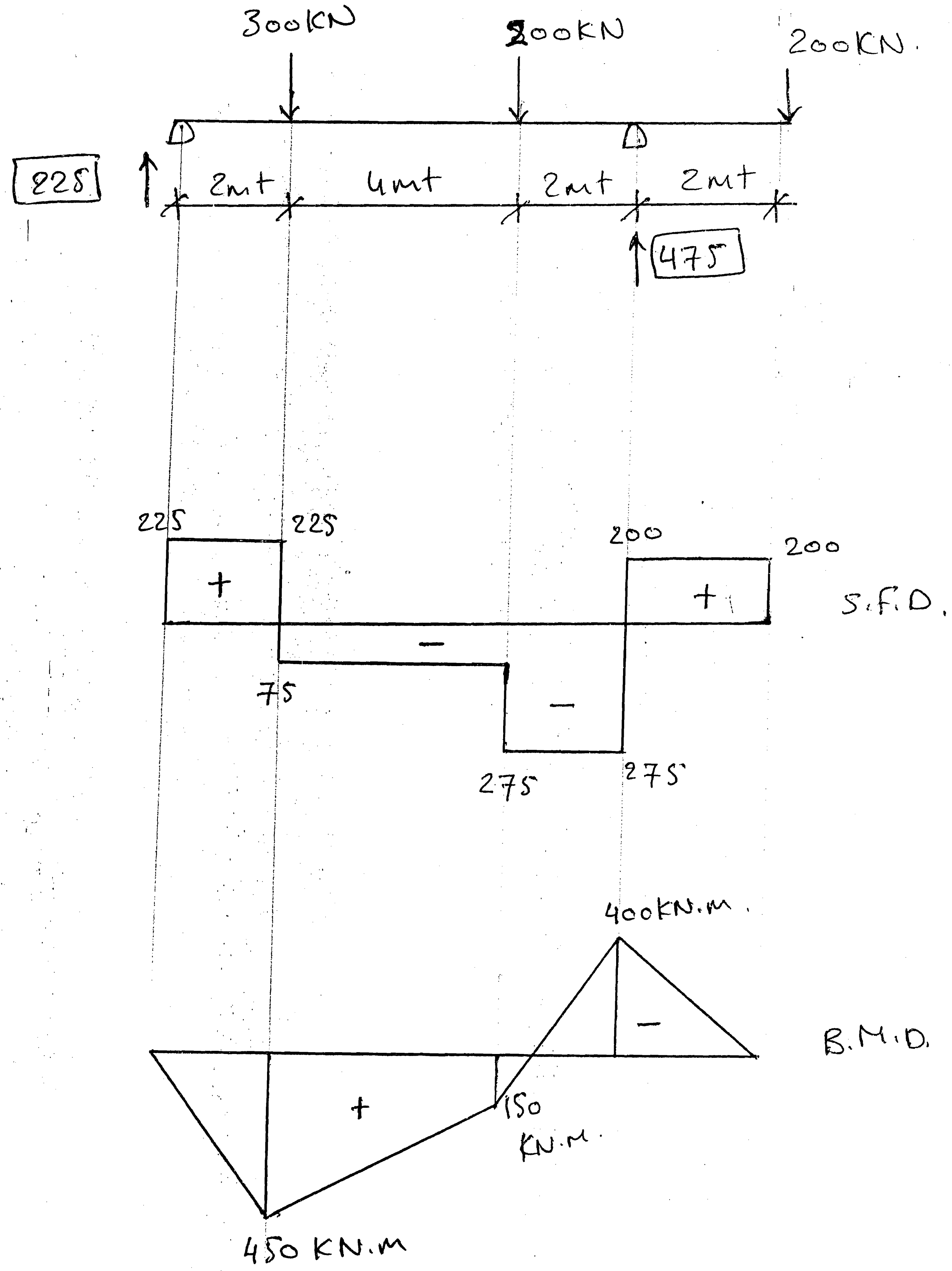
if the outer diameter = 700 mm $\rightarrow A_s = ??$

$$P_u = 0.35\,f_{cu}\,A_c + 0.67\,f_y\,A_s.$$

$$6375 \times 10^3 = 0.35 \times 30 \times (\pi/4 \times 700^2) + 0.67 \times 400 \times A_s$$

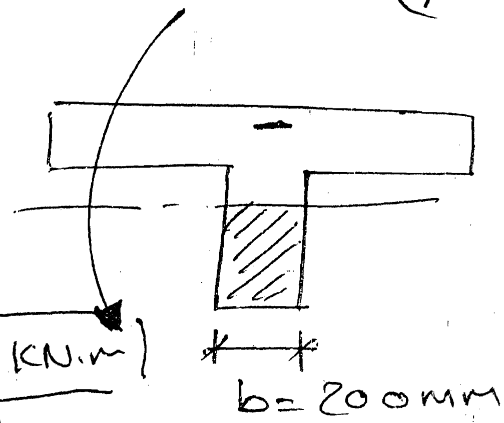
$$\boxed{A_s = 8709.427\,mm^2} \rightarrow \boxed{18\,\#25}$$

Qu4


300KN
200KN
200KN.
225
2mt
4mt
2mt
2mt
475
225
225
200
200
+
+
S.F.D.
−
−
75
275
275
400KN.m.
−
B.M.D.
+
150
KN.M.
450 KN.m

Design for (−ve) Moment:-

عزم سالب ، يتم تصميم قطاع مستطيل



$$M^{-ve} = 400\ kN.m$$

$$d_{min} = \sqrt{\frac{1}{R_{max}\frac{f_{cu}}{\gamma_c}}} * \sqrt{\frac{M_u}{b}}$$

$$d_{min} = \sqrt{\frac{1}{0.187 \times \frac{30}{1.5}}} * \sqrt{\frac{400 \times 10^6}{200}} = 731.27\ mm.$$

given

$$h = d + d' = 731 + \boxed{70} = 801 mm$$

take $h_{act} = 850\ mm$

$d_{act} = 780\ mm$

RFT:

$$M_u = C_c\,(d - a/2)$$

$$400 \times 10^6 = 0.67 \times \frac{30}{1.5} \times a \times 200\,(780 - a/2)$$

$$\longrightarrow a = 223.32\ mm$$

$$a_{min} = 0.1d = 78mm$$

اوكي

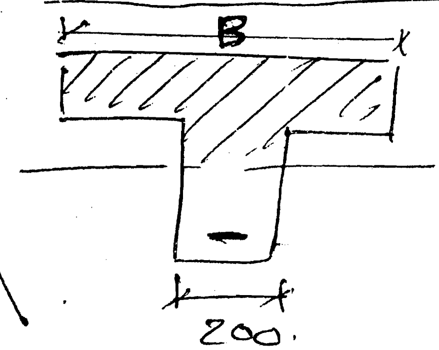
$$A_s^{-ve} = \frac{M_u^{-ve}}{\frac{f_y}{\gamma_s}\left(d - \frac{a}{2}\right)} = \frac{400 \times 10^6}{\frac{400}{1.15}\left(780 - \frac{223.32}{2}\right)}$$

$$A_s^{-ve} = 1720.68\ mm^2 \longrightarrow \boxed{6\ \#20}$$

Design for +ve Moment :

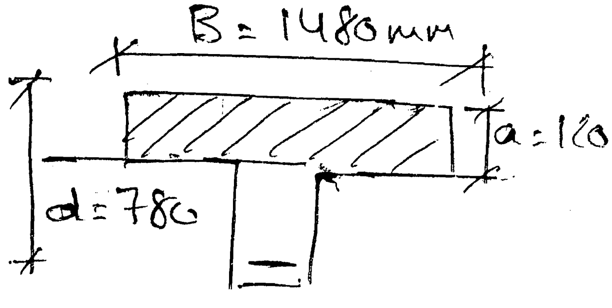
$\boxed{M^{+ve}_{max} = 450\ KN.m}$

∴ عزم موجب ، سيتم تصميم قطاع T-section.



B:
- $b + 16t_s = 200 + 16(120) = 2120\ mm$
- $b + \frac{\ell_2}{5} = 200 + \frac{0.8(8000)}{5} = \boxed{1480\ mm}$ أقل
- $\text{℄} \mid \text{℄}$ (spacing) $= 3500\ mm$

assume $a = t_s = 100\ mm$:



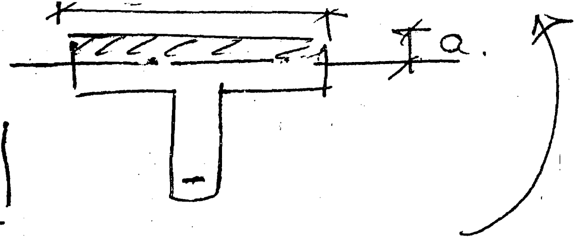
$$M_{u\,max} = C_c\left(d - \frac{a}{2}\right)$$
المقاومة

$$= 0.67 \times \frac{30}{1.5} \times 120 \times 1480 \left(780 - \frac{120}{2}\right) / 10^6$$

$$M_{u\,max} = 1713.48\ KN.m > M_u^{+ve} = 450$$
المقاومة

$\boxed{a < t_s}$

$a < t_s$



$M_u = 450$ kN.m

$M_u = C_c (d - a/2)$

$$450 \times 10^6 = 0.67 \times \frac{30}{1.5} \times a \times 1480 (780 - a/2)$$

$\longrightarrow a = 29.65$ mm

$a_{min} = 0.1d = 78$ mm

$\} \delta_1$

RFT:

$$A_s^{+ve} = \frac{M_u^{+ve}}{f_y/\gamma_s (d - a/2)}$$

$$A_s^{+ve} = \frac{450 \times 10^6}{\frac{400}{1.15}\left(780 - \frac{78}{2}\right)} = 1745.9 \text{ mm}^2$$

$\longrightarrow$ 6 #20

$A_s' = 0.1 A_s^{+ve}$ = 174.5 mm^2

$\longrightarrow$ 2 #12

b Design of shear Reinforcement

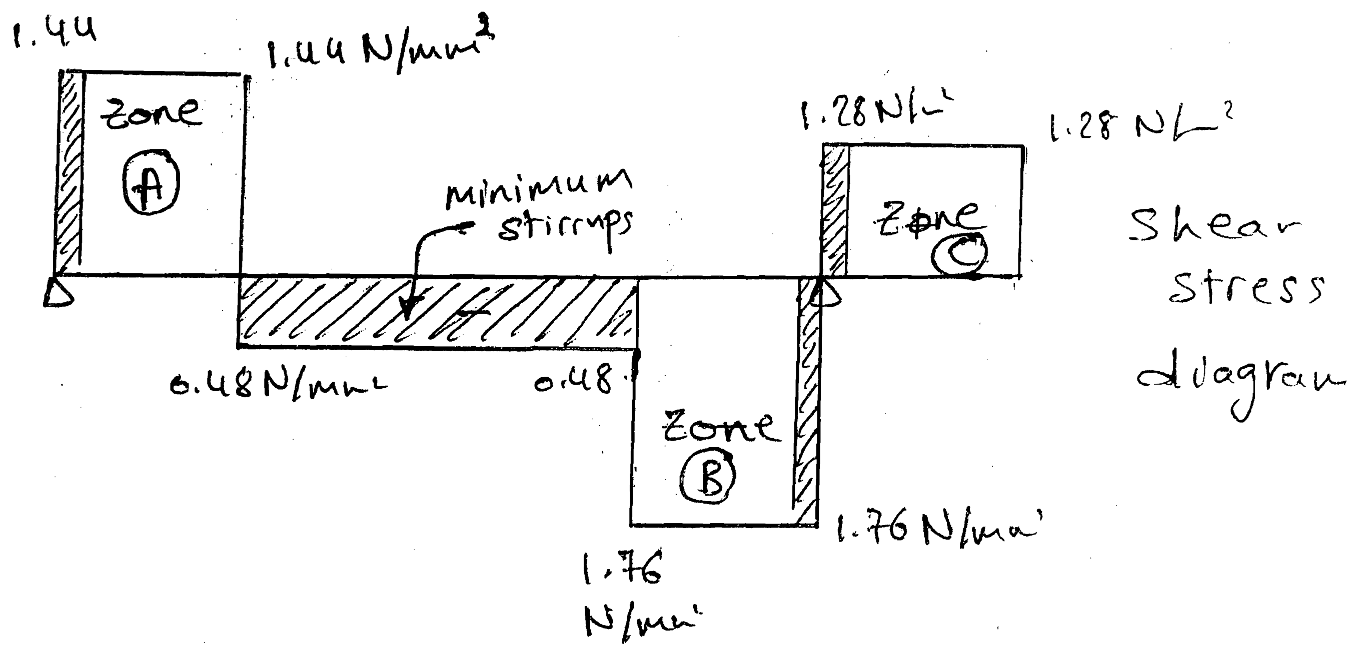
$$q_{cu} = 0.24\sqrt{\frac{f_{cu}}{\gamma_c}} = 0.24\sqrt{\frac{30}{1.5}} = 1.07\ N/mm^2$$

$$q_{umax} = 0.7\sqrt{\frac{f_{cu}}{\gamma_c}} = 0.7\sqrt{\frac{30}{1.5}} = 3.13\ N/mm^2$$

$$q = \frac{Q \times 10^3}{bd} = \frac{Q \times 10^3}{200(780)}$$

$$\boxed{q = 0.0064\, Q}$$

* للتحويل من (S.F.D) إلى (shear stress diag.)
يتم استخدام العلاقة السابقة



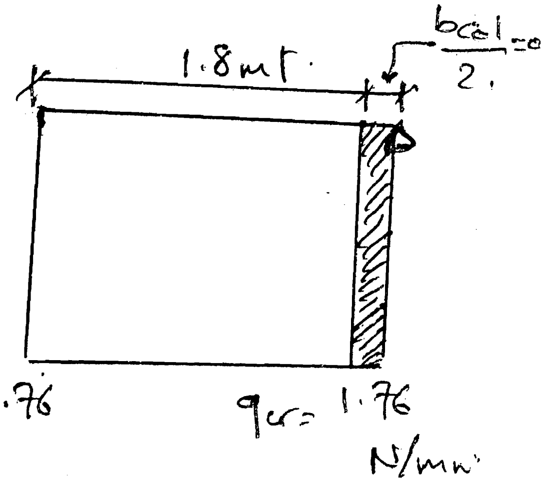
Zone [B]:

يتم حل هذه المنطقة اولاً عشان
فيها اكبر اجهادات قص.

$$q_{u_{max}} > q_{cr} > q_{cu}$$ ⟶ use special shear Reinforcement

(stirrups only) ⟵ المطلوب كده:

$$q_{cr} = \frac{q_{cu}}{2} + q_{sus}$$



$$1.76 = \frac{1.07}{2} + q_{sus}$$

$$q_{sus} = 1.225 \ N/mm^2$$

$$q_{sus} = \frac{A_{st}\,(f_y/\gamma_s)}{b\,s}$$

ass 2br st. ϕ 8mm
⟶ $A_{st} = 2 \times 50$

$$1.225 = \frac{2 \times 50\,(240/1.15)}{200 \times s}$$ ⟶ $s = 85.18 < 100$

try 2br st. ϕ 10mm ⟶ $A_{st} = 2 \times 79$

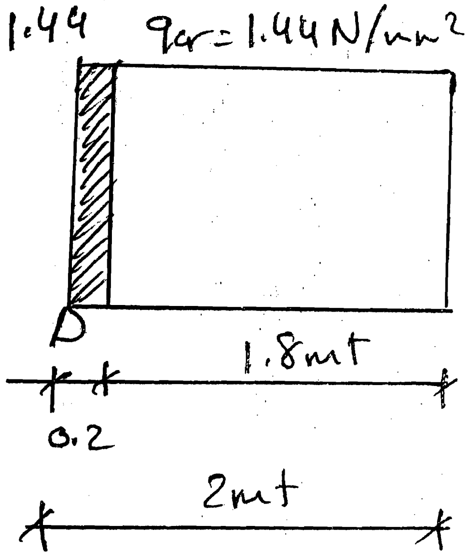
⟶ $s = 134$ take $s = 125$

use 2br st. ϕ 10mm @ $s = 125$mm

Zone [A]:

$q_{u_{max}} > q_{cr} > q_{cu}$

use special shear RFT (stirrups only)



$$q_{cr} = \frac{q_{cu}}{2} + q_{sus}$$

$$1.44 = \frac{1.07}{2} + q_{sus} \longrightarrow q_{sus} = 0.905 \; N/mm^2$$

$$q_{sus} = \frac{A_{st}\,(f_y/\gamma_s)}{b\,S}$$

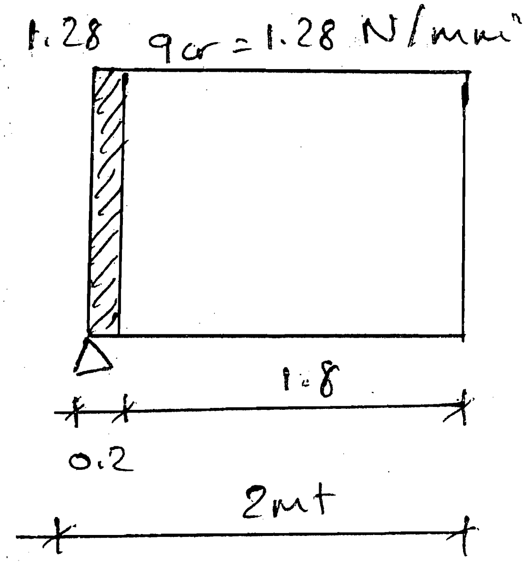
ass 2br st $\phi 8$ ⟶ $A_{st} = 2 \times 50$

$$0.905 = \frac{2 \times 50 \,(240/1.15)}{200 \times S} \longrightarrow S = 115.3$$

take: $S = 100$

use 2br st. ϕ 8mm @ S = 100mm.

Zone [C] 1.



$q_{u_{max}} > q_{cr} > q_{cu}$ → use special shear RFT. (stirrups only)

$$q_{cr} \leq \frac{q_{cu}}{2} + q_{sus}$$

$$1.28 = \frac{1.07}{2} + q_{sus} \longrightarrow q_{sus} = 0.745\ N/mm^2$$

$$q_{sus} = \frac{A_{st}\,(F_y/\gamma_s)}{b\,S}$$

ass 2br st ϕ8mm

→ $A_{st} = 2 \times 50$

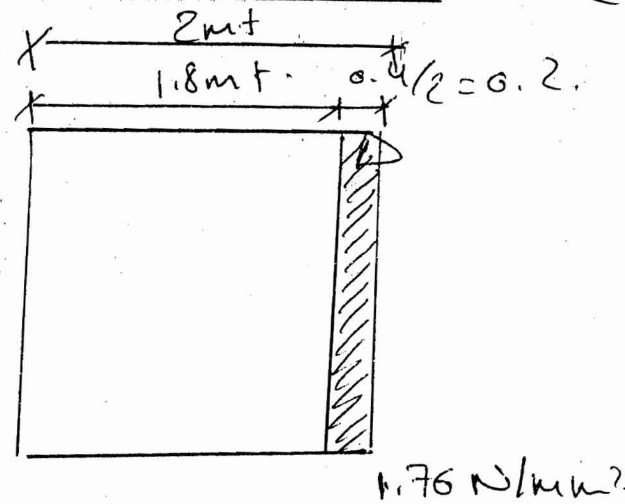
$$0.745 = \frac{2 \times 50\,(240/1.15)}{200 * S} \longrightarrow S = 140.06\,mm$$

take, $S = 125\,mm$

use 2br st. ϕ8mm @ S = 125mm.

[d] Vertical stirrups & bent up bars ::

Zone [B] ::



$q_{cr} = 1.76 \ N/mm^2$

$q_{u_{max}} > q_{cr} > q_{cu}$ → use sp. shear RFT.

stirrups + Bent up Bars

$$q_{cr} = \frac{q_{cu}}{2} + q_{sus} + q_{sub}$$

use 2br st. Φ8mm @ S = 200mm → $A_{st} = 2 \times 50$

$$q_{sus} = \frac{A_{st}\,(f_y/\gamma_s)}{b\,S} = \frac{2 \times 50\,(240/1.15)}{200 \times 200} = 0.521 \ N/mm^2$$

$$1.76 = \frac{1.07}{2} + 0.521 + q_{sub}$$

$\therefore q_{sub} = 0.7 \ N/mm^2$

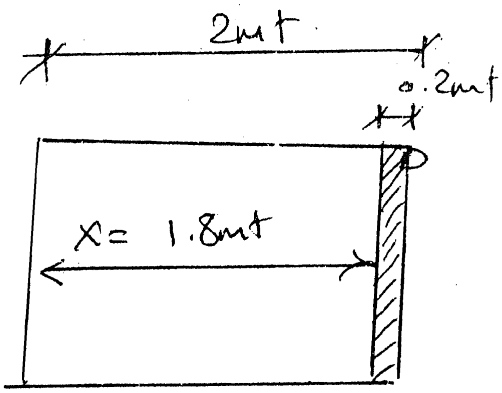
$$q_{sub} = \frac{A_{sb}\,(f_y/\gamma_s)\,\sqrt{2}}{b\,S}$$

$q_{cr} = 1.76 \ N/mm^2 > 1.5\,(q_{cu}) = 1.605 \ N/mm^2$

→ $S = d = 780 \ mm$

$$0.7 = \frac{A_{sb}\,(400/1.15)\sqrt{2}}{200 \times 780}$$

$\longrightarrow A_{sb} = 222\ mm^2 \longrightarrow$ **1 Φ20**



حساب عدد التكسيات $= \frac{X}{S}$

$= \frac{1.8}{0.78} = 2.3$ تكسية

$=$ **3 تكسيات**

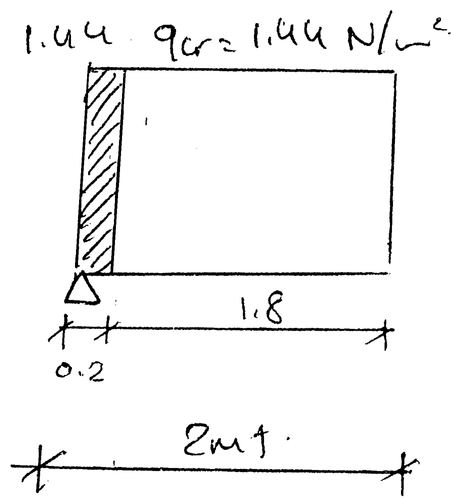
التقسيم الفعلي

spacing actual $= \frac{X}{\text{عدد مرات التكسيح}} = \frac{1.8}{3} = 0.6mt$

$S_{act} = 600mm$

Zone A :

$q_{cr} = 1.44$



$q_{u_{max}} > q_{cr} > q_{cu}$ $\longrightarrow$ use sp. shear RFT.

(stirrups + Bent up Bars).

$q_{cr} = \frac{q_{cu}}{2} + q_{sus} + q_{sub}$

use 2br st ϕ8mm @ S = 200 mm

→ $A_{st} = 2 \times 50$

$$q_{sus} = \frac{2 \times 50 \,(240/1.15)}{200 \times 200} = 0.522 \ N/mm^2$$

$$1.44 = \frac{1.07}{2} + 0.522 + q_{sub}$$

→ ∴ $q_{sub} = 0.384 \ N/mm^2$

$$q_{sub} = \frac{A_{sb}\,(f_y/\gamma_s)\sqrt{2}}{b\,S}$$

$q_{cr} = 1.44 \ N/mm^2 < q_{cu} * 1.5 = 1.605 \ N/mm^2$

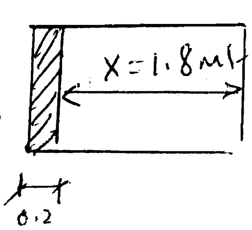
→ take: $S = 1.5\,d = 1.5\,(780)$

$S = 1170$ mm

$$0.384 = \frac{A_{sb}\,(400/1.15)\sqrt{2}}{200 \times 1170}$$

∴ $A_{sb} = 182 \ mm^2$ → 1 #20

$$\text{عدد مرات التكسيح} = \frac{X}{S} = \frac{1.8}{1.17} = 1.53 = 2 \text{ تكسيحة}$$



$$\text{actual spacing (التقسيط الفعلي)} = \frac{X}{\text{عدد مرات}} = \frac{1.8}{2} = 0.9 \text{ mt.}$$

$S_{act} = 900$ mm

Zone [e] : (لا بولي)

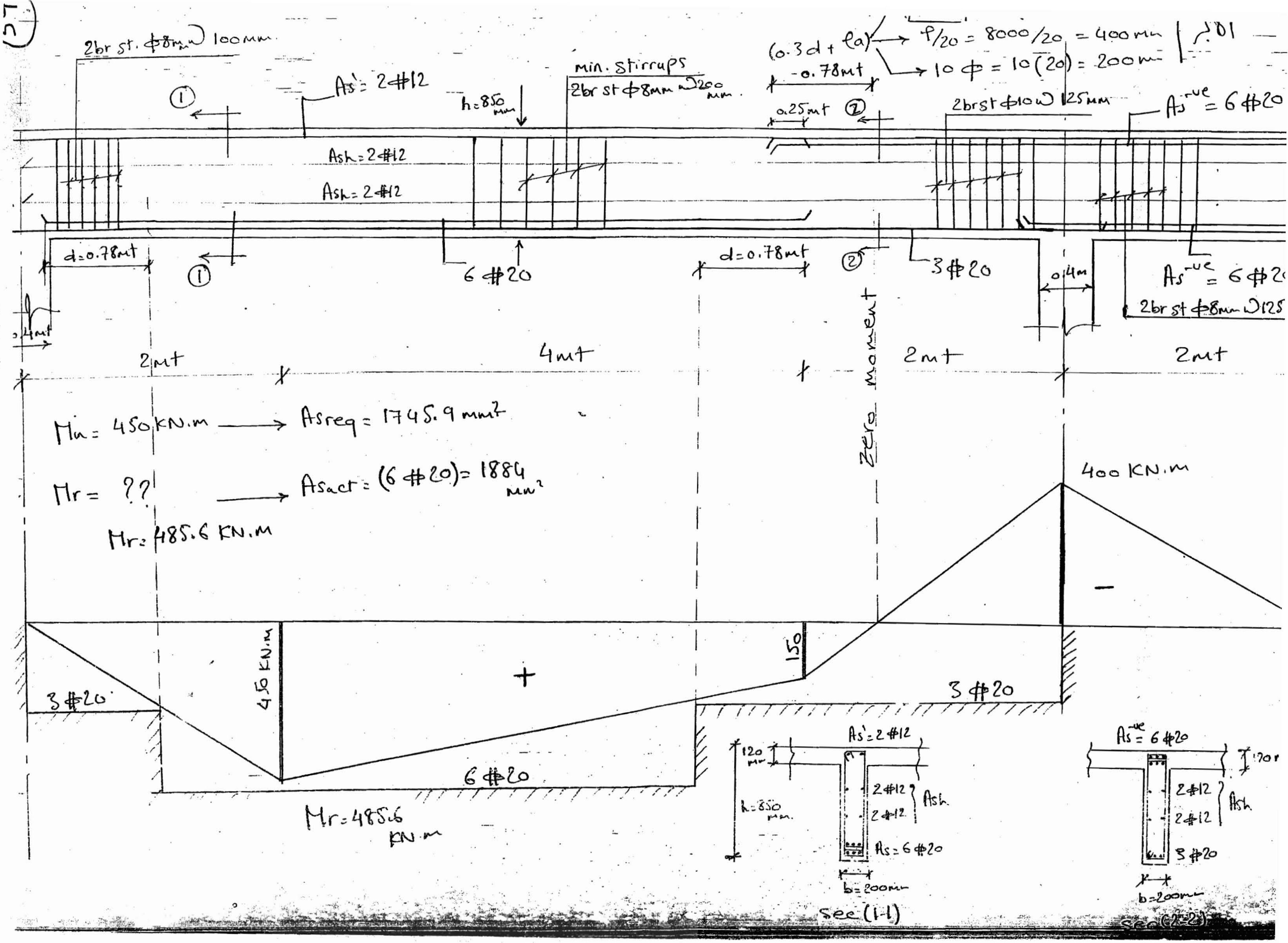
(5

(stirrups only) ← كابولي (Zone [c])

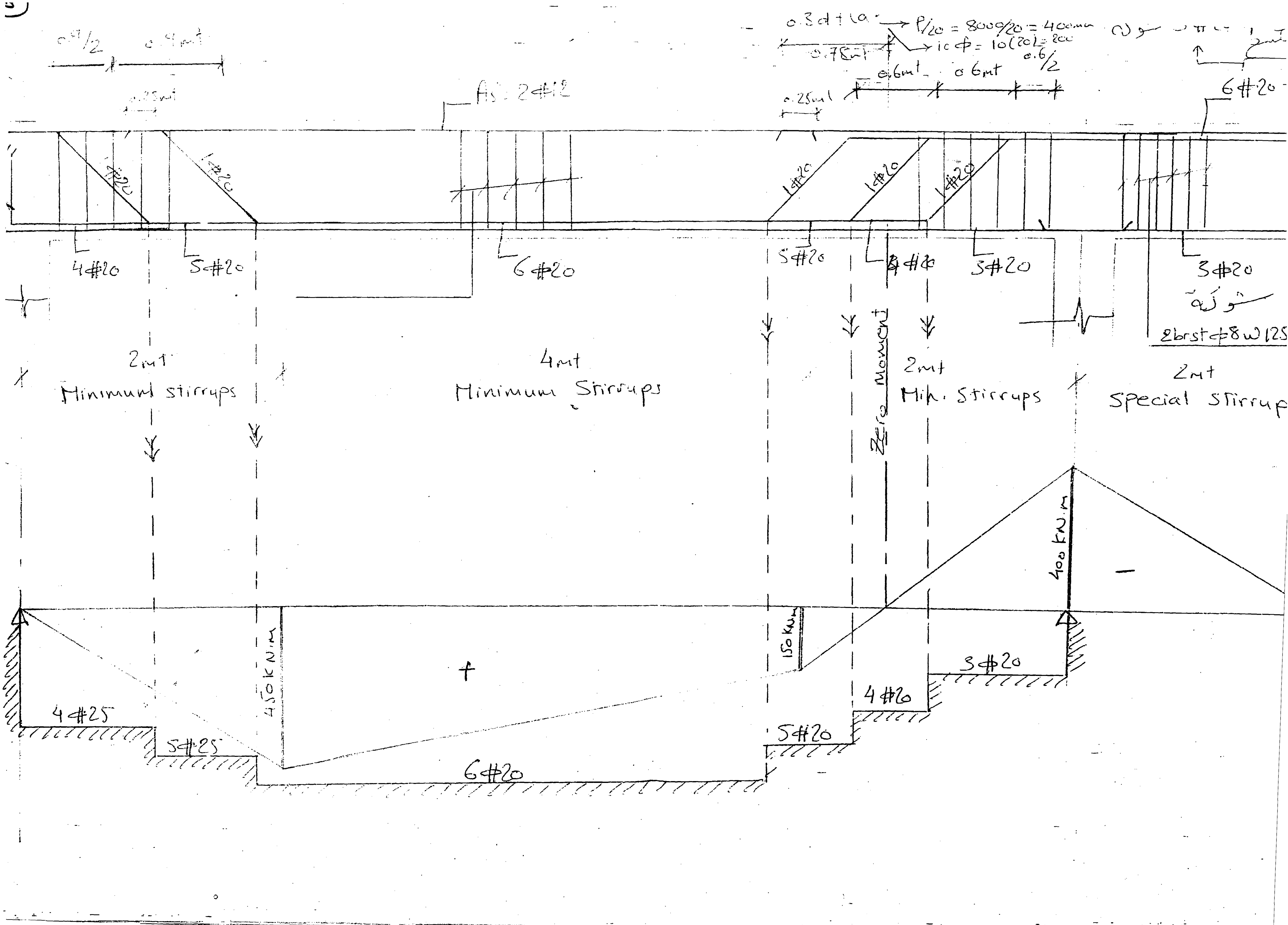
لا يوجد تكسيح في الكابولي

وسط كما هي (Zone [c])

2br st Φ8mm @ s=125mm.



2br st. φ8mm @ 100mm
As' = 2#12
h = 850 mm
min. stirrups
2br st φ8mm @ 200 mm
(0.3d + ℓa)
ℓ/20 = 8000/20 = 400 mm
10 φ = 10(20) = 200 mm
0.78 mt
0.25 mt
2br st φ10 @ 125 mm
As^-ve = 6 φ20
Ash = 2#12
Ash = 2#12
d = 0.78 mt
6 #20
d = 0.78 mt
3 #20
0.4 m
As^-ve = 6 φ20
2br st φ8mm @ 125
0.4 mt
2 mt
4 mt
2 mt
2 mt
zero moment
Mu = 450 KN.m → Asreq = 1745.9 mm²
Mr = ?? → Asact = (6 #20) = 1884 mm²
Mr = 485.6 KN.M
400 KN.m
450 KN.m
150
3 #20
3 #20
6 #20
Mr = 485.6 KN.m
As' = 2 #12
120 mm
h = 850 mm
2#12
2#12
Ash
As = 6 #20
b = 200 mm
sec (1-1)
As^-ve = 6 φ20
120 mm
2#12
2#12
Ash
3 #20
b = 200 mm
sec (2-2)


0.9/2
0.9mt
0.25mt
As: 2#12
0.3d + la
ℓ/20 = 8000/20 = 400mm
10 Φ = 10(20) = 200
0.78mt
0.6mt
0.6mt
0.6/2
0.25mt
6#20
1#20
4#20
5#20
6#20
3#20
2mt
Minimum stirrups
4mt
Minimum Stirrups
Zero Moment
2mt
Min. Stirrups
2mt
Special Stirrup
2brst Φ8 w 125
450 KN.m
150 KN.m
400 KN.m
+
−
4#25
5#25
6#20
5#20
4#20
3#20

Alexandria University
Faculty of Engineering
Second year Civil Engineering (تخلفات)

Reinforced concrete-1
June 2009
time allowed: ***3 hours***

Materials to be used: **concrete:** f_{cu}=25MPa
Steel: st.360/520 (for longitudinal reinforcement) & st.240/350 (for stirrups)

Working Stress Design Method:
$f_{c\ allowable}=9.5N/mm^2$, $f_{s\ allowable}$ (for st.360/520)=$200N/mm^2$, $f_{ctr}=3.0N/mm^2$

Ultimate Strength Design Method:
$c_{max}/d=0.44$, $\mu_{max}=5.0\times10^{-4}f_{cu}$, $R_{max}=0.194$
$q_{cu}=0.24(f_{cu}/\gamma_c)^{1/2}$, $q_{u\ max}=0.7(f_{cu}/\gamma_c)^{1/2}$
$L_d=55\varphi$ (for η=1.0)
η=1.0 (for bottom bars), η=1.3 (for top bars)

Question 1: (15% of max credit)
Define briefly (using sketches) the following:
a) Balanced section.
b) Under-reinforced section.
c) Over-reinforced section.

State the Egyptian Code requirements for the following:
d) Minimum reinforcement for sections subjected to flexure.
e) Minimum web reinforcement for beams.
f) Minimum longitudinal reinforcement for short columns.
g) Stirrups for tied columns.

Question 2: (20% of max credit)
For the reinforced concrete rectangular section shown in Fig.1, calculate the following:
a) Cracking moment.
b) Service moment capacity.
c) Ultimate moment capacity.

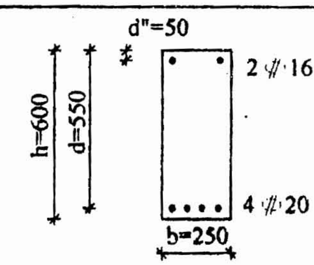


Fig.1

Question 3: (15% of max credit)
For a reinforced concrete rectangular beam section (b=300mm, d=730mm), calculate the following:
a) Maximum area of tensile reinforcement allowed in the section and the corresponding ultimate moment.
b) Reinforcement required to resist an ultimate moment (M_u=600 kN.m).

Question 4: (10% of max credit)
Calculate the ultimate moment capacity for the reinforced concrete T-section shown in Fig.2.

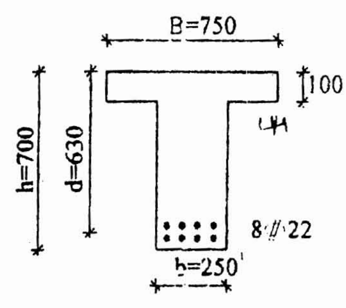


Fig.2

uestion 5: (40% of max credit)

g.3 shows a reinforced concrete beam (span=6.00m) with two overhanging ends (length=2.00m) pported on two columns (0.30×0.30m). The spacing between the beams is 3.00m. The beam cross ction and the **ultimate loads** acting on the beam are shown in the figure. It is required to:

a) Draw the bending moment and the shearing force diagrams.
b) Design the reinforcement required for the positive and negative bending moments.
c) Design the web reinforcement using vertical stirrups only.
d) Draw a longitudinal section of the beam (scale 1:40) and a cross section at mid-span (scale 1:20) showing all reinforcement details using reasonable cutoff points.

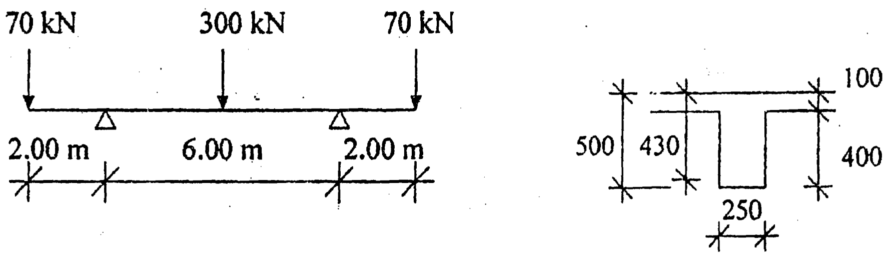


Fig.3

Best wishes...

70

Qu 1:

*Define briefly (using sketches):

a) Balanced section:

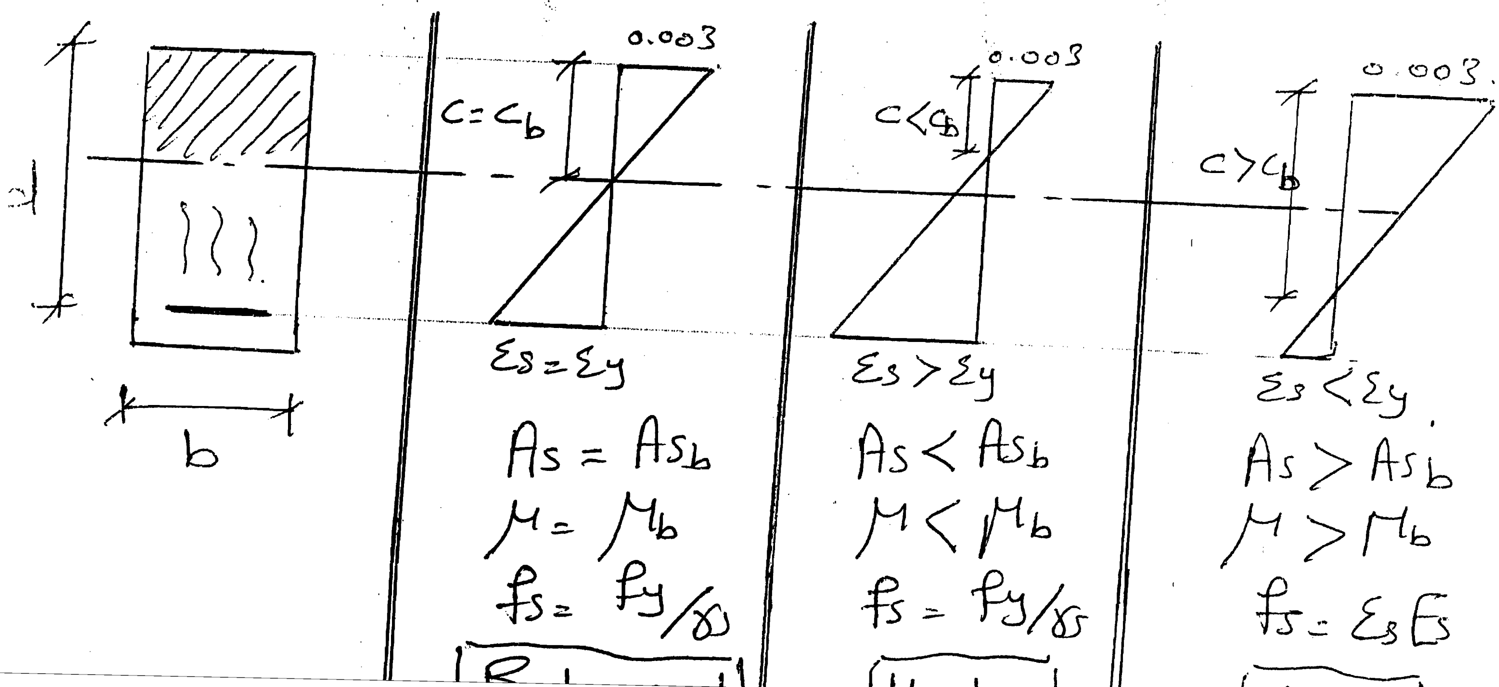
هو القطاع الذى يحدث فيه انهيار فى الحديد فى نفس وقت انهيار الخرسانة.

b) Under-Reinforced section:

هو القطاع الذى يحدث فيه انهيار فى الحديد أولاً ويكون انهيار مطيل ← لذلك هو مقبول من الكود المصرى لأنه يعطى إنذار قبل الانهيار.

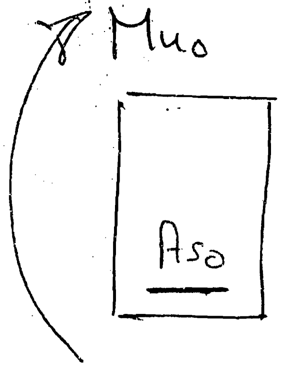
c) Over-Reinforced section:

هو القطاع الذى يحدث فيه انهيار للخرسانة أولاً ويكون انهيار مفاجئ ← لذلك هو غير مقبول من الكود المصرى لأنه لا يعطى إنذار قبل الانهيار.



$d_{giv} = 730\ mm < d_{min} = 786.48\ mm$

→ use C.S + T.S



$$M_{uo} = R_{max} \frac{f_{cu}}{\gamma_c} b d_{giv}^2$$

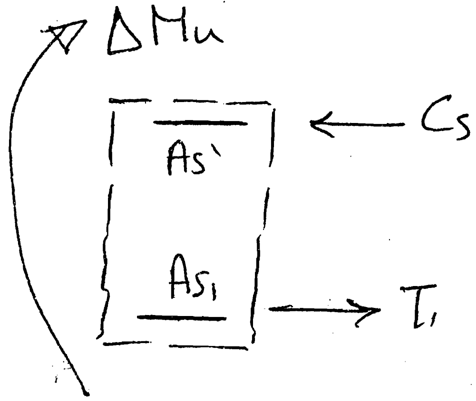
$$M_{uo} = 0.194 \times \frac{25}{1.5} \times 300 \times 730^2 / 10^6$$

$$M_{uo} = 516.9\ KN.m < M_u$$

$$A_{so} = \mu_{max}\ b d_{giv}$$

$$= 5 \times 10^{-4} \times 25 \times 300 \times 730$$

$$\boxed{A_{so} = 2737.5\ mm^2}$$



$$\Delta M_u = M_u - M_{uo}$$

$$= 600 - 516.9$$

$$\Delta M_u = 83.1\ KN.m$$

$$C_s = T_1 = \frac{\Delta M_u}{d - d''} = \frac{83.1 \times 10^6}{730 - 50}$$

$$C_s = T_1 = 122205.88\ N$$

$$\boxed{T_1 = f_y/\gamma_s\ A_{s1}}$$

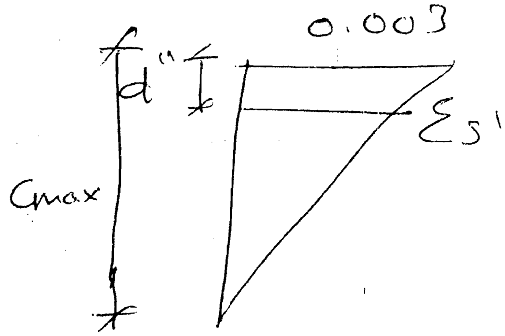
$$122205.88 = \frac{360}{1.15} A_{s1} \longrightarrow A_{s1} = 390.38\ mm^2$$

$$\boxed{As_{tot} = As_o + As_1}$$

$$= 2737.5 + 390.38 = 3127.88\ mm^2 \rightarrow \boxed{9 \# 22}$$

$$\boxed{C_s = f_s' A_s'}$$

$$\varepsilon_s' = 0.003\left(\frac{C_{max} - d''}{C_{max}}\right)$$



$$C_{max} = 0.44\,(d)$$

$$C_{max} = 0.44\,(730) = 321.2\,mm$$

$$\varepsilon_s' = 0.003\left(\frac{321.2 - 50}{321.2}\right) = 0.00253.$$

$$\varepsilon_y = \frac{f_y}{\gamma_s E_s} = \frac{360}{1.15(2\times10^5)} = 0.00156.$$

$$\varepsilon_s' > \varepsilon_y \longrightarrow f_s' = f_y/\gamma_s.$$

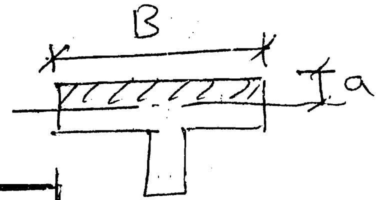
$$\boxed{C_s = f_s' A_s'}$$

$$122205.88 = \frac{360}{1.15} A_s'$$

$$\longrightarrow A_s' = 390.38\,mm^2 \rightarrow \boxed{4 \# 12}$$

Qu 4 :

assume $a < t_s$:



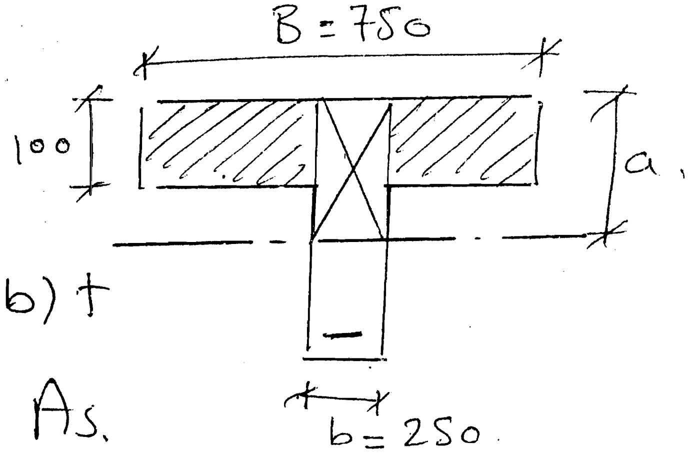
$$C_c = T$$

$$0.67 \times \frac{f_{cu}}{\gamma_c} aB = \frac{f_y}{\gamma_s} A_s$$

$$0.67 \times \frac{25}{1.5} \times a \times 750 = \frac{360}{1.15} * 3040$$

$$\longrightarrow a = 113.63 > t_s \longrightarrow$$ الفرض غلط

$a > t_s$



$$C_w + C_f = T$$

$$0.67 \frac{f_{cu}}{\gamma_c} ab + 0.67 \frac{f_{cu}}{\gamma_c} (B-b) t = \frac{f_y}{\gamma_s} A_s$$

$$0.67 \times \frac{25}{1.5} \times a \times 250 + 0.67 \times \frac{25}{1.5} (750-250) 100 = \frac{360}{1.15} * 3040$$

$$\longrightarrow a = 140.9 > t_s$$

$$a_{min} = 0.1d = 63$$

أكبر

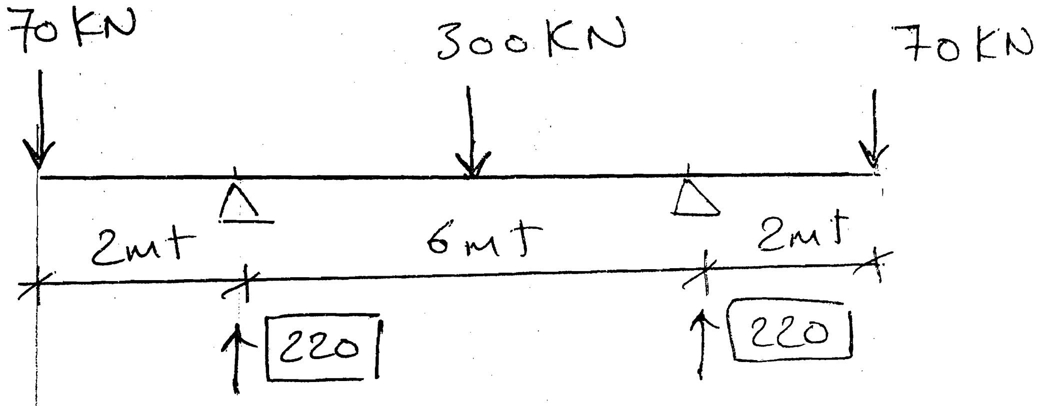
$$M_u = C_w (d - a/2) + C_f (d - t/2)$$

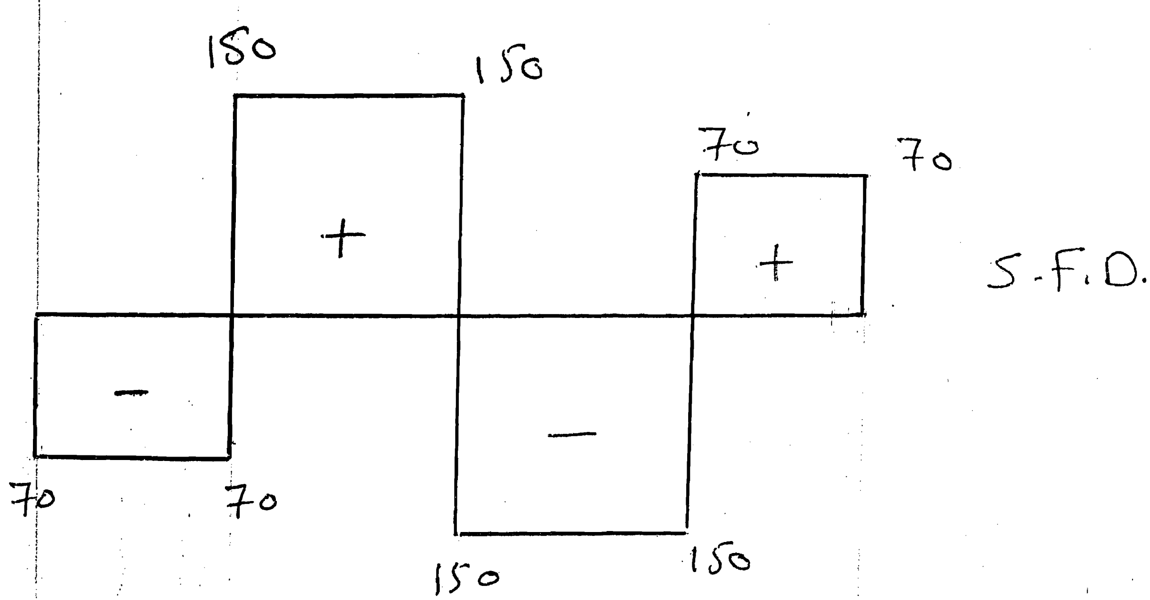
$$M_u = 0.67 \times \frac{25}{1.5} \times 140.9 \times 250 \left(630 - \frac{140.9}{2}\right)$$

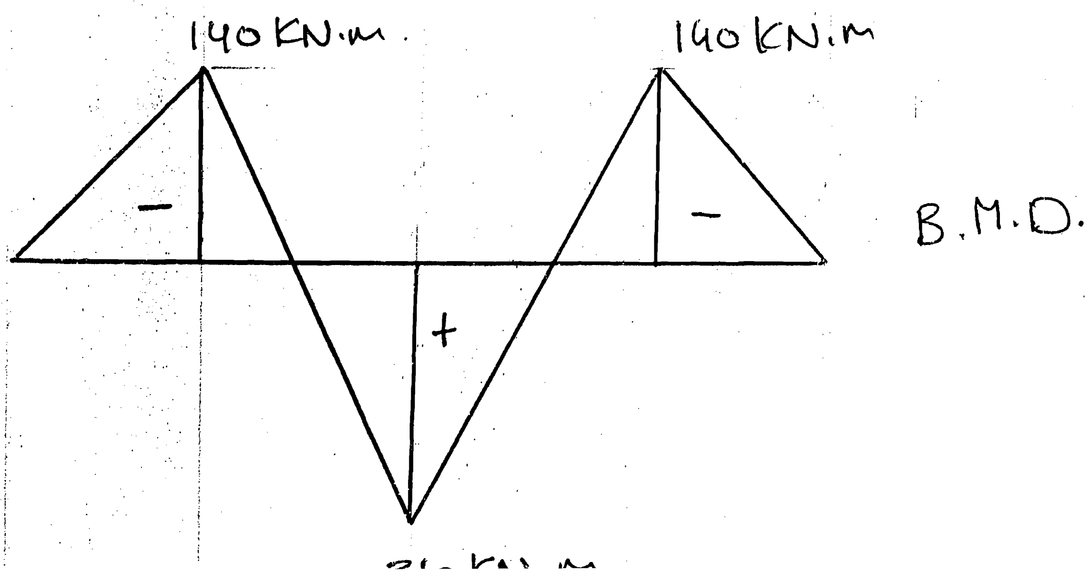
$$+ 0.67 \times \frac{25}{1.5} \times (750 - 250)(100) \left(630 - \frac{100}{2}\right) \Big/ 10^6$$

$$\boxed{M_u = 543.93 \text{ KN.m.}}$$

Qu 5 :


70 KN
300 KN
70 KN
2mt
6mt
2mt
220
220


150
150
70
70
+
+
−
−
70
70
150
150
S.F.D.


140 KN.m
140 KN.m
−
−
+
B.M.D.

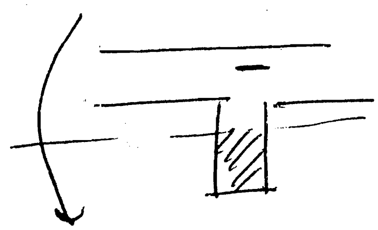
Note في هذه المسألة ممكن نبدأ بتصميم العزم

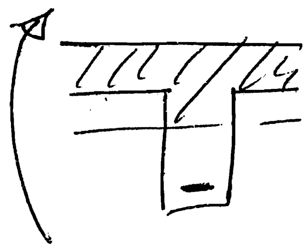
الموجب او السالب لأن (dgiven)

ولكن من المسألة التي يكون فيها (d) مجهولة

لازم نبدى بتصميم العزم السالب عشان نصمم

Rect. sec ، ثم نستفيد بال (d)



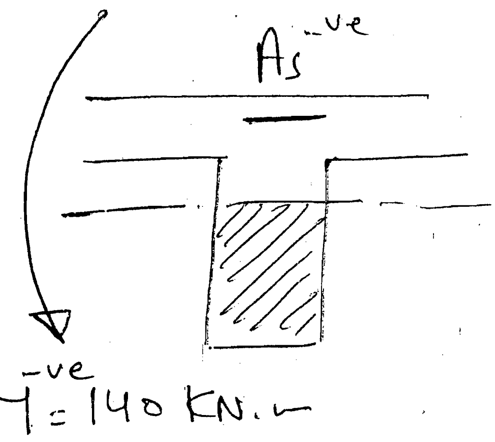


ونصمم بعديها العزم الموجب

T-section

Design for -ve Mom.:

dgiven = 430mm



$$d_{min} = \sqrt{\frac{1}{R_{max}\frac{f_{cu}}{\gamma_c}}} * \sqrt{\frac{M_u}{b}}$$

$M^{-ve} = 140$ KN.m

b = 250mm

$$d_{min} = \sqrt{\frac{1}{0.194 \times \frac{25}{1.5}}} * \sqrt{\frac{140 \times 10^6}{250}} = 416.17 \text{ mm}$$

(30

$d_{giv} = 430\,mm > d_{min} = 416.17\,mm$

→ use tension steel only.

RFT:

$$M_u = C_c\,(d - a/2)$$

$$140 \times 10^6 = 0.67 \times \frac{25}{1.5} \times a \times 250\,(430 - a/2)$$

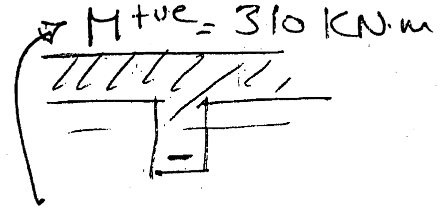
→ $a = 139.14\,mm$

$a_{min} = 0.1d = 43\,mm$ } أكبر

$$A_s^{-ve} = \frac{M_u^{-ve}}{f_y/\gamma_s\,(d - a/2)} = \frac{140 \times 10^6}{\frac{360}{1.15}\left(430 - \frac{139.1}{2}\right)}$$

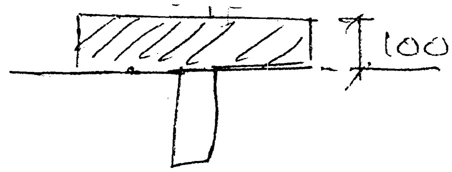
$A_s^{-ve} = 1240.8\,mm^2$ → $8 \# 16$

Design for +ve Moment:



B:
- $b + 16\,t_s = 250 + 16\,(100) = 1850\,mm$
- $b + \ell_2/5 = 250 + \frac{0.7\,(6000)}{5} = 1090\,mm$ → أكبر
- spacing $= 3000\,mm$

assume: $a = t = 100mm$.



$$Mu_{max} = C_c (d - a/2)$$

العلاقة ، في

$$= 0.67 \times \frac{25}{1.5} \times 100 \times 1090 \left(430 - \frac{100}{2}\right) / 10^6$$

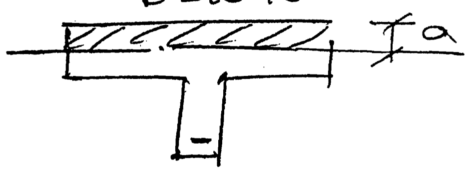
$$\boxed{Mu_{max} = 462.52 \ KN.m}$$

$Mu_{max} = 462.52 \ KN.m > Mu = 310 \ KN.m$.

↳ $a < 100mm$.

$\boxed{a < ts}$ ∴

$B = 1090$



$$\boxed{Mu = C_c (d - a/2)}$$

$$310 \times 10^6 = 0.67 \times \frac{25}{1.5} \times a \times 1090 (430 - a/2)$$

$\longrightarrow a = 64 \ mm$

$a_{min} = 0.1d = 43mm$ } اكبر

$$\boxed{As^{+ve} = \frac{Mu^{+ve}}{f_y/\gamma_s (d - a/2)}} = \frac{310 \times 10^6}{\frac{360}{1.15} \left(430 - \frac{64}{2}\right)}$$

$As^{+ve} = 2488.13 \ mm^2$ ⟶ $\boxed{8 \# 20}$

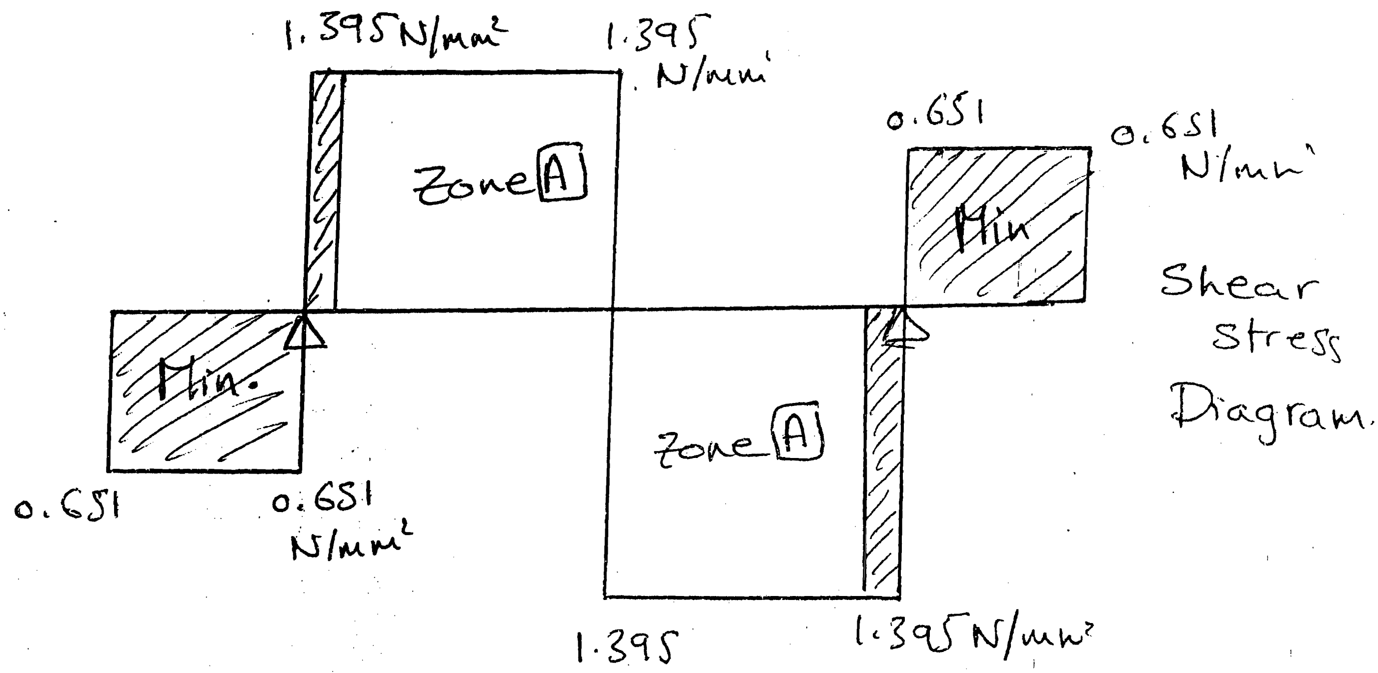
$\boxed{As' = 0.1 \ As^{+ve}}$ ⟶ $\boxed{2 \# 12}$ على طول

بدون حسابات .

[C] Design of shear Reinforcement:

$$q = \frac{Q}{bd} = \frac{Q \times 1000}{250 \times 430} = 0.0093\,Q$$

$$\boxed{q = 0.0093\,Q}$$



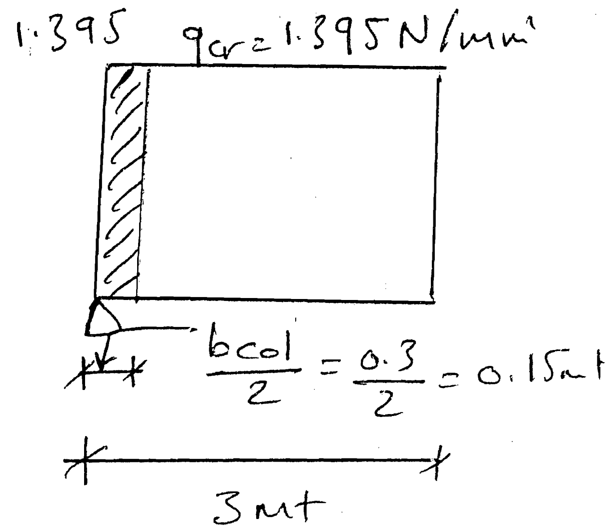
$$q_{cu} = 0.24\sqrt{\frac{f_{cu}}{\gamma_c}} = 0.24\sqrt{\frac{25}{1.5}} = 0.98\ N/mm^2$$

$$q_{umax} = 0.7\sqrt{\frac{f_{cu}}{\gamma_c}} = 0.7\sqrt{\frac{25}{1.5}} = 2.86\ N/mm^2 < 4 \rightarrow ok.$$

Zone [A] :

$$q_{u_{max}} > q_{cr} > q_{cu}$$

↳ use special shear RFT. (stirrups only)



$$q_{cr} = \frac{q_{cu}}{2} + q_{sus}$$

$$1.395 = \frac{0.98}{2} + q_{sus}$$

$\therefore q_{sus} = 0.905 \ N/mm^2$

$$q_{sus} = \frac{A_{st}\,(f_y/\gamma_s)}{b\,s}$$

ass: 2br st ϕ 8mm

↳ $A_{st} = 2 \times 50$

$$0.905 = \frac{2 \times 50\,(240/1.15)}{250 \times S'} \longrightarrow S = 92.24\ mm, < 100$$

ass. 2br st ϕ 10mm ⟶ $A_{st} = 2 \times 79$

⟶ $S = 145.7$ mm

take: $S = 125$ mm

use 2br st ϕ 10mm @ $S = 125$ mm

Minimum stirrups:

$$\mu_{min} = \frac{0.4}{f_y} = \frac{0.4}{240} \times 100 = 0.167\% > 0.15\%$$

$$\mu_{min} = \frac{A_{st}}{b s}$$

ass 2br st ϕ8mm

$A_{st} = 2 \times 50$

$$\frac{0.167}{100} = \frac{2 \times 50}{250 \times S} \longrightarrow S = 239.52 \text{ mm}$$

take $s = 200$ mm.

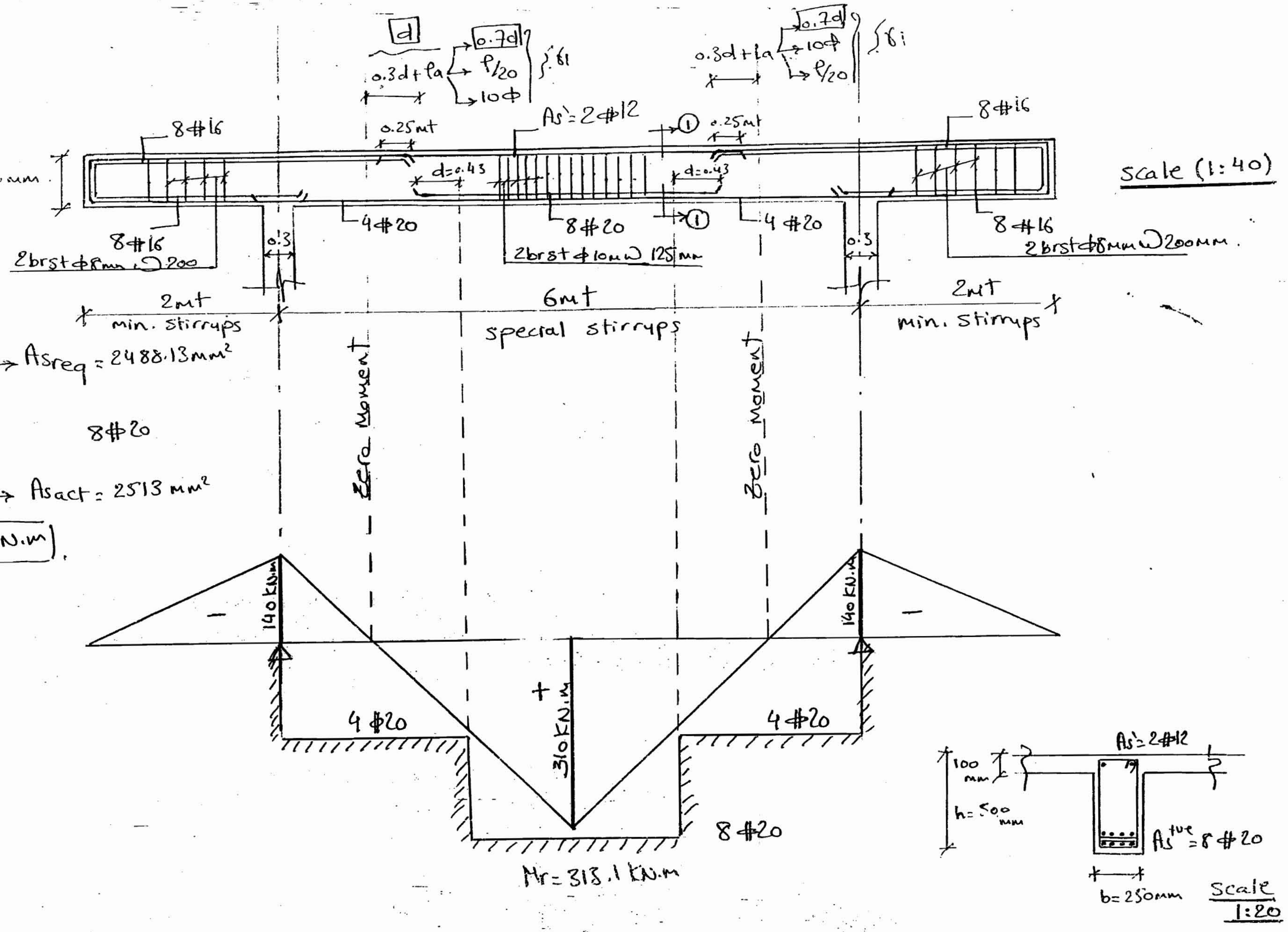
use 2br st. ϕ8mm w/ $s = 200$mm.

$M_u = 310\ kN.m \longrightarrow As_{req} = 2488.13\ mm^2$

8#20

$M_r = ?? \longrightarrow As_{act} = 2513\ mm^2$

$M_r = 313.1\ kN.m$



Sec (1-1)

Cross sec at mid span

* State The Egyptian code req.:

d) Min. Reinforcement for sections subjected to flexure:

$$\mu_{min} = \frac{1.1}{f_y}$$

Mild steel < 240/350, 280/450 } → $\nless 0.25\%$

High tensile < 360/520, 400/600 } → $\nless 0.15\%$

---

e) Minimum web Reinf. for beams:

$$\mu_{min} = \frac{0.4}{f_y} = \frac{A_{st}}{b \cdot S}$$

Mild steel < 240/350 ϕ, 280/450 ϕ } $\mu_{min} \nless 0.15\%$

High tensile < 360/520 #, 400/600 Φ } $\mu_{min} \nless 0.1\%$

f) Minimum longitudnal Rft for Short Columns :-

seperate stirrups:

$\mu_{min} = 0.8\%$ (Required area)

$= 0.6\%$ (Actual area)

} الأكبر

spiral stirrups:

$\mu_{min} = 1\%$ (Actual area)

$= 1.2\%$ (A_k → inner area)

} الأكبر

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g) Stirrups for tied columns :-

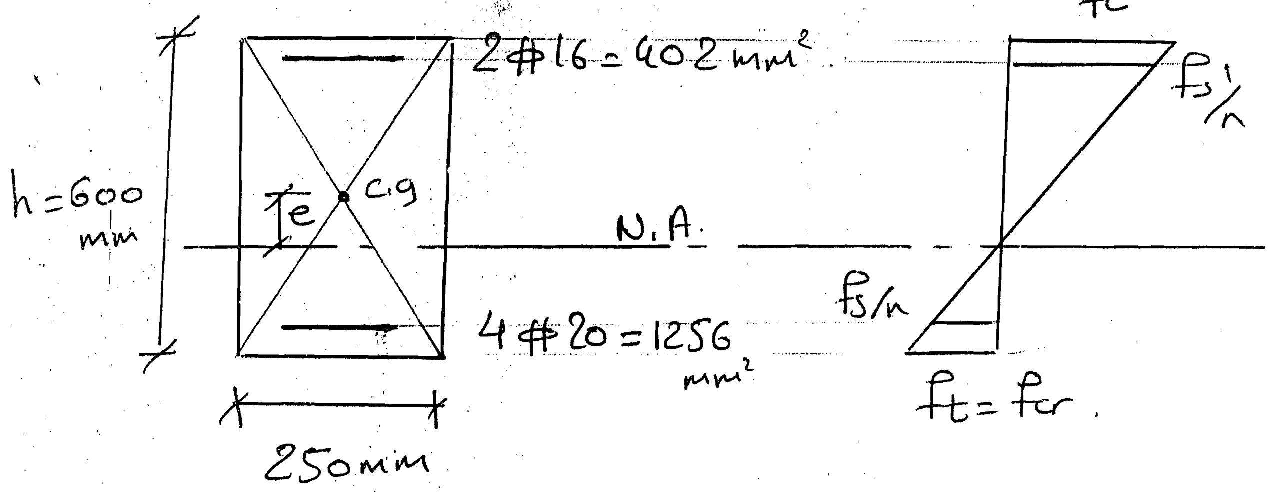
ϕ_{st} →
- $\frac{\phi_{max}}{4}$
- 8mm

} الأكبر

S →
- $15\phi_{min}$
- 200mm

} الأقل

Qu 2 : I a M_{cr} :



* $\sum M$ @ c.g : عزوم المساحات

$$10(1256)\left(\frac{600}{2}-50\right)-10(402)\left(600/2-50\right)$$

$$=\left[250(600)+10(1256)+10(402)\right]e$$

$\longrightarrow$ $e = 12.81\ mm$

* $$I_{N.A} = \frac{250(600)^3}{12} + 250(600)(12.81)^2$$

$$+10(1256)\left(\frac{600}{2}-12.81-50\right)^2$$

$$+10(402)\left(\frac{600}{2}+12.81-50\right)^2 = 5.5\times10^9\ mm^4$$

$f_{cr} = 0.6\sqrt{f_{cu}}$

$f_{cr} = 0.6\sqrt{25} = 3\ N/mm^2$

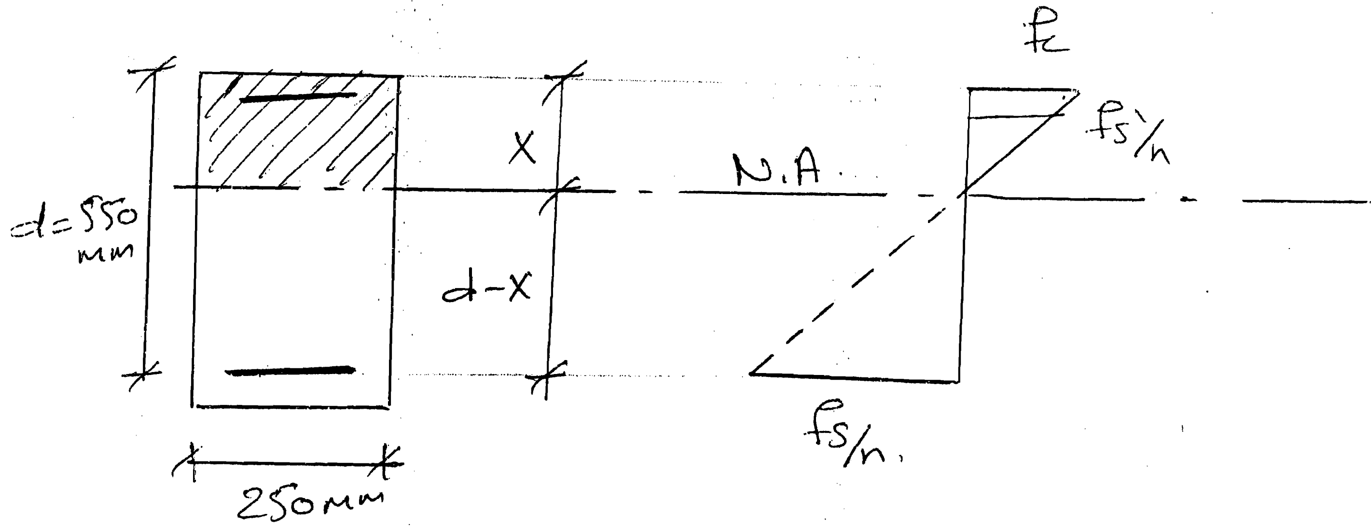
$$f_{cr} = \frac{M_{cr}}{I_{N.A}} \left(h/2 - e \right)$$

$$3 = \frac{M_{cr} * 10^6}{5.5 \times 10^9} \left(\frac{600}{2} - 12.81 \right)$$

$$M_{cr} = 57.45 \text{ KN.m}$$

---

[b] Service moment capacity: M_{max}^{w}



* $\Sigma M @ N.A = 0.0$

$$250 \, x^2/2 + 15(402)(x-50) = 15(1256)(550-x)$$

$$\longrightarrow X = 209.07 \text{ mm}$$

* $$I_{N.A} = \frac{250 (209.07)^3}{3} + 15(402)(209.07-50)^2$$

$$+ 15(1256)(550 - 209.07)^2 = 3.1 \times 10^9 \text{ mm}^4$$

let: $f_c = f_{call} = 9.5 = \frac{M_1 * 10^6}{3.1 \times 10^9}(209.07)$ C

$$\boxed{M_1 = 140.86 \ KN.m}$$

let: $\frac{f_s}{n} = \frac{f_{sall}}{n} = \frac{200}{15} = \frac{M_2 * 10^6}{3.1 \times 10^9}(550 - 209.0$

$$\boxed{M_2 = 121.24 \ KN.m}$$

$\longrightarrow \boxed{M_{w\,max} = 121.24 \ KN.m}$ الاقل من الاثنين

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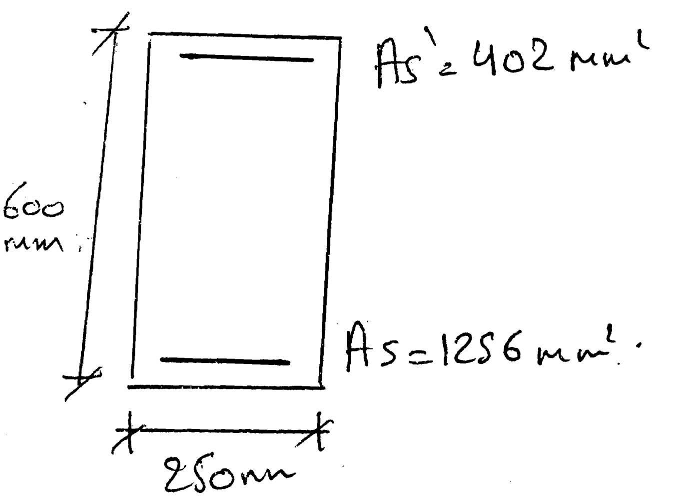
c) failure Moment: (M_u)



ass $\varepsilon_s > \varepsilon_y \longrightarrow T = \frac{f_y}{\gamma_s} A_s$

check: $\frac{A_s'}{A_s} = 32\% < 60\%$

ass $\varepsilon_s' > \varepsilon_y \longrightarrow C_s = \frac{f_y}{\gamma_s} A_s'$

From equilibrium:

$$C_c + C_s = T$$

$$0.67 \times \frac{25}{1.5} * (0.8c) * 250 + \frac{360}{1.15} * 402$$

$$= \frac{360}{1.15} * 1256$$

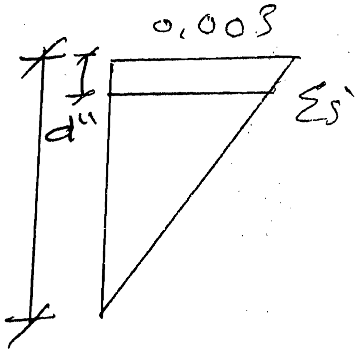
$$\boxed{c = 119.7\ mm}$$

check:

$$C_b = \frac{600}{600 + \frac{360}{1.15}}(550) = 361.43\ mm$$

$$\rightarrow \boxed{c < C_b}$$ الفرض الاول صحيح

بالتشابه :



$$\varepsilon_s' = 0.003\left(\frac{119.7 - 50}{119.7}\right)$$

$$\varepsilon_s' = 0.00174$$

$$\varepsilon_y = \frac{360}{1.15(2\times10^5)} = 0.00156 \rightarrow \boxed{\varepsilon_s' > \varepsilon_y} \rightarrow$$ الفرض الثاني صحيح

$$M_u = 0.67 \times \frac{25}{1.5} \times (0.8 \times 119.7)(250)\left(550 - \frac{0.8 \times 119.7}{2}\right)$$

$$+ \frac{360}{1.15}(402)(550 - 50) \Big/ 10^6$$

$$\boxed{M_u = 197.15\ KN.m}$$

Qu 3 :

Given: $b = 300\,mm$ $d = 730\,mm$

a) $A_{s\,max} = \mu_{max}\, b d$

$A_{s\,max} = 5 \times 10^{-4} \times 25 \times 300 \times 730$

$A_{s\,max} = 2737.5\ mm^2$ → 9 Φ 20

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

$M_{u\,max} = 0.194 * \frac{25}{1.5} \times 300 \times 730^2 / 10^6$

$M_{u\,max} = 516.9\ KN.m$

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b) Given: $b = 300\,mm$ $d = 730\,mm$

$M_u = 600\ KN.m$

$d_{min} = \sqrt{\frac{1}{R_{max}\, f_{cu}/\gamma_c}} * \sqrt{\frac{M_u}{b}}$

$d_{min} = \sqrt{\frac{1}{0.194 \times \frac{25}{1.5}}} * \sqrt{\frac{600 \times 10^6}{300}} = 786.48\ mm$