Name: [redacted]

41/100

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Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335 Reinforced Concrete Design I

Mid-Term Exam **Tuesday, December 6, 2016**

Part I – 3 pages

Q1. (2 points each) Answer very briefly. Use sketches where appropriate.

1. The ACI Code requires minimum shear reinforcement for beams even if Vu does not exceed ϕVc.

becaus worker is the site walk on the beams
so we need stirups to support the workers wight &
for the barse so they dont go down

0

2. Beams can support some additional moment even after the tension steel yields.

because that the concreat can support a tension force but
very small compering with steel

3. Cylindrical tanks are often pre-stressed circumferentially.

because they need ~~str more~~
to support more lode

4. Why does the ACI-Code set a minimum reinforcement level for flexural members?

To make a worning ~~when~~ @ failier

5. Compression reinforcement in doubly reinforced beams will not increase the strength significantly. Explain.

because it's just for the deflection & when we
increas reinforcement the arme will be smaller signifikant
M=(T or C) arme

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6. More than one stirrup is usually required for beams with a width exceeding 40 cm.

becaus when d ≥ 40 the crack in 45° will be bass than 40 or 40 so if S=d or more there is no need for it becaus the crack will go between the stirrups whe S≥d ⇒ [illegible] when S<d

7. What is the main purpose of using the strength reduction factor ϕ according to the ACI Code?

To make the [illegible] more safty & tolerence is assume increas the Resister

8. What are the over-reinforced sections?

The section that Rinforcement @ the maximum with 0.004 Et

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Q2. (24 points) Circle the appropriate letter, T for true or F for false.

1. (T) F Compression steel is effective in reducing long term deflection of beams.

2. (T) (F) Folded plate roof construction may be used to cover spans of more than 60 m.

3. (T) (F) The use of high-strength materials in ordinary reinforced concrete results in large deflections under ordinary loading conditions.

4. (T) F Prestressed concrete construction allows using very high strength concrete and steel with reduced deflection and cracking problems.

5. (T) (F) Earthquake loads are considered environmental loads.

6. (T) (F) In the working stress method, stresses resulting from factored loads and computed by mechanics of elastic members should not exceed allowable values.

7. (T) F Excessive deflection and cracking are considered serviceability, not strength, problems.

8. (T) F Under-reinforced sections are those that have less reinforcement than the balanced amount.

9. (T) F A tension-controlled section will exhibit excessive cracking on the tension side

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of the member.

10. T F Superplasticizers are used mainly to improve workability or to reduce the required amount of mixing water.

11. T F Air-entraining admixtures are used to provide resistance to freezing and thawing.

12. T F Long-term deflection is caused by creep and shrinkage.

13. T F Under-reinforced sections are those that do not have sufficient reinforcement to support the design moments.

14. T F If the compression reinforcement does not yield under ultimate load, the beam will not give a sufficient warning of imminent failure.

15. T F According to the ACI Code, concrete fails at a strain of 0.003 regardless of its strength.

16. T F Shear cracks are usually inclined.

17. T F In the design of concrete structures, code provisions can sometimes serve only as a guide, and the engineer must rely upon a good understanding of mechanics and behavior of materials.

18. T F Placing is the process of transferring the fresh concrete from the conveying device to its final place in the forms.

19. T F According to the ACI-Code, a strength test is the average of two or three cylinder tests, depending on cylinder size.

20. T F Consolidation of concrete is achieved by vibrators.

21. T F Poor conveying of concrete may result in honeycombing.

22. T F If drop beams can be used, slabs (ribbed or solid) must be used along the longer direction.

23. T F If drop beams may not be used such as for architectural reasons, one-way ribbed slabs, rather than one-way solid slabs, must be used to allow for hidden beams.

24. T F Shear cracks usually occur near the midspan of beams.

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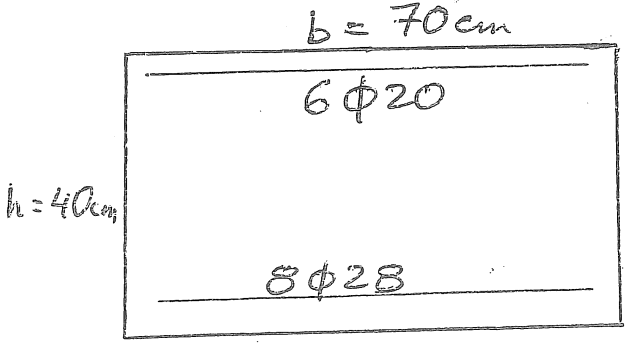
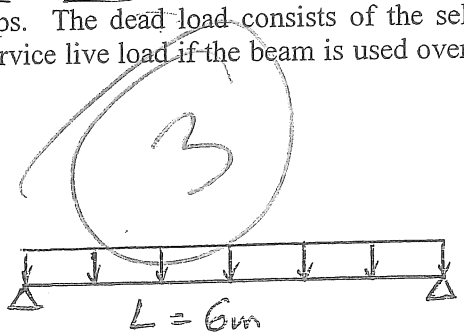
Part III – 4 pages

For all questions, use fc' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3).

Q4. (25 points) A doubly reinforced beam has b = 70 cm, h = 40 cm, and is reinforced with 8 Φ 28 tension bars, 6 Φ 20 compression bars, and Φ10 stirrups. The dead load consists of the self-weight only. Determine the allowable uniformly distributed service live load if the beam is used over a simple span of 6 m.





3

$M_u = \frac{wl^2}{8} = \frac{w36}{8} = w\,4.5$ t.m

$d_t = 37.6$ cm

$\rho_{max} = 0.31875\left(\frac{28}{420}\right)0.85 = 0.018063$

$A_{s\,max} = \rho_{max}(70)(37.6)$

$A_{s\,max} = 42.48\ cm^2$

$d' = 6$ cm

$C_c = 178.4$ t

$a_{max} = \frac{178.4}{.85(.28)(70)} = 10.71$ cm

$c_{max} = 12.6$ cm

$\Rightarrow M_{nc} = 178.4\left(\frac{37.6 - \frac{10.71}{2}}{100}\right) = 50.39$ t.m

$w_{sw} = \frac{40(60)}{16}$

$DL = 0.7\times0.4\times1\times2.4 = 0.672$ t

$1.2\times DL = 0.806$ t/m

Case 1

4.84 t 2.42

2.42

1.6L.L + 0.806

0.806

1.5 3m 3m 1.5

(2.4+3.6 L.L)

(2.4+1.2 L.L)

Assume compretion steel will yield → $f_s' = f_y = 420$ MPa

$A_s' = 36.95 = \frac{C_s}{4.2 - 0.85(\frac{6}{37.6})}$ → $C_s = 146.4$ t

$C_{total} = C_s + C_c = 324.8$ t

~~$C_s = 12.6 = 6$~~

~~Assume the~~ $C_c = 0.85(.28)$

$M_{n\,max} = M_u$ the max Moment can the beam support

$M_n =$

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$C_c = 1.87 A_{ac} +$

$T =$

$$M_n = 178.1\left(\frac{33.6 - \frac{10.7}{2}}{100}\right) + 146.4\left(\frac{33.6-6}{100}\right)$$

$$= 50.3 + 40.4$$

$$= 90.8 \text{ t.m}$$

$$\epsilon_t = \left(\frac{d - x}{x}\right) 0.003 = 0.005$$

$$=$$

$\phi = 0.9$

$$\phi M_n = M_u = 81.7 \text{ t.m}$$

$$81.7 = \frac{w l^2}{8}$$

$$81.7 = \frac{w 6^2}{8}$$

$$w = 18.2 \text{ t}$$

There are not the maximum conditions

$$w = 1.2 D.L + 1.6 L.L$$

$$18.2 = 0.806 + 1.6 L.L$$

$$L.L = 10.87 \text{ t}$$

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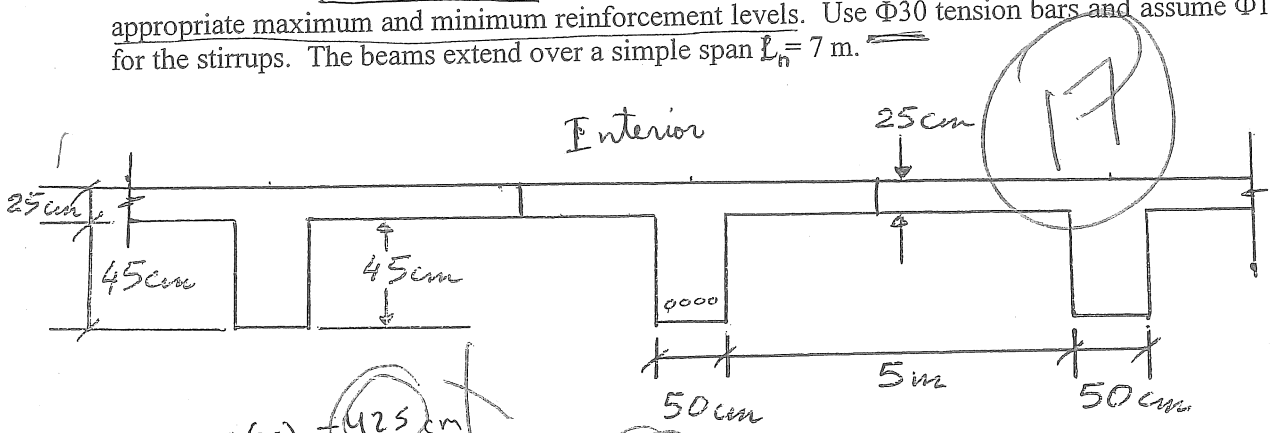
Q5. (25 points) The sketch shows drop-beams supporting a solid slab with a thickness of 25 cm. Determine the required reinforcement to support an ultimate positive moment Mu = 60 t.m. Check the appropriate maximum and minimum reinforcement levels. Use Φ30 tension bars and assume Φ10 bars for the stirrups. The beams extend over a simple span ℓ_n = 7 m.



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$b_E = 50 + 16(25) = 425$ cm

$= 50 + 500 = 550$ small control

$= 50 + 700 = 750$

3

$d_t = 63.5$ cm

$m = 17.65$

$$M_{n\,req} = \frac{60}{0.9} = 66.67 \text{ t.m}$$

If $a = t = 25$cm

$$C = 0.85(0.28)(425)(25) = 2529 \text{ t}$$

$$M_n = 2529\left(\frac{63.5 - 12.5}{100}\right) = 1290 \text{ t.m}$$

$M_n \gg M_{n\,req}$ so $a < t$

$$R_{n\,req} = \frac{6667}{425(63.5)^2} = 0.003890 \text{ t/cm}^2$$

$$\rho_{req} = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2(17.65)(0.003890)}{fy}}\right) = 0.0009339$$

$$A_{s\,req} = 0.0009339(425)(63.5) = 25.2 \text{ cm}^2$$

↳ $A_{s\,act} = 28.27$

# of bars ⇒ 4 Φ30 one layer

Check $A_{s\,min}$

$$\frac{0.25\sqrt{28}}{420}(425)(63.5) \geq \frac{1.4}{420}(425)(63.5)$$

$85 \geq 90$

4

$A_{s\,act} < A_{s\,min}$ so we need more Reinforcement

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So I need 13 ϕ30

$A_{sact} = 91.91\ cm^2$

2 layer 6ϕ30 / 7ϕ30

$$\bar{y} = \frac{(7*6.5) + (6*12)}{13} = 9.04$$

$d = 60.96\ cm$

$A_{sact} > A_{smin}$

check

A_{smax}

$x_{max} = 23.81\ cm$

$a_{max} = 20.24\ cm$

$C_{max} = 2472.1\ t$

$A_{max} = \frac{2472.1}{4.2} = 588.6\ cm^2$

$a_{act} = \frac{91.91 * 4.2}{0.85(0.28)\ 425} = 3.82\ cm$

$x_{act} = 4.5\ cm$

$A_{smin} < A_{sact} < A_{smax}$ ✓

$$M_n = 91.91(4.2)\left(\frac{60.96 - 1.91}{100}\right) = 227.9\ t.m$$

$$\epsilon_{tact} = \left(\frac{63.5 - 4.5}{4.5}\right)0.003 = 0.039 > 0.005$$

$\phi = 0.9$

$\phi M_n = 205.1 > 60\ t.m$ ✓

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Part II

Q3. (10 points) Write the exact section in the ACI Code that specifies the following:

1. fc' for concrete shall be based on 28-day tests. 19.2.1.3
2. Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003 22.2.2.1
3. Tensile strength of concrete shall be neglected in flexural and axial strength calculations 2.1.2.1
4. ε_t for beams shall be at least 0.004 7.3.3.1
5. Critical section for shear in beams is located at a distance equal to d from the face of support 9.9.4.5
6. The value of β_1 for determining a of the Whitney block 22.2.2.4.3
7. The upper limit for category 5 for shear strength of beams 22.5.1.2
8. The formula for determining Vs for shear reinforcement 22.5.10.1
9. Formula for determining fr for concrete 19.2.3.1
10. Concrete cover for beams not exposed to weather = 40 mm 20.6.1.3.1

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Birzeit University
Faculty of Engineering
Department of Civil Engineering

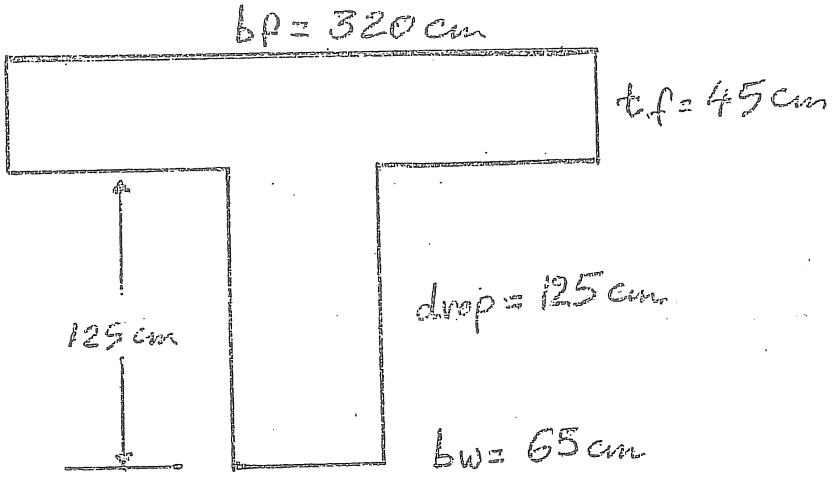
ENCE 335 Reinforced Concrete Design I

Mid-Term Exam Monday, March 30, 2015

Part I – 6 pages

For all questions, use fc' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3).

Q1. An isolated T-beam extends over a simple span of 13 m. The beam has the dimensions shown, with Φ28 longitudinal bars and Φ10 stirrups. Determine:



a) (5 points) As_{min} for negative moment.

$d_t = 170 - (4 + 1 + 2.8/2) = 163.6$ cm 1

$t_f = 45$ cm $> b_w/2 = 32.5$ cm

$b_E = 320$ cm $\leq 4(65) = 260$ cm 2

1

$$As_{min(-ve)} = \frac{0.5\sqrt{28}\,(65)(163.6)}{420} \leq \frac{0.25\sqrt{28}\,(320)(163.6)}{420}$$

$$= 66.99\ cm^2 \leq 164.89\ cm^2$$

1

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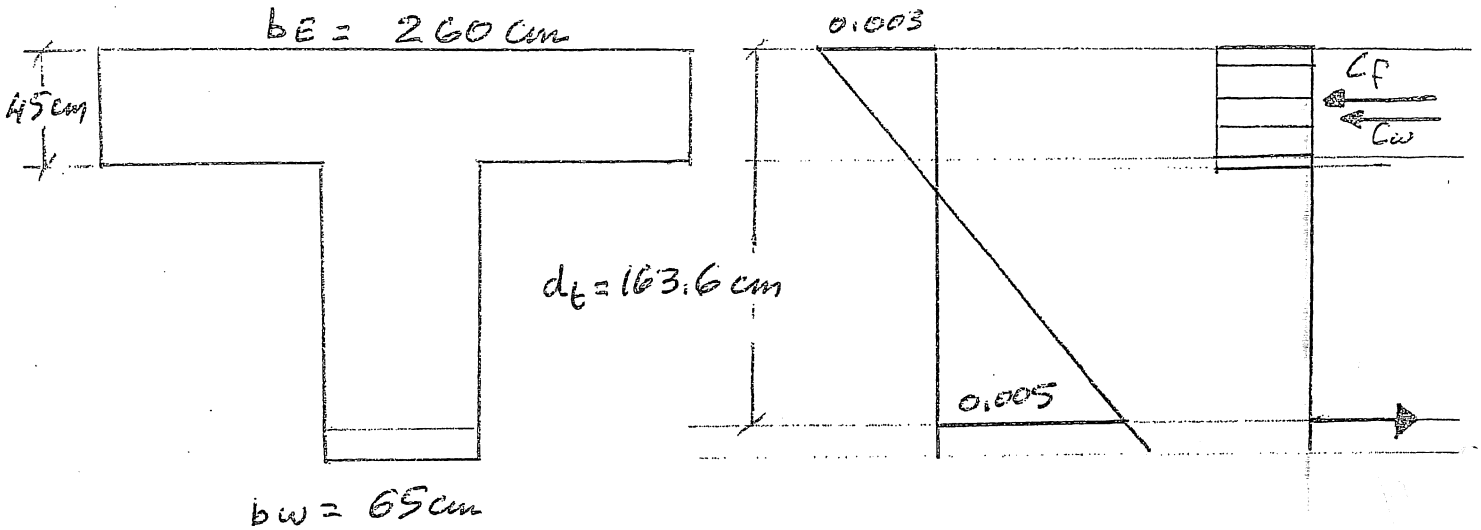
b) (10 points) As_{max} for $\varepsilon_t = 0.005$ for positive moment.



$$x_{max} = \frac{3}{8}(163.6) = 61.35\ cm$$

$$a_{max} = 0.85\,(61.35) = 52.15\ cm$$

$$C_{max} = 0.85\,(0.28)(260-65)(45) + 0.85\,(0.28)(65)(52.15)$$

(3)

$$= 2088.4 + 806.7 = 2895.1\ t$$

$$As_{max\ \varepsilon_t=0.005} = \frac{2895.1}{4.2} = \underline{\underline{689.3\ cm^2}}$$

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c) (10 points) Determine As_{req} for a positive moment Mu = + 190 t.m. Determine the required number of Φ 28 bars.

$Mn\,req = \frac{190}{0.9} = 211.1$ t.m $\qquad m = \frac{420}{0.85(28)} = 17.65$

if $a = t$, $C = 0.85(0.28)(260)(45) = 2785$ t

for which $Mn = 2785\left(\frac{163.6 - 45/2}{100}\right) = 3929$ t.m

4 $\therefore\ a < t$

$Rn\,req = \frac{21110 \text{ t.cm}}{(260)(163.6)^2} = 0.003034$ t/cm²

$Preq = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2(17.65)(0.003034)}{4.2}}\right)$

$= 0.000727$

$As\,req = 0.000727 \times 260 \times 163.6 = 30.93$ cm²

$As\,min = \frac{0.25\sqrt{28}\,(65)(163.6)}{420} \geq \frac{1.4}{420}(65)(163.6)$

$= 33.49$ cm² $\geq$ 35.45 cm² 2

$\therefore$ The minimum controls 2

$\frac{35.45}{6.16} = 5.75 \Rightarrow$ 6Φ28 bars 1

$As\,actual = 36.96$ cm² in one layer

Note that using $\phi = 0.90$ was correct.

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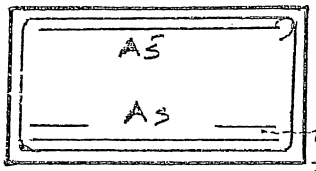
Q2. (15 points) Determine whether the doubly reinforced beam shown can support an ultimate moment Mu = 150 t.m.

$b = 80\ cm$

$h = 40\ cm$



$\phi 10$ stirrups

$A's = 10\ \phi 30 = 70.69\ cm^2$ (one layer)

$A_s = 18\ \phi 30 = 127.26\ cm^2$

12 bottom layer, 6 second layer

$d' = 6.5$ (6.5 cm) $\quad d_t = 33.5$ (12 cm)

$$\bar{y} = \frac{(12 \times 6.5) + (6 \times 12)}{18} = 8.33, \quad d_\epsilon = 31.67\ cm$$

Note: $\epsilon_t = 0.005$

$$x_{max} = \frac{3}{8}(33.5) = 12.56\ cm, \quad a_{max} = 10.68\ cm$$

$$\epsilon_s' = \frac{12.56 - 6.5}{12.56}(0.003) = 0.00145, \quad f_s' = 2.89\ t/cm^2$$

$$C_{max} = 0.85(0.28)(80)(10.68) + 70.69(2.89 - 0.85(0.28))$$

$$= 203.3 + 187.8 = 391.1\ t$$

$$A_{s\,max} = 391.1/4.2 = 93.12\ cm^2 < A_{s\,actual}$$

$\epsilon_t = 0.004$

$$x_{max} = \frac{3}{7}(33.5) = 14.36\ cm, \quad a_{max} = 12.20\ cm$$

$$\epsilon_s' = \frac{14.36 - 6.5}{14.36}(0.003) = 0.00164, \quad f_s' = 3.28\ t/cm^2$$

$$C_{max} = 0.85(0.28)(80)(12.20) + 70.69(3.28 - 0.85(0.28))$$

$$= 232.3 + 215.3 = 447.6\ t$$

$$A_{s\,max} = 447.6/4.2 = 106.57\ cm^2 < A_{s\,actual}$$

∴ This beam may not be put in service!

8
7
8
10
12
13

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Alternatively:

$T = 127.26 \times 4.2 = 534.5\ t$

assume that the compression steel yields,

$C_s = 70.69(4.2 - 0.85(0.28)) = 280.1\ t$

$C_c = 0.85(0.28)(80)(0.85x) = 16.18x$

$534.5 = 280.1 + 16.18x \Rightarrow x = 15.72\ cm$

$\epsilon_s' = \frac{15.72 - 6.5}{15.72}(0.003) = 0.00176 < \epsilon_y$

∴ the assumption is wrong

$534.5 = 16.18x + 70.69\left(\frac{x - 6.5}{x}(6) - 0.85(0.28)\right)$

$x^2 - 7.86x - 170.4 = 0 \Rightarrow x = 17.56\ cm$

$\epsilon_t = \frac{33.5 - 17.56}{17.56}(0.003) = 0.00272$

which is much less than the minimum strain of 0.004 required for beams,

∴ This beam may not be put in service!

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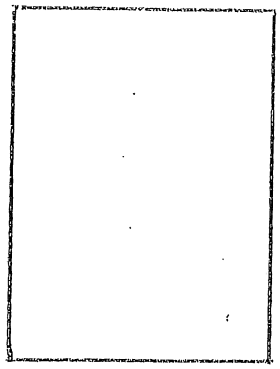
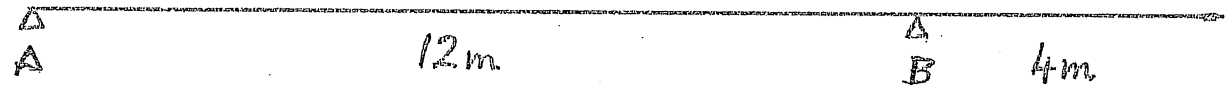
Q3. (20 points) The beam shown has a positive moment capacity $\phi Mn = +130$ t.m. and a negative moment capacity $\phi Mn = -170$ t.m. Dead load consists of self-weight only. Determine the maximum service distributed live load that the beam can support.



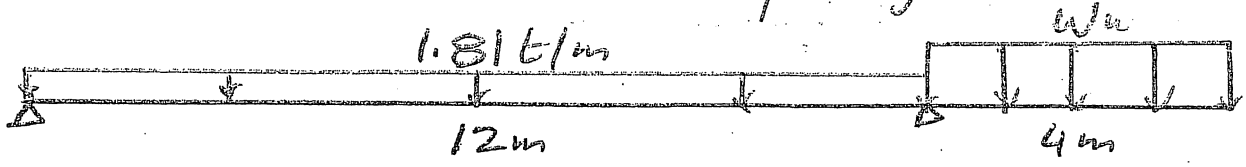
Hint:
Use appropriate cases of loading:

$W_{DL} = (0.7 \times 0.9 \times 2.4) = 1.512$ t/m

$1.2DL = 1.2 \times 1.512 = 1.81$ t/m



a) based on the -ve moment capacity,

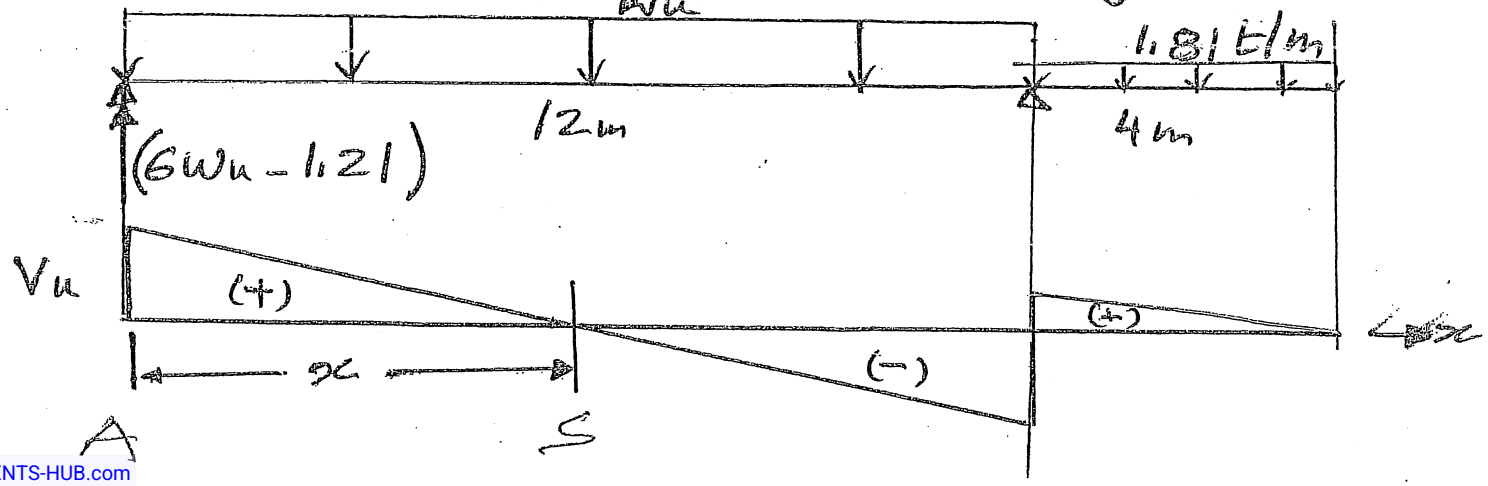


$$\frac{(W_u)(4^2)}{2} = 170 \Rightarrow W_u = 21.25 \text{ t/m}$$

$(W_L)_{ultimate} = 21.25 - 1.81 = 19.44$ t/m

$(W_L)_{service} = 19.44/1.6 = 12.15$ t/m

b) based on the +ve moment capacity,



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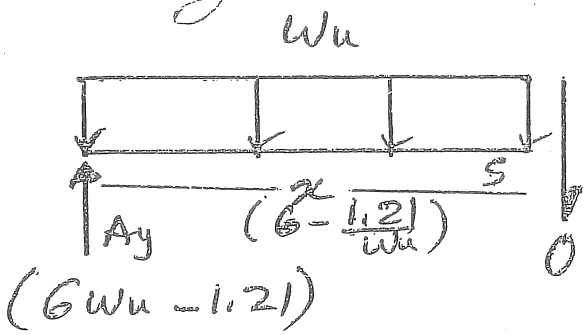
Taking a section of the beam (A to S)



$M_{max} = 130$ t.m

ΣM @ support $B = 0$ +↻

$$+Ay(12) - \frac{Wu(12)^2}{2} + \frac{(1.81)(4)^2}{2} = 0$$

$$Ay = 6Wu - 1.21$$

For the section of the beam shown,

$\Sigma F_y = 0$ +↑

$$+(6Wu - 1.21) - Wu(x) = 0$$

$$x = 6 - \frac{1.21}{Wu}$$

$$\therefore \underbrace{\frac{1}{2}\left(6 - \frac{1.21}{Wu}\right)(6Wu - 1.21)}_{\text{Area of the shear diagram between A and S}} = \underbrace{+130 \text{ t.m}}_{\text{Maximum +ve Mu}}$$

$$36Wu - 7.26 - 7.26 + \frac{1.46}{Wu} = 260$$

$$36Wu^2 - 14.52Wu - 260Wu + 1.46 = 0$$

$$Wu^2 - 7.626Wu + 0.04 = 0$$

$$Wu = 7.62 \text{ t/m}$$

$\therefore (W_{LL})_{ultimate} = 7.62 - 1.81 = 5.81$ t/m

$\therefore (W_{LL})_{service} = \frac{5.81}{1.6} = \underline{3.63 \text{ t/m}}$ Controls

⇒ maximum LL

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Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

Mid-Term Exam **July 27, 2009**

1. A beam has b = 70 cm and d = 53 cm. Using fc' = 25 MPa and fy = 400 MPa,

a. (2 points) Determine $As_{max-et=0.005}$.

62.83 cm^2

b. (2 points) Determine As_{min}.

11.59 > 2.985

controls

c. (3 points) Determine $As_{required}$ to carry a moment Mu = 63 t.m.

36.38 < 62.83

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d. (2 points) Use a general relationship of deformation versus time graph to show true elastic, shrinkage, and creep strain changes.

e. (2 points) If the tension steel in a properly designed flexural member reaches the yielding point, will it be able to support any additional load? Explain using proper diagrams.

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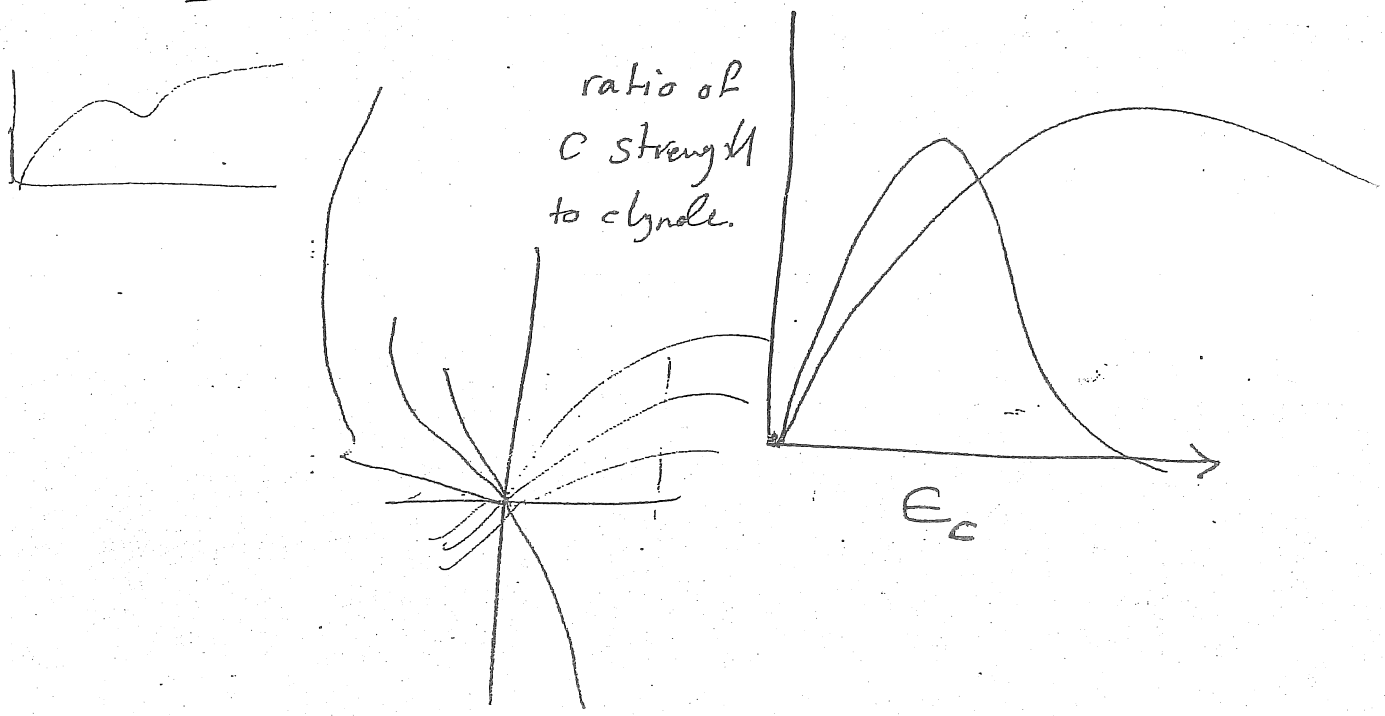
2. a. (2 points) Explain briefly the term "sand replacement".

b. (2 points) What are the purposes of using air-entraining admixtures?

c. (2 points) Is the shape of the stress – strain curve for concrete influenced by the rate of applying strain. Explain using an appropriate figure.



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g. (3 points) Determine $As_{required}$ and select reinforcement to carry a positive moment Mu = 23 t.m. Use a sketch to show your design.

$$Mn_{req} = 23/0.9 = 25.566 \text{ t.m}$$

$$Rn_{req} = \frac{2556 \text{ t.cm}}{(80)(26)^2} = 0.04726 \text{ t/cm}^2$$

$$m = \frac{400}{0.85(0.25)} = 18.82$$

$$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.04726)}{4}}\right)$$

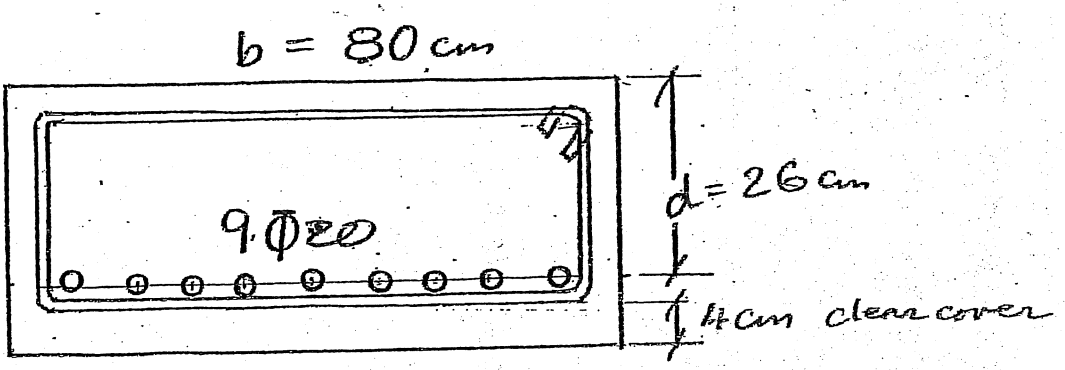
$$= 0.01354$$

$$As_{req} = (0.01354)(80)(26) = 28.17 \text{ cm}^2$$

$$< 35.22 \text{ cm}^2 \text{ max}$$

$\therefore \phi = 0.9$ is OK

use 9 Φ 20 bars, As provided = 28.27 cm² in one layer.



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Dr Jamal Zalatimo

4

f (5 points) If this beam is doubly reinforced with As = 10Φ22 bars, and As' = 5Φ20 bars, determine Φ Mn. Draw the strain and stress diagrams.

$A_s = 10\,\Phi 22 = 38.01\ cm^2$, $A_s' = 5\Phi 20 = 15.71\ cm^2$

It is obvious that compression steel does not yield — see part c

$$T = 152.04 = 0.85(0.25)(80)(0.85x) + 15.71\left(\frac{6(x-6)}{x} - 0.85(0.25)\right)$$

ϵ_s'

$$14.45x - 61.18 - \frac{565.6}{x} = 0$$

$$x^2 - 4.234x - 39.14 = 0$$

$$x = 8.72\ cm,\quad a = 7.41\ cm$$

Check calculations: $T = 152.04\ t = C_c + C_s$

$= 126.0 + 26.04\ t$

$$M_n = 126\left(\frac{26 - 7.41/2}{100}\right) + 26.04\left(\frac{26-6}{100}\right)$$

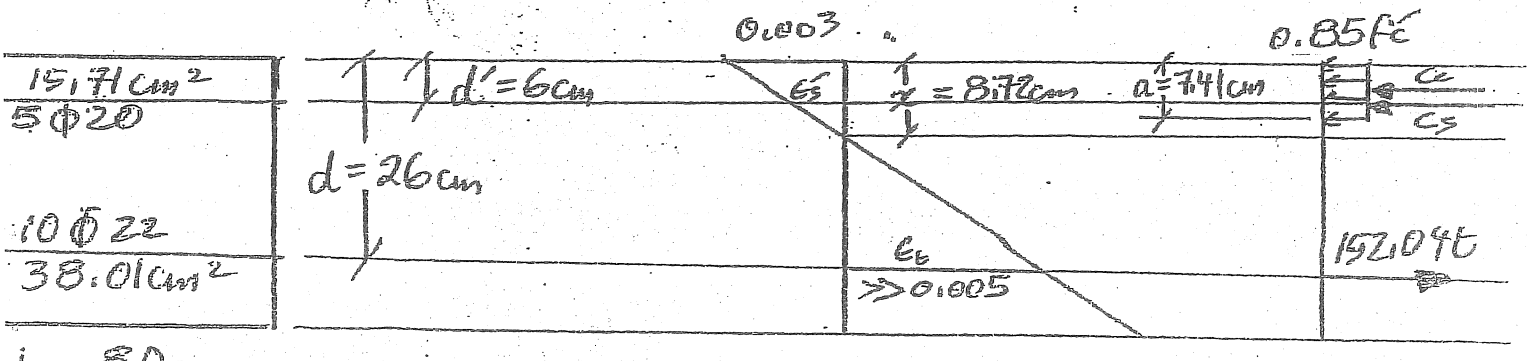
$= 33.3\ t.m$

Note: $A_{s\,max} = 43.45\ cm^2$ ∴ $\phi = 0.9$

$\epsilon_t = 0.005$, $A_s' = 5\Phi 20$

Note: $\epsilon_t = 0.00594$

∴ $\phi M_n = 0.9(33.3) = 29.97\ t.m$



Note: $\epsilon_s' \Rightarrow \left(\frac{8.72-6}{8.72}\right)(0.003) = 0.000936 < 0.002$

$f_s' = 1.872\ t/cm^2$, $C_s = 15.71(1.872 - 0.85(0.25))$

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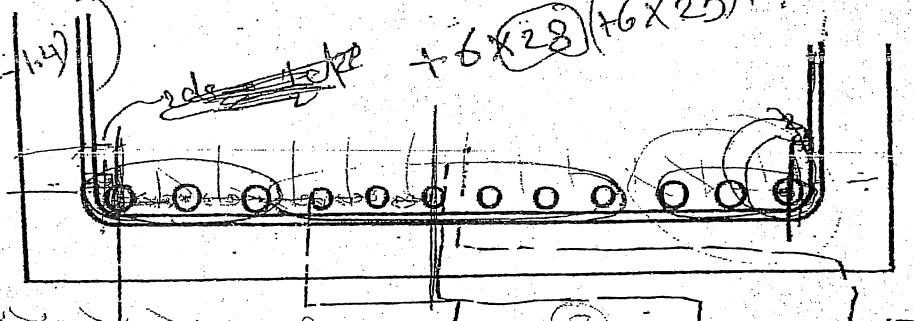
d. (2 points) What is the minimum beam width required to place 6Φ28 and 6Φ25 in one layer. Explain your calculations with a sketch.

36.15 cm x 2 = 72.3 cm



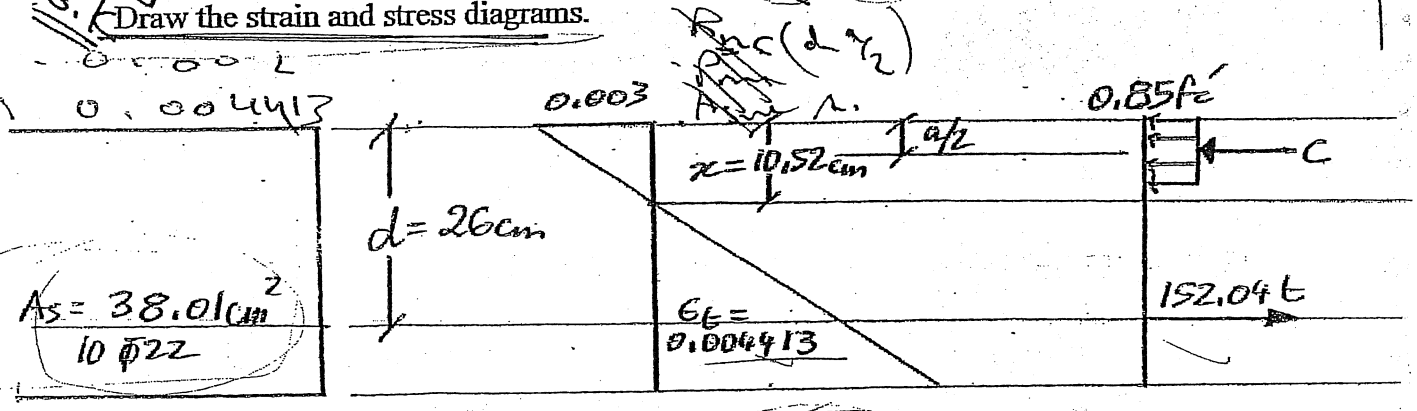
$$\left[4+1+2+1.4+(5\times 2.8)+(5\times 2.5)+\frac{2.5}{2}\right]\times 2$$

70.5

3 spaces and 2 bars

2 spaces and 3 bars

e. (3 points) If this beam is singly reinforced with As = 10Φ22 bars, determine ΦMn. Draw the strain and stress diagrams.



b = 80cm

$A_{s\,min} = 7.28\,cm^2 < A_s = 38.01\,cm^2$ but also $< A_{s\,max} = 35.22\,cm^2$ ($\varepsilon_t = 0.005$)

$\therefore \phi < 0.9$

$$T = (38.01)(4) = 152.04t$$

$$a = \frac{152.04}{0.85(0.25)(80)} = 8.94\,cm \Rightarrow x = 10.52cm$$

$\varepsilon_t = 0.004413$

$$\phi = 0.65 + \frac{(0.004413 - 0.002)(0.25)}{0.003} = 0.851$$

$$M_n = 152.04\left(\frac{26 - 8.94/2}{100}\right) = 32.73\,t.m$$

$\phi M_n = 0.851(32.73) = 27.86\,t.m$

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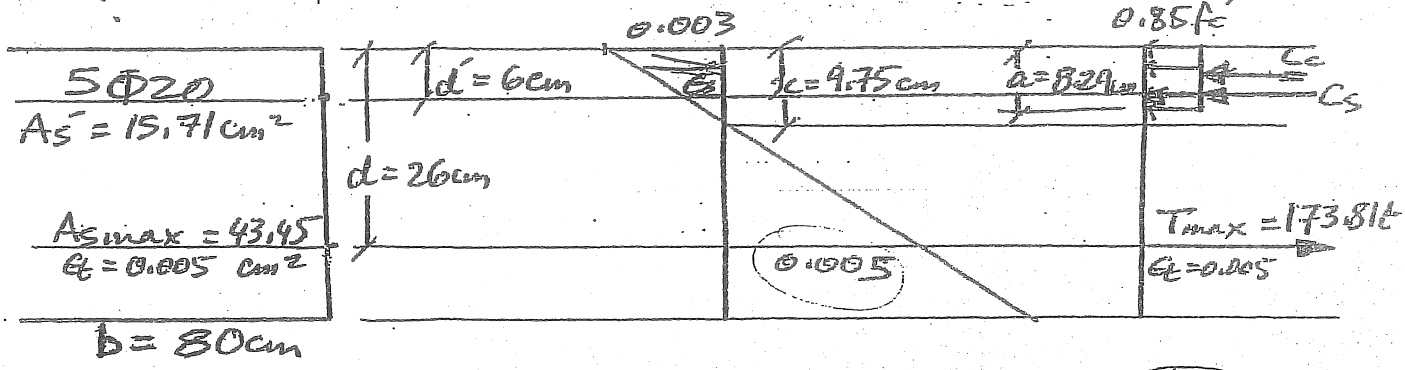
$A_s = \frac{\varepsilon_s + C_c}{4}$ → f_s, then ε_s

c. (3 points) If the beam is doubly reinforced with compression steel (A_s') = 5Φ20, and d' = 6 cm, determine ($A_{s_{max}}$) at ($\varepsilon_t = 0.005$). Draw the strain and stress diagrams.



$C_s' = \frac{0.003}{x}(\varepsilon_s' - d) = \left(\frac{9.75 - 6}{9.75}\right)(0.003) = 0.001154 < \varepsilon_y = 0.002$

$< \varepsilon_y$

$f_s' = 0.001154 \times 200\,000 = 230.8\ MPa$

f_s'

$C_s = (15.71)(2.308 - 0.85(0.25)) = 32.91t$

doubly tied

$T = 140.9 + 32.91 = 173.81\ t$

$A_{smax} = \frac{173.81}{4} = 43.45\ cm^2$

$\varepsilon_t = 0.005$

$A_s' = 5Φ20$

$T = C_s + C_c$

$A_s'(f_s' - 0.85f_c')$

ε_s'

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DONE

Name: Key Total number of pages = 7

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

First Exam **February 21, 2010**

1. A beam has a width b = 80 cm and an effective depth d = 26 cm. Using fc' = 25 MPa, fy = 400 MPa, Es = 200 GPa, and assuming Φ10 stirrups are used,

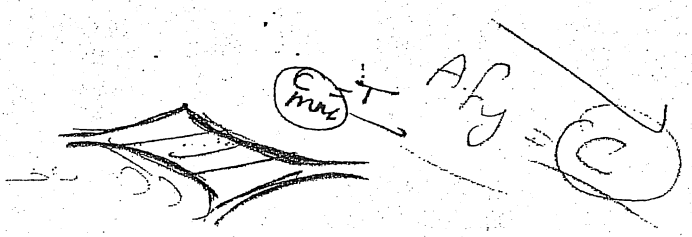
a. (1 point) Determine As_{min}.

O.K

$$\frac{\sqrt{25}}{(4)(400)}(80)(26) \geq \frac{1.4}{400}(80)(26)$$

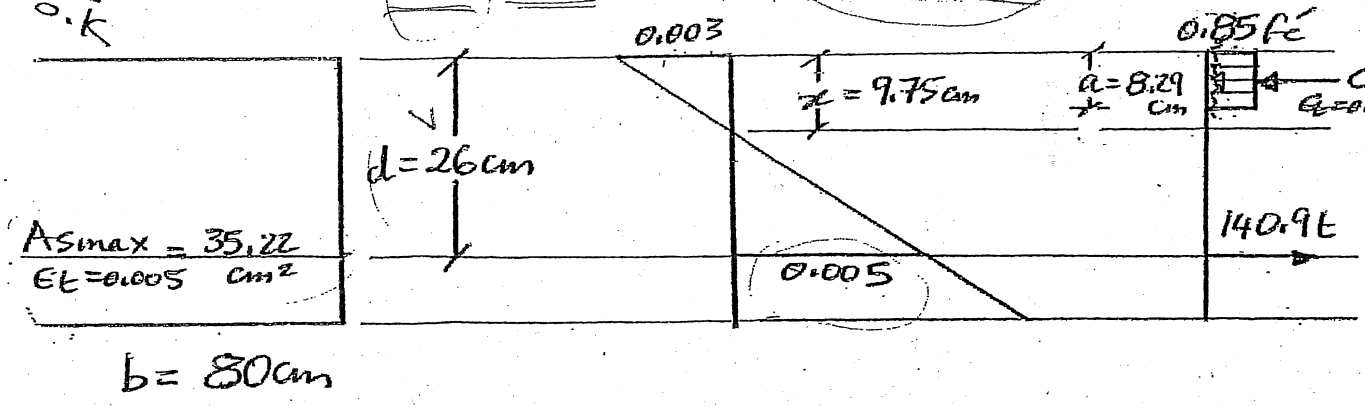
$$= 6.5\ cm^2 \geq 7.28\ cm^2$$

Controls



b. (3 points) Determine $As_{max-\varepsilon t=0.005}$. Draw the strain and stress diagrams.

O.K



$$x_{max}\ (\varepsilon_t = 0.005) = \frac{3}{8}(26) = 9.75\ cm, \quad a_{max}\ (\varepsilon_t = 0.005) = 0.85x = 8.29\ cm$$

$$C_{max} = (8.29)(80)(0.85 \times 0.25) = 140.9t$$

$$As_{max}\ (\varepsilon_t = 0.005) = \frac{140.9}{4} = 35.22\ cm^2$$

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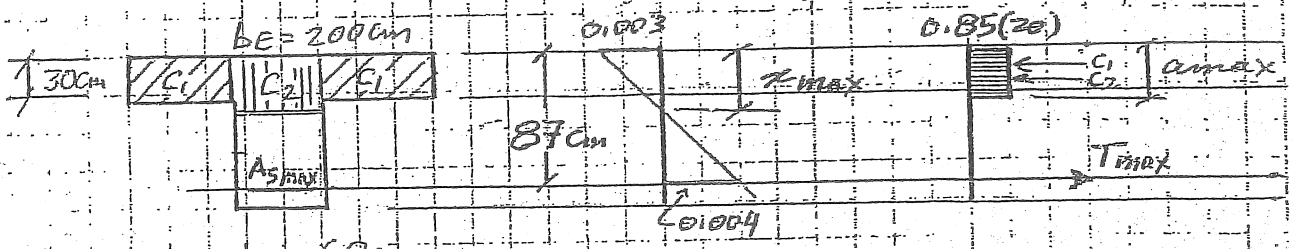
b. (5 points) Check dimensions then determine if the reinforcement satisfies As_{max}–ε_t=0.004 requirements at sections A-A and B-B. Draw appropriate strain and stress diagrams.

$t = 30\,cm \geq \frac{1}{2}(60) = 30\,cm$ ∴ OK ✓

$b_E \leq 4(60) = 240\,cm$, $b_E = b_f = 200\,cm$ (controls)

Section A-A (+ve moment, compression in the flanges)



$b_w = 60\,cm$

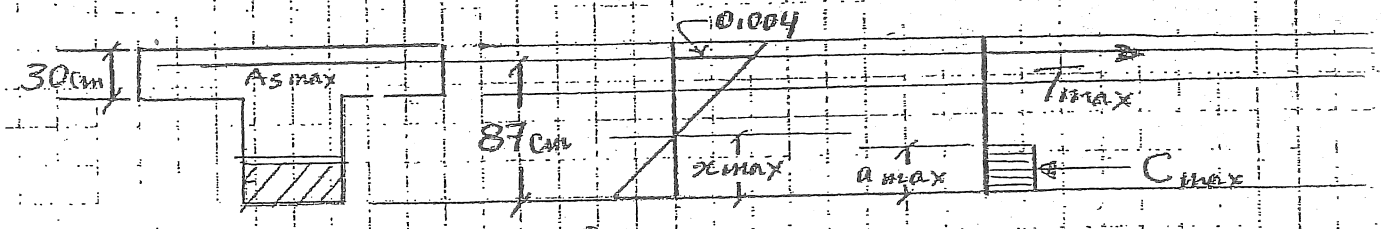
$x_{max} = \frac{3}{7}(87) = 37.3\,cm$, $a_{max} = 0.85x$

$= 31.7\,cm$

$C = 0.85(0.2)(200-60)(30) + 0.85(0.2)(60)(31.7) = 1037t$
(714t) (323t)

∴ $As_{max\,\varepsilon_t=0.004} = \frac{1037}{4} = \frac{259\,cm^2}{(+ve)}$ ($As_{actual} = 56.55\,cm^2$ ✓OK)

Section B-B (-ve moment, compression in the web)



$C_{max} = 0.85(0.2)(60)(31.7) = 323t$

∴ $As_{max\,\varepsilon_t=0.004}\,(-ve) = \frac{323}{4} = \frac{80.8\,cm^2}{(-ve)}$

($As_{actual} = 64.34\,cm^2$ ✓OK)

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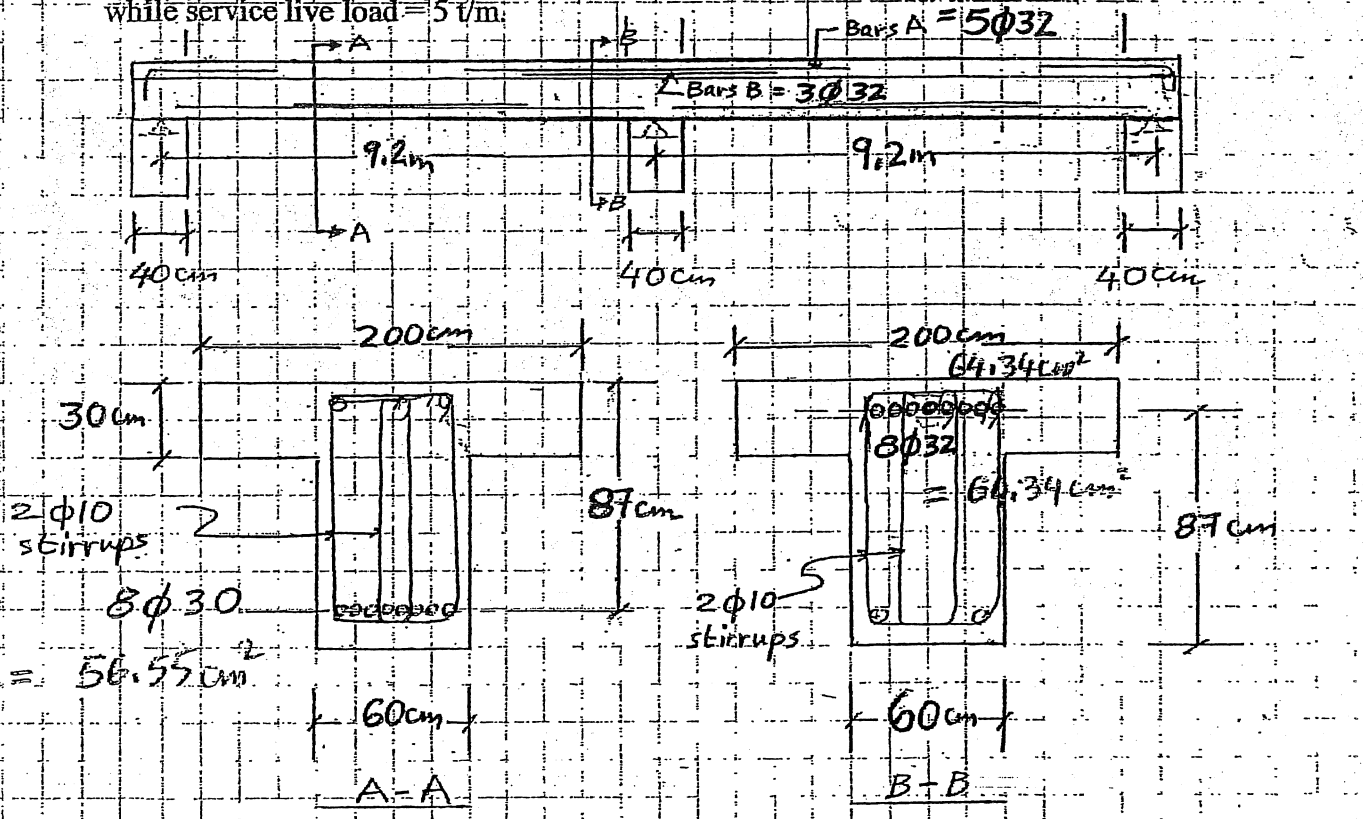
Name: Key Total number of pages = 7

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

Second Exam **April 11, 2010**

1. This isolated T-beam was designed for shear and flexure with fc' = 20 MPa, fy = 400 MPa, and Es = 200 GPa. Service dead load = 9 t/m including self-weight, while service live load = 5 t/m.



a. (4 points) Check if the reinforcement satisfies As_{min} requirements at sections A-A and B-B.

Section A-A, Positive moment (tension in the web)

$$As_{min} = \frac{0.25\sqrt{20}}{400}(60)(87) \geq \frac{1.4}{400}(60)(87)$$

$$= 14.59\ cm^2 \geq \underbrace{18.27\ cm^2}_{\text{controls minimum}} \quad (A_{s\,actual} = 56.55\ cm^2\ \checkmark OK)$$

Section B-B, negative moment (tension in the slab-flanges)

$$As_{min} = \frac{0.5\sqrt{20}}{400}(60)(87) \leq \frac{0.25\sqrt{20}}{400}(200)(87)$$

$$= \underbrace{29.18\ cm^2}_{\text{controls minimum}} \leq 48.63\ cm^2 \quad (A_s = 60.34\ cm^2\ \checkmark OK)$$

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Name Key

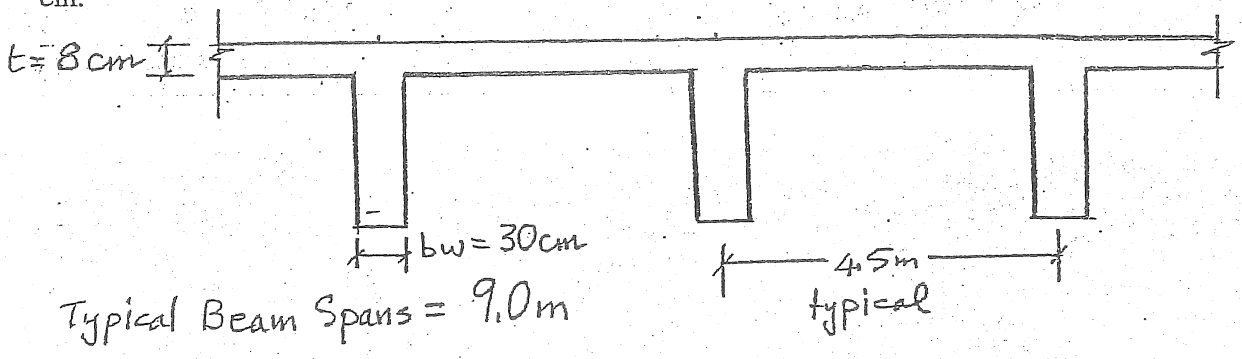
Birzeit University
Faculty of Engineering
Civil Engineering Department

CE 433, Reinforced Concrete Design I

Second Exam **Sunday May 4, 2008**

30 min

1. For the given T-sections forming the supporting system for a floor slab, fc' = 25 MPa, and fy = 400 MPa, and the effective depth for positive and negative moments is d = 77 cm.



Typical Beam Spans = 9.0m

a. (3 points) Determine the required reinforcement to carry a nominal negative bending moment, Mn required = 850 kN.m (85 t.m).

$$R_{n\,req} = \frac{85 \times 100}{(30)(77)^2} = 0.04779 \ t/cm^2$$

$$m = \frac{400}{0.85 \times 25} = 18.82$$

$$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.04779)}{4}}\right) = 0.01372$$

$$A_{s\,req} = 0.01372 \times 30 \times 77 = 31.70 \ cm^2$$

use 10 ϕ 20 bars, A_s provided = $31.42 \ cm^2$ ~

5 min

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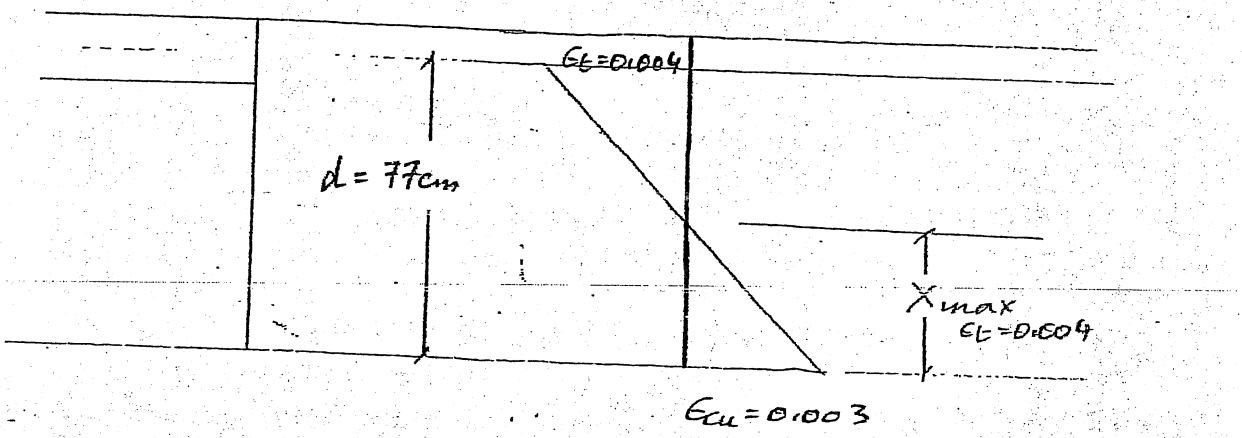
Dr, Jamal Zalatimo

b. (5 points) Check compliance with ACI – 318 requirements for maximum and minimum reinforcement.



$$x_{max} = \frac{0.003}{0.007}(77) = 33\ cm$$

$$a = 0.85(33) = 28.05\ cm$$

$$C_{\substack{\varepsilon t=0.004 \\ max}} = 0.85(0.25)(30)(28.05)$$

$$= 178.8t$$

$$\therefore A_{\substack{s\,max \\ \varepsilon t=0.004}} = \frac{178.8}{4} = 44.70\ cm^2 \qquad \rho_{max} = 0.01935$$

$$A_{s\,min} = \frac{\sqrt{25}}{2(400)}(30)(77) \leq \frac{\sqrt{25}}{4(400)}(450)(77)$$

(0.00625 and 0.003125)

$$= \frac{14.43\ cm^2}{controls} \leq 108.28\ cm^2$$

$A_{s\,min} = 14.43\ cm^2$ < A_s provided $= 31.42\ cm^2$ < $A_{s\,max} = 44.70\ cm^2$

2/7

∴ OK

10 min

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c. (2 points) Provide a sideview (and x-sections as necessary) of span AB showing the design spacings and the number of stirrups for each part.

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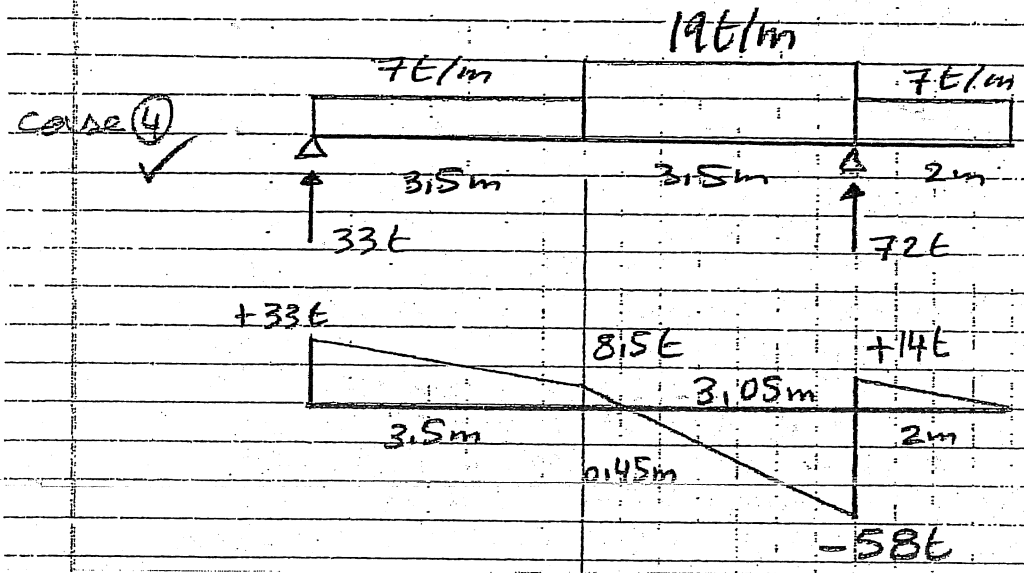
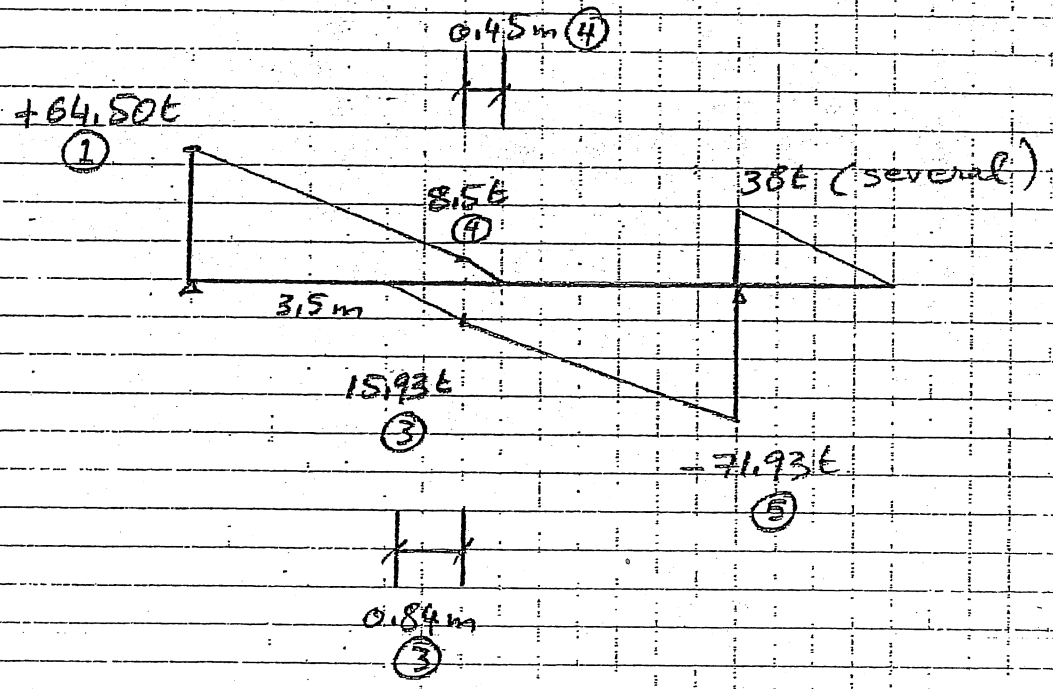


Shear Envelope :



Note that only four cases of loading are required.

① ③ ④ ⑤

Refer to the I.L. diagrams

40 min

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Dr Jamal Zalatimo

∴ Bars B must extend from the face of support,

$32.6 + 87 = 119.6\ cm \geq L_d = 219\ cm$

controls

∴ Total length of Bars B $= [(219) \times 2] + 40\ cm$

$= 478\ cm$

Bars A must extend beyond the I.P. at least,

$\underset{\text{controls}}{d = 87\ cm}$, $12 d_b = 38.4\ cm$, $\frac{L_n}{16} = \frac{880}{16} = 55\ cm$

∴ Length from the face of support $= 180 + 87 = 267\ cm$

However, $267 - \underset{\text{Bars B}}{219} < L_d = 219$

∴ Required length $= 219 + 219 = 438$ from face of support

∴ Total Length of Bars A $= [(438) \times 2] + 40$

$= 916\ cm$

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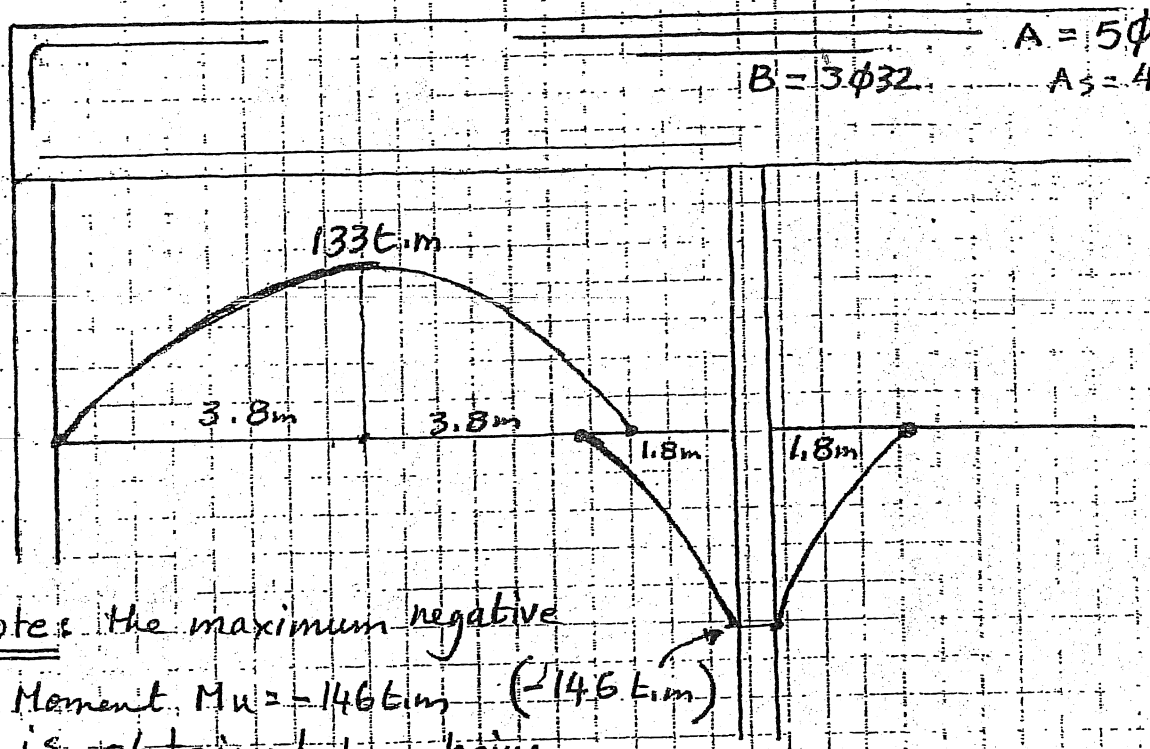
d. (4 points) Using the provided Mu-envelope, determine the most appropriate length for bars A and B.



Note: The maximum negative Moment Mu = -146 t.m (-146 t.m) is obtained by placing maximum load on both spans.

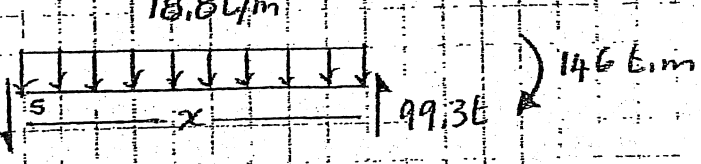
For bars B (and A): $L_d = \frac{(400)(1.3)(1.0)}{(1.7)(1.0)\sqrt{20}}(3.2) = 68.4(3.2) = 219\,cm$ > 30

$M_n(5\phi32) = (40.21)(4)\left(\frac{87 - 15.77/2}{100}\right) = 127.2\ t.m$

where $a = 40.21 \times 4 / 0.85(0.2)(60) = 15.77\,cm$

$\phi M_n = (0.9)(127.2) = 114.5\ t.m$

$W_u = 1.2(9) + 1.6(5) = 18.8\ t/m$



$\Sigma M_{@S} = 0$ +↻

$$-114.5 + \frac{18.8x^2}{2} - 99.3x + 146 = 0$$

$$x^2 - 10.56x + 3.351 = 0 \Rightarrow x = 0.326\,m$$

$d = 87\,cm$, $12\,db = 12 \times 3.2 = 38.4\,cm$

Centrals

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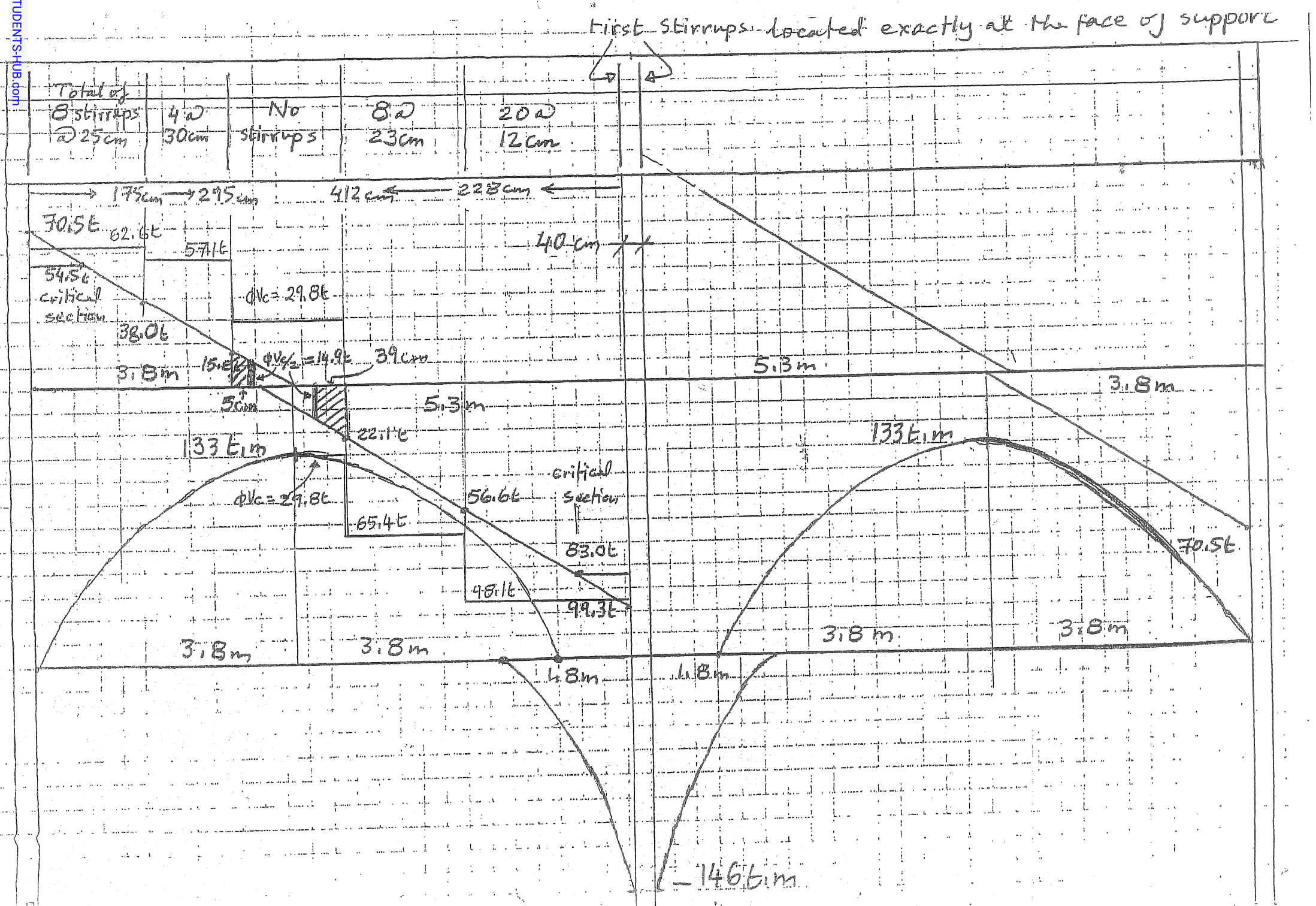
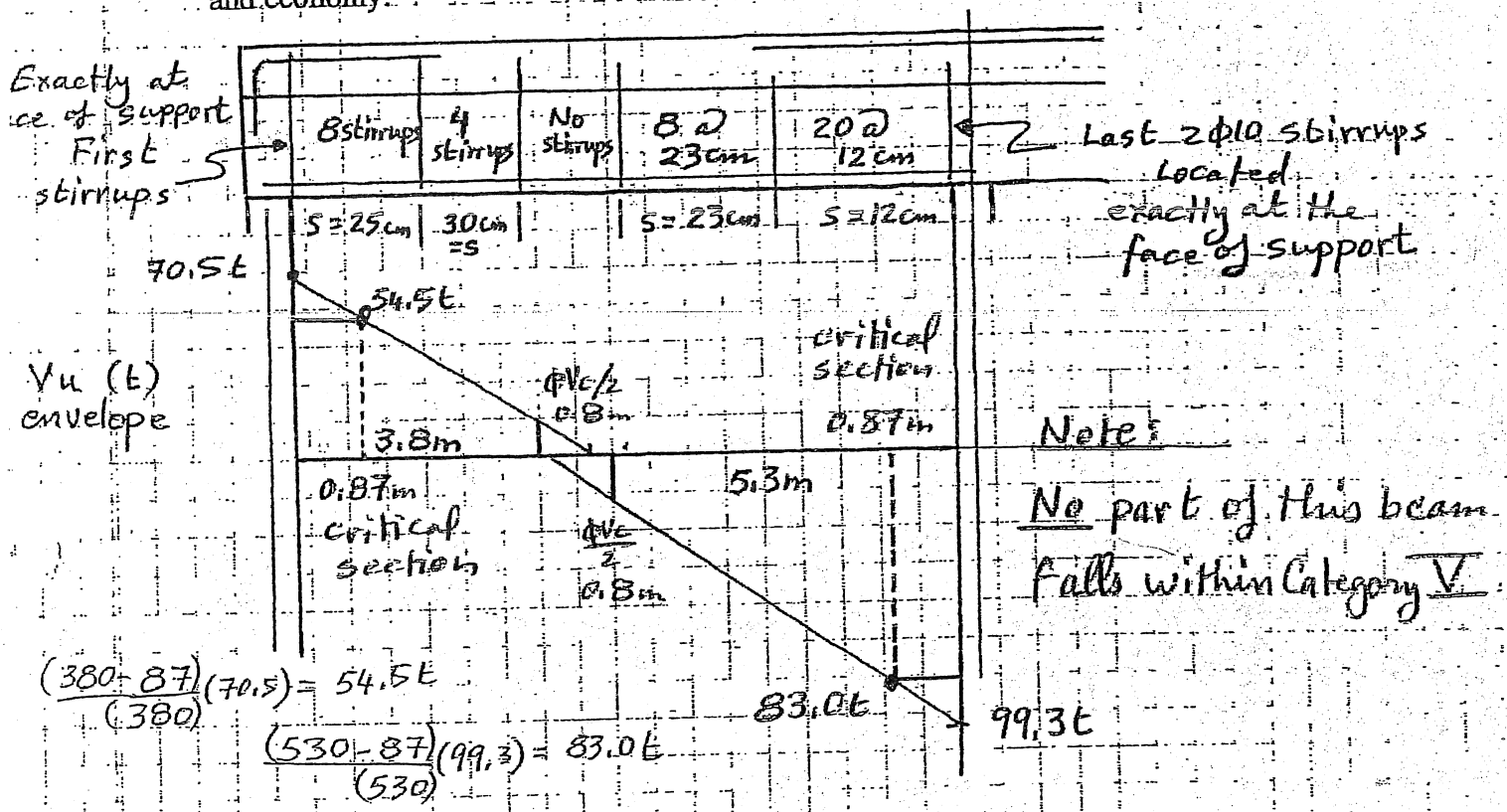


c. (4 points) Draw the ϕV_n diagram superimposed on the provided Vu-envelope. Is the beam properly designed for shear? Consider minimum and maximum limits, and economy.



Note:

No part of this beam falls within Category V

$\phi V_c = 0.75\,(0.17)\,(\sqrt{20}/100)\,(60)\,(87) = 29.8t$

$\phi V_c/2 = 14.9t$, $3\phi V_c = 89.3t$, $5\phi V_c = 148.8t$

$S_{max} = 3.14\,(400)/0.062\sqrt{20}\,(60) = 75.5\,cm$

$\leq 3.14\,(400)/0.35\,(60) = 59.8\,cm$

$d/2 = 43.5\,cm$ (Controls) , $\leq 60\,cm$

$S = 25\,cm$, $\phi V_s = 0.75\,(3.14)\,(4)\,(87)/25 = 32.8t$

$\therefore \phi V_n = 32.8 + 29.8 = \underline{62.6t}$

$S = 30\,cm$, $\phi V_s = 27.3t$, $\phi V_n = 27.3 + 29.8 = \underline{57.1t}$

$S = 12\,cm$, $\phi V_s = 68.3t$, $\phi V_n = 68.3 + 29.8 = \underline{98.1t}$

$S = 23\,cm$, $\phi V_s = 35.6t$, $\phi V_n = 35.6 + 29.8 = \underline{65.4t}$

Notes: * 4 @ 30 — a longer spacing should be used and extended to cover the hatched area where minimum is required

* 8 @ 23 — two more spacings are required to cover the hatched area.

* Other requirements are properly satisfied, reasonably! OK

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2. Answer very briefly,

a. (2 points) Using proper sketches, explain briefly the truss model for beams.

b. (2 points) Using proper sketches, explain the concept of effective flange width.

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c. (1 points) How is the determination of the required embedment length of standard hooks in compression different from the procedure for the case of tension?

d. (1 points) In the treatment of development of reinforcement at simple supports, the ACI Code requires that La + 1.3 Mn/Vu ≥ Ld. The 1.3 factor is not used in the case of inflection points, why?

e. (1 points) La for continuous supports is the straight embedment length beyond the inflection point (to the end of the bars) while at simple supports it is only the straight embedment length beyond the centerline of support (to the end of the bars), why?

f. (1 points) How is La at simple supports determined if the reinforcement is terminated in a standard hook?

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b. (2 points) Is the beam expected to show objectionable deflection under service conditions?

Based on $\rho = 0.7\,\rho_{max}$ ($\epsilon_t = 0.005$)

or $A_s = 0.7\,(61.81) = 43.27\ cm^2$

$A_{s\,req} = 47.74\ cm^2 > 43.27\ cm^2$

or

$$\frac{A_{s\,req}}{A_{s\,max}\ (\epsilon_t = 0.005)} = \frac{47.74}{61.81} = 0.77$$

Objectionable deflection is possible since the ratio is larger than 0.7

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For the structural concrete (as a material):

4. a. (2 points) Use a simple strain versus time diagram to explain the change in strain of a loaded and drying specimen. Consider elastic, creep, and shrinkage strains.

b. (1 points) What are the two requirements specified by the ACI code for adequate control of strength.

c. (1 points) Explain the difference between fc' and fcr'.

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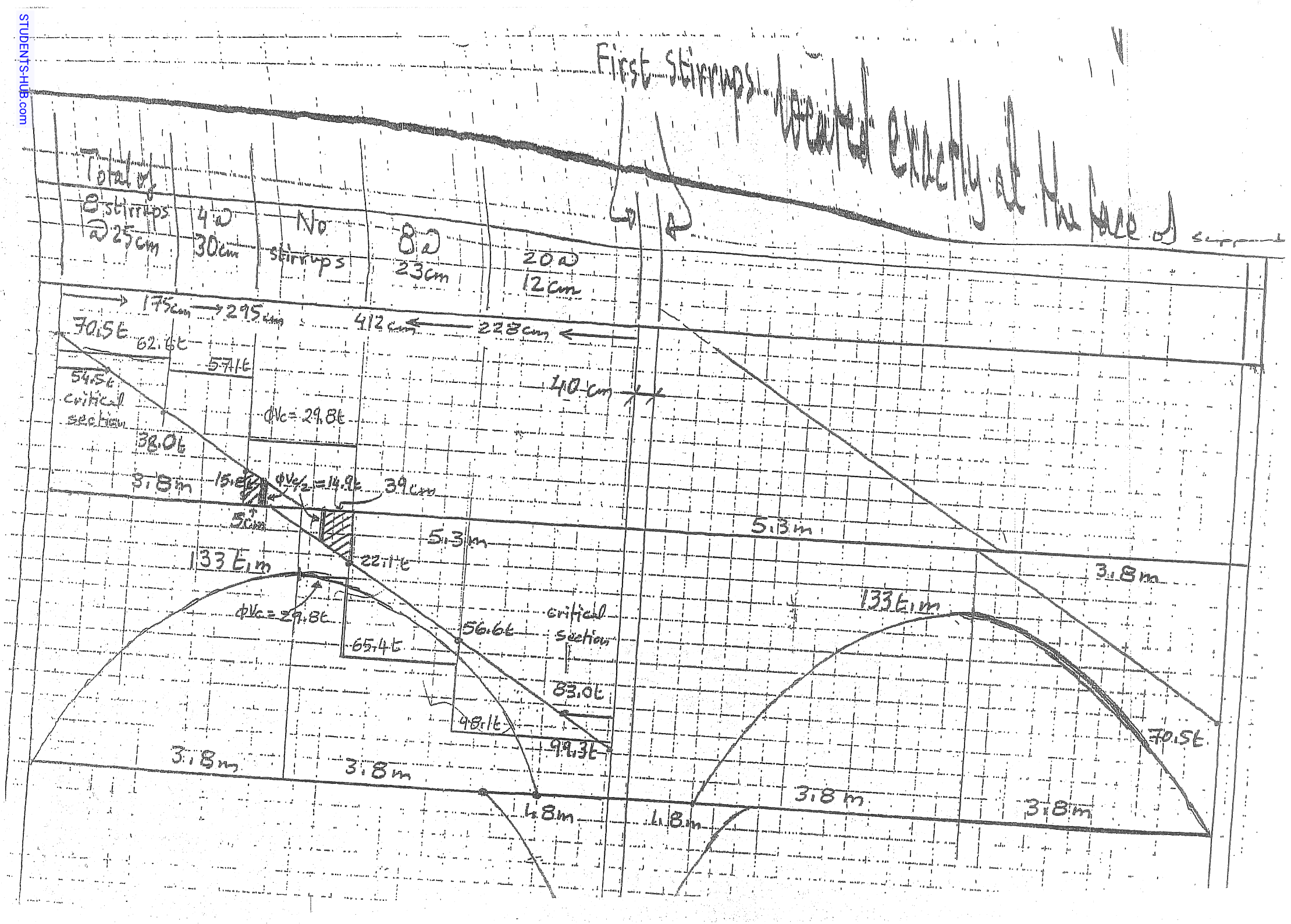
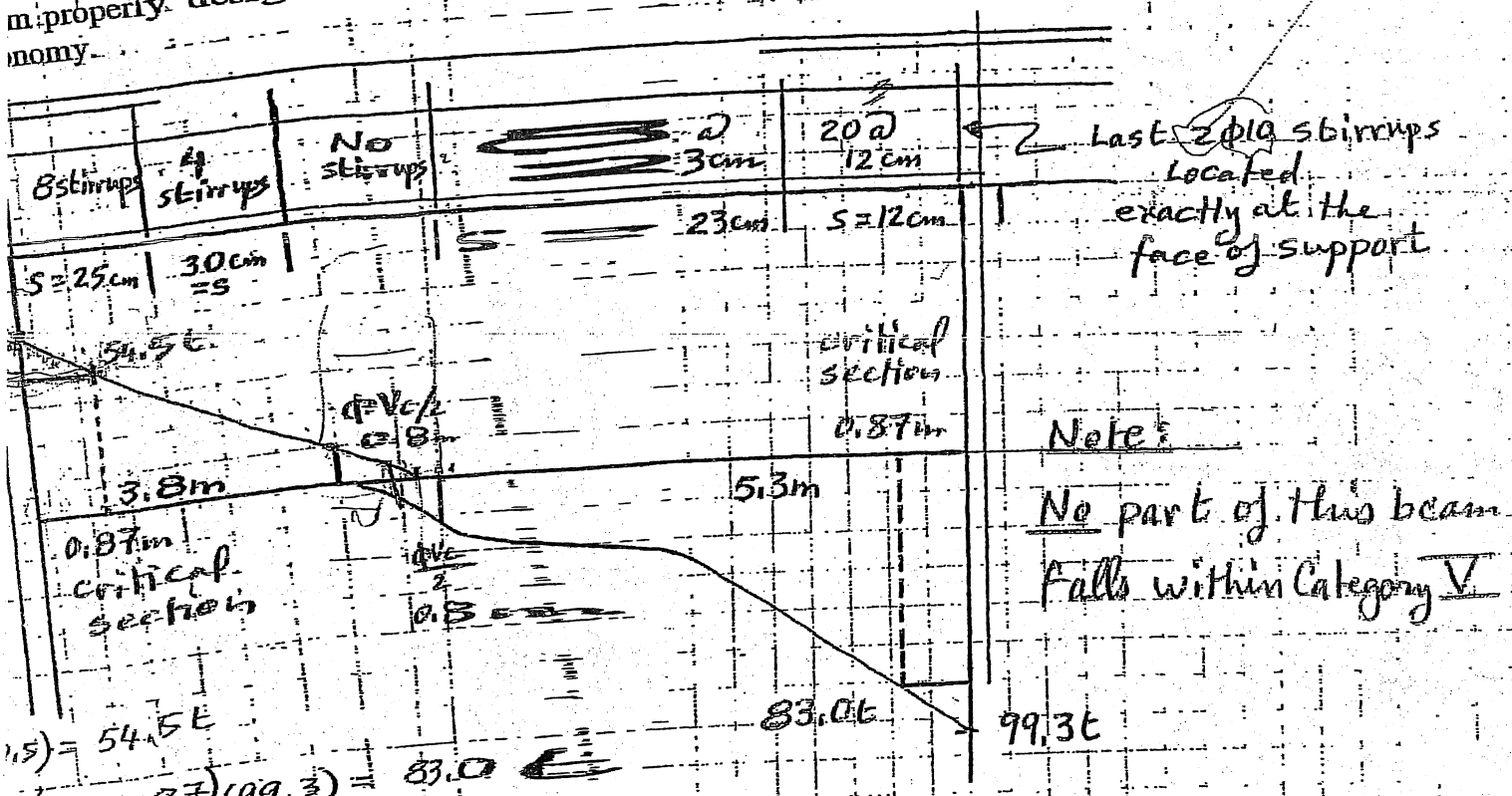


s) Draw the ϕV_n diagram superimposed on the provided Vu-envelope. Is m properly designed for shear? Consider minimum and maximum limits, nomy



Note:
No part of this beam falls within Category V

$(530-87)(99.3)/(530) = 83.0$ t

$= 0.75(0.17)(\sqrt{20}/100)(60)(87) = 29.8$ t

$/2 = 14.9$ t $\rightarrow 3\phi V_c = 89.3$t $> 5\phi V_c = 14.8.8$t

$ax = 3.14(400)/0.62\sqrt{20}(60) = 75.5$ cm

$\leq 3.14(400)/0.35(60) = 59.8$ cm

$d/2 =$ 43.5 cm (Controls) < 60 cm

25 cm, $\phi V_s = 0.75(3.14)(4)(87)/25 = 32.8$t, $\phi V_n = 32.8 + 29.8 =$ 62.6t

= 30 cm, $\phi V_s =$ 27.3t, $\phi V_n = 27.3 + 29.8 =$ 57.1t

= 12 cm, $\phi V_s =$ 68.3t, $\phi V_n = 68.3 + 29.8 =$ 98.1t

= 23 cm, $\phi V_s =$ 35.6t, $\phi V_n = 35.6 + 29.8 =$ 65.4t

4 @ 30 — a larger spacing should be used and extended to cover the hatched area where minimum is required

8 @ 23 — two more spacings are required to cover the hatched area

measurements are properly satisfied, reasonably! economically OK

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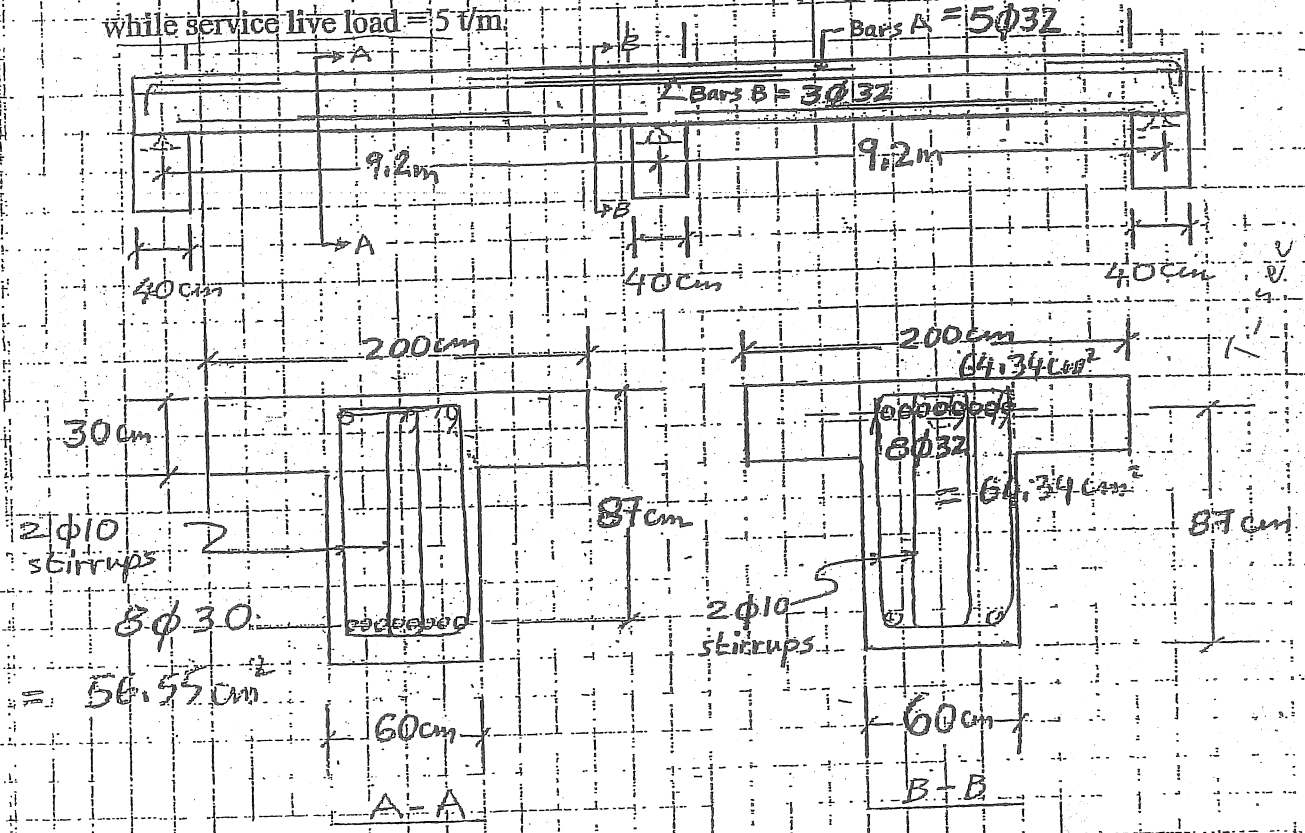
Name: Key Total number of pages = 7

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

Second Exam **April 11, 2010**

1. This isolated T-beam was designed for shear and flexure with fc' = 20 MPa, fy = 400 MPa, and Es = 200 GPa. Service dead load = 9 t/m including self-weight, while service live load = 5 t/m.



a. (4 points) Check if the reinforcement satisfies As_{min} requirements at sections A-A and B-B.

Section A-A, Positive moment (tension in the web)

$$As_{min} = \frac{0.25\sqrt{20}}{400}(60)(87) \geq \frac{1.4}{400}(60)(87)$$

$$= 14.59\ cm^2 \geq 18.27\ cm^2 \quad (As_{actual} = 56.55\ cm^2 \checkmark OK)$$

(18.27 cm² controls minimum)

Section B-B, negative moment (tension in the slab-flanges)

$$As_{min} = \frac{0.5\sqrt{20}}{400}(60)(87) \leq \frac{0.25\sqrt{20}}{400}(200)(87)$$

$$= 29.18\ cm^2 \leq 48.63\ cm^2 \quad (OK)$$

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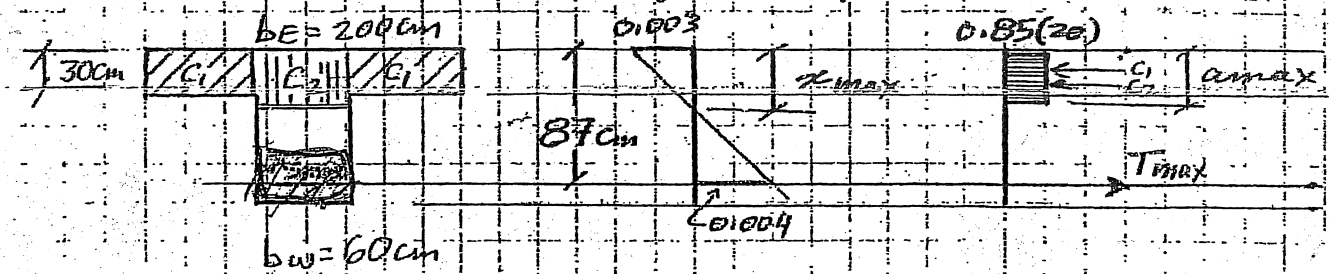
b. (5 points) Check dimensions then determine if the reinforcement satisfies $A_{s_{max}}$ $_{\varepsilon_t=0.004}$ requirements at sections A-A and B-B. Draw appropriate strain and stress diagrams.

$t = 30\,cm \geq \frac{1}{2}(60) = 30\,cm$ ∴ OK ✓

$b_E \leq 4(60) = 240\,cm$, $b_E = b_f = 200\,cm$ (controls)

Section A-A (+ve moment, compression in the flanges)



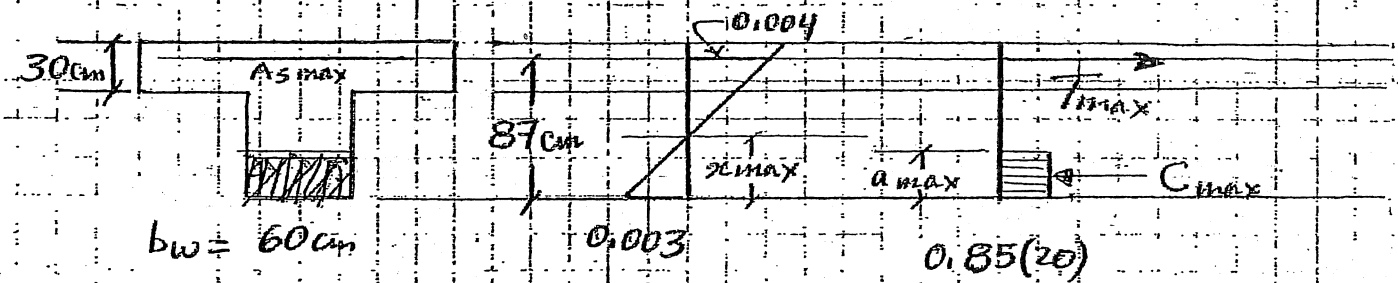
$x_{max} = \frac{3}{7}(87) = 37.3\,cm$, $a_{max} = 0.85x$

$= 31.7\,cm$

$C = \underbrace{0.85(0.2)(200-60)(30)}_{(714t)} + \underbrace{0.85(0.2)(60)(31.7)}_{(323t)} = 1037t$

∴ $A_{s_{max}}{}_{\varepsilon_t=0.004} = \frac{1037}{4} = \underbrace{259\,cm^2}_{(+ve)}$ ($A_{s_{actual}} = 56.55\,cm^2$ ✓OK)

Section B-B (-ve moment, compression in the web)



$C_{max} = 0.85(0.2)(60)(31.7) = 323t$

∴ $A_{s_{max}}{}_{\varepsilon_t=0.004}\,(-ve) = \frac{323}{4} = \underbrace{80.8\,cm^2}_{(-ve)}$

($A_{s_{actual}} = 64.34\,cm^2$ ✓OK)

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c. (1 points) How is the determination of the required embedment length of standard hooks in compression different from the procedure for the case of tension?

d. (1 points) In the treatment of development of reinforcement at simple supports, the ACI Code requires that La + 1.3 Mn/Vu ≥ Ld. The 1.3 factor is not used in the case of inflection points, why?

e. (1 points) La for continuous supports is the straight embedment length beyond the inflection point (to the end of the bars) while at simple supports it is only the straight embedment length beyond the centerline of support (to the end of the bars), why?

f. (1 points) How is La at simple supports determined if the reinforcement is terminated in a standard hook?

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2. Answer very briefly,

a. (2 points) Using proper sketches, explain briefly the truss model for beams.

b. (2 points) Using proper sketches, explain the concept of effective flange width.

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Dr Jamal Zalatimo

∴ Bars B must extend from the face of support,

$32.6 + 87 = 119.6\ cm \geq \underline{L_d = 219\ cm}$ controls

∴ Total length of Bars B $= [(219) \times 2] + 40\ cm$

$= \underline{478\ cm}$

Bars A must extend beyond the I.P. at least,

$\underline{d = 87\ cm}$ controls, $12 d_b = 38.4\ cm$, $\frac{L_n}{16} = \frac{880}{16} = 55\ cm$

∴ Length from the face of support $= 180 + 87 = 267\ cm$

However, $267 - 219 < L_d = 219$

Bars B

∴ Required length $= 219 + 219 = 438$ from face of support

∴ Total Length of Bars A $= [(438) \times 2] + 40$

$= \underline{916\ cm}$

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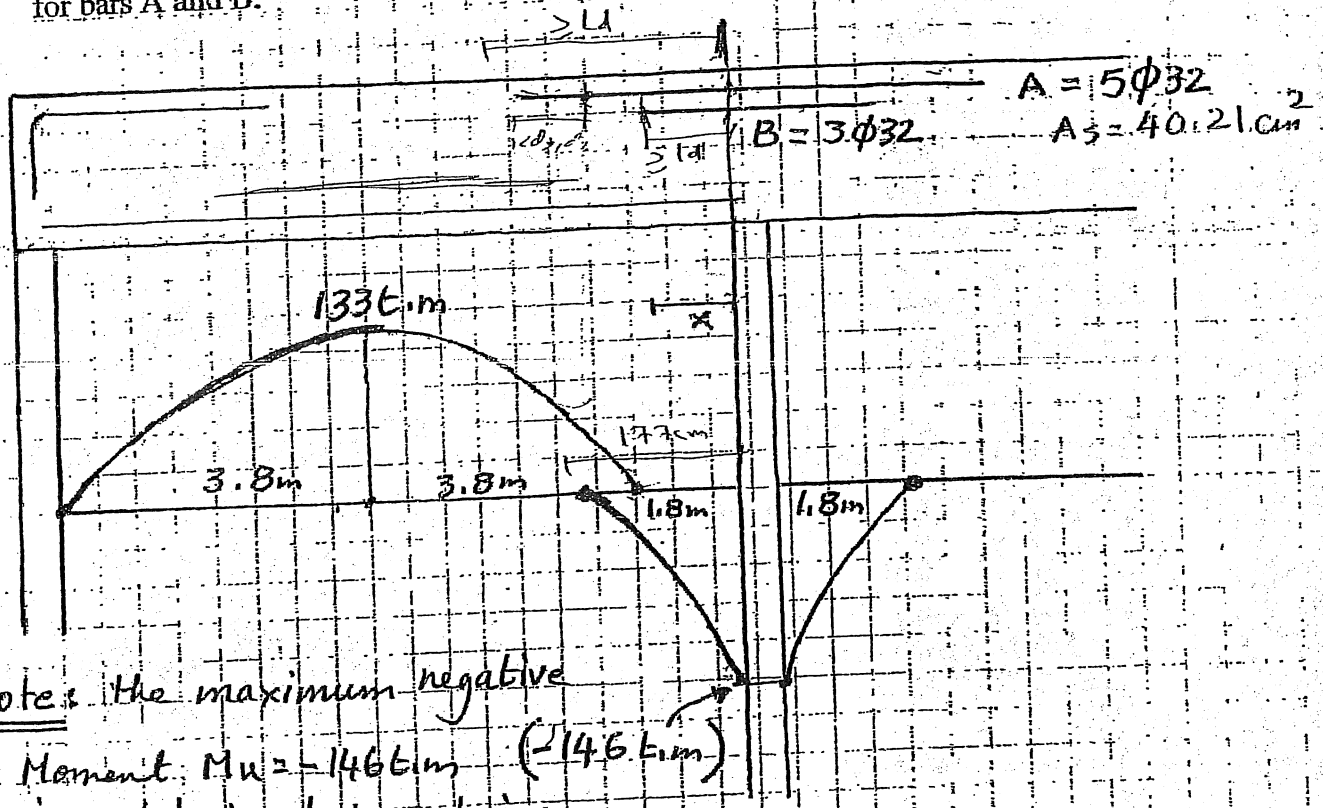
d. (4 points) Using the provided Mu-envelope, determine the most appropriate length for bars A and B.



Note: the maximum negative Moment Mu = -146 t.m (-146 t.m) is obtained by placing maximum load on both spans.

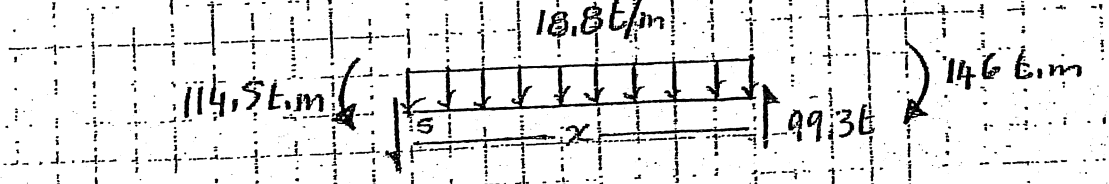
For bars B (and A): $Ld = \frac{(400)(1.3)(1.0)}{(1.7)(1.0)\sqrt{20}}(3.2) = 68.4(3.2) = 219\,cm$ >30

$M_n(5\phi32) = (40.21)(4)\left(\frac{87 - 15.77/2}{100}\right) = 127.2$ t.m

where $a = 40.21 \times 4 / 0.85(0.2)(60) = 15.77$ cm

$\phi M_n = (0.9)(127.2) = 114.5$ t.m

$W_u = 1.2(9) + 1.6(5) = 18.8$ t/m



$\Sigma M_{@S} = 0$ ↻

$-114.5 + \frac{18.8x^2}{2} - 99.3x + 146 = 0$

$x^2 - 10.56x + 3.35) = 0 \Rightarrow x = 0.326$ m

$d = 87$ cm, $12\,db = 12 \times 3.2 = 38.4$ cm

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b. (3 points) The most appropriate stirrup spacing "s" at the critical section.

$3\phi V_c = 69.8t$

$5\phi V_c = 116.4t$

$0.30 + 0.73 = 1.03m$

$\frac{(5.80-1.03)}{(5.80)}(85) + (15) = \frac{4.77}{5.80}(85) + 15$

$\therefore$ Vu at the critical section $= 69.9 + 15 = 84.9t \Rightarrow$ Category 5

$\phi V_{s\,req} = 84.9 - 23.27 = 61.6t$

$S_{req} = \frac{(0.75)(1.57)(4)(73)}{61.6} = 5.58cm$ (= 11.16 cm for double ϕ10)

$S_{max} \leq 40.5cm$
$\leq 35.9cm$ } as before

$S_{max} \leq 73/4 = 18.25cm$
$\leq 30cm$ controls minimum

$\therefore$ use 2ϕ10 @ 11 cm c/c

c. (2 points) Explain why the ACI-Code places lower and upper limits on Vs (shear reinforcement).

$M_{ud} \leq \phi M_n$

$M_u = M_n/\phi$

$M_n/\phi = M_n$

$C_c \times arm + C_s \times arm = 0.85 f'_c \times b \times B_1(X) \times \left(d - \frac{B_1 X}{2}\right) + A'_s (f'_s - 0.85 f'_c)(d - d')$

$X =$

$C_c + C_s = F_y A_s$

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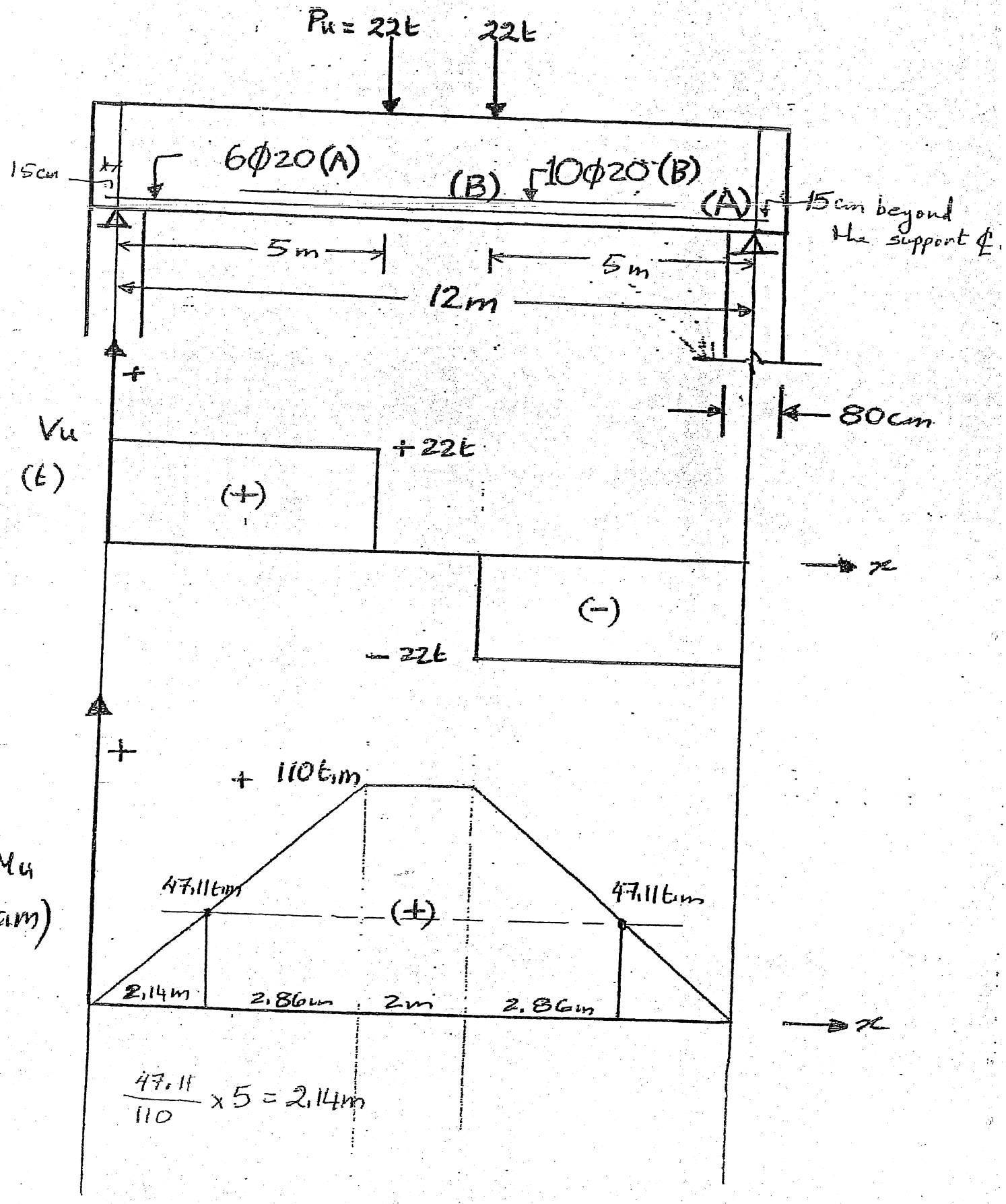
B. A beam has b = 50 cm, d = 73 cm, fc' = 25 MPa, fy = 400 MPa, and Φ 10 stirrups. The shear and bending moment diagrams for the beam are provided.

(use d = 73cm in all calculations)



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∴ Bars A must be extended

127 − 106 = 21 cm more.

(15 + 21) = 36 cm from the face of support.

This distance is available since the columns are 70 cm wide as shown.

∴ Total length for Bars A = 852 cm

= 850 − (2 × 35) + (2 × 36)

Total length for Bars B = 2(218 + 81)

= 2 × 299

= 598 cm

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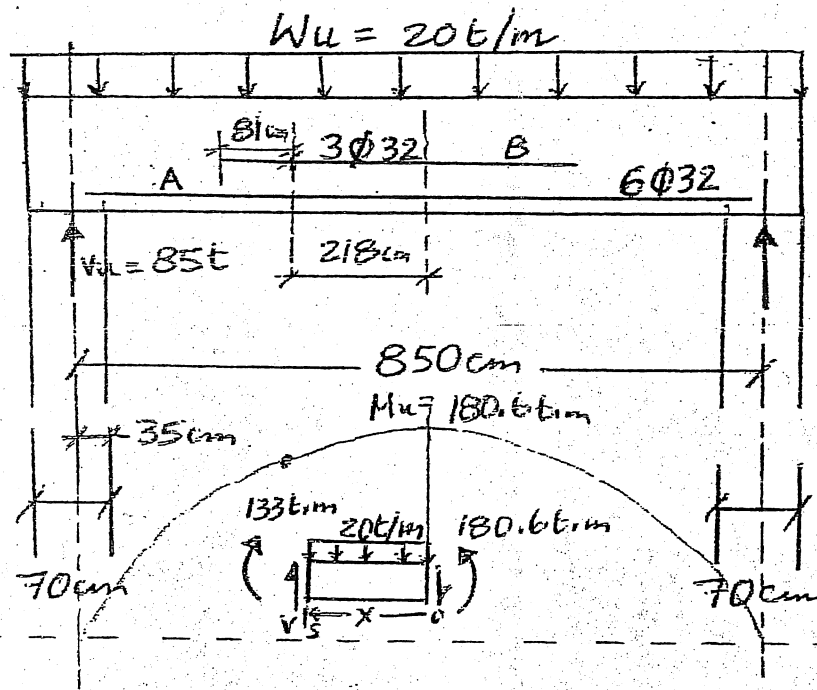
5. a. (10 points) Check if the long bars A are properly anchored if they are extended 15 cm only into the support.

b. (10 points) Determine the exact length required for the long bars A and the short bars B. (Note: No need to check As_{max} or As_{min})
Use b = 75 cm, d = 81 cm, fc' = 35 MPa, and fy = 400 MPa.



All bars (A+B) are placed in the same layer.

$6\Phi32 = 48.24\ cm^2$, $T = 193\ t$, $a = 8.65\ cm$

$Mn = 193\left(81 - \frac{8.65}{2}\right)/100 = 148\ t.m$, $\phi Mn = 133\ t.m$

$\frac{1.3(148)}{85} + 0 = 2.26\ m > ld = 127\ cm$ ✓ ∴ OK

All category A requirements are satisfied,

$ld = \frac{(400)(1.0)(1.0)}{1.7(1.0)(\sqrt{35})}(3.2) = 127\ cm$

$\Sigma M_{@3} = 0$ +↻

$+133 + \frac{20x^2}{2} - 180.6 = 0$ $\quad x = 2.18\ m$

$d = 81\ cm$, $12d_b = 38.4\ cm$ ∴ use $d = 81\ cm$

Adding $d = 81\ cm$ to the T.C.O.P., leaves 106 cm to the end of bars A – must be $\geq ld = 127\ cm$

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Name: Key

Total = 12 pages
(Part 1 = 8 pages, Part 2 = 4 pages)

Birzeit University
Faculty of Engineering
Department of Civil Engineering
Reinforced Concrete Design I

First Exam Tuesday, December 3, 2013

Part 1 = 8 pages

Q1. A beam has b = 110 cm, d = 37 cm, and d' = 7 cm. The beam is reinforced with 10Φ25 compression bars. Use fc' = 35 MPa, and fy = 420 MPa.

a. (8 points) Determine the maximum amount of reinforcement that can be used.

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Name: Key

Part 2 = 4 pages

Q4. (15 points) Circle the appropriate letter, T for true or F for false.

1. T (F) Under-reinforced sections do not have sufficient reinforcement to support the design moments.

2. (T) F Over-reinforced sections have more reinforcement than $As_{balanced}$.

3. (T) F Steel and concrete have similar rates of thermal expansion.

4. (T) F The minimum permissible reinforcement for doubly reinforced sections is the same as that for singly reinforced sections.

5. T (F) Concrete ordinarily requires about 7 days to attain adequate strength so that forms can be removed and construction and dead loads carried.

6. (T) F A tension-controlled section will exhibit a ductile failure mode with visible flexural cracks and deflection.

7. T (F) Minimum steel reinforcement in beams is required by the ACI Code to prevent cracking of the tension side of beams.

8. (T) F The nominal maximum size of coarse aggregate may not exceed 3/4 the minimum clear spacing between reinforcing bars.

9. T (F) If the actual steel reinforcement exceeds $As_{max\ at\ =0.004}$ the compression side of the beam will not reach a crushing strain $\varepsilon_{cu} = 0.003$ at failure.

10. T (F) The modulus of rupture measures the shear strength of concrete.

11. T (F) Excessive deflection under ultimate loads is not permitted because it may result in objectionable cracking.

12. T (F) The strength reduction factor ϕ is intended as a safety factor against possible construction mistakes.

13. (T) F If a beam is supported on the side face of a girder, not a column, the critical section is taken at the face of support.

14. T (F) Welded wire fabric may be used as the main reinforcement for thin slabs and shallow beams.

15. T (F) The ACI Code does not allow using bar sizes that differ by more than 4 mm in diameter, together in the same layer, for beam reinforcement.

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e. What are over-reinforced sections?

Over reinforced sections have an amount of reinforcement in excess of $A_{s\,balanced}$ and exhibit a compression failure as the concrete crushes in compression before yielding of the tension steel.

f. What is the balanced strain condition and why is it not permitted for beams?

In this condition the concrete in compression crushes just as the tension steel reaches yielding.
It is not permitted for beams because the failure would be sudden without enough warning.

g. What is the purpose of using bolsters and chairs (bar supports) in construction?

To maintain proper bar spacing and Concrete cover for reinforcement. Hold the bars in place properly during construction.

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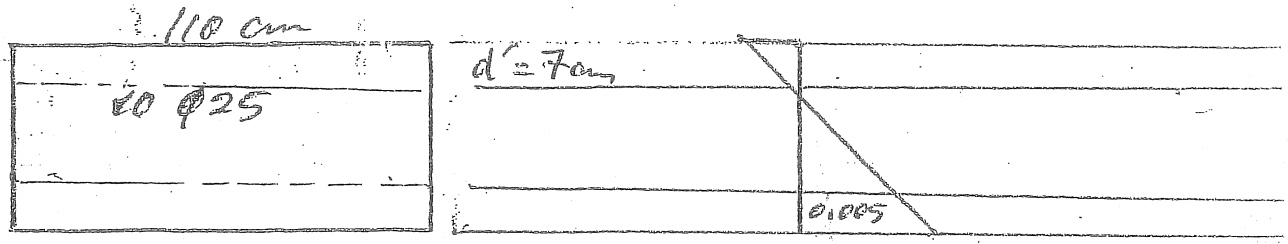
Q1 $b = 110\,cm$, $d = 37\,cm$, $d' = 7\,cm$, $A_s' = 10\phi 25$

$f_c' = 35\,MPa$, $f_y = 420\,MPa$ $\beta_1 = 0.80$

a)



(8 points)

x_{max} ($\epsilon_t = 0.005$) $= \frac{3}{8}(37) = 13.875\,cm$ $a = \beta_1 x = 11.1\,cm$

$\epsilon_s' = \frac{13.875 - 7}{13.875}(0.003) = 0.001486$

$f_s' = 2.973\ t/cm^2$

$C_c = 0.85(0.35)(110)(11.1) = 363.2\,t$

$C_s = 10 \times 4.91(2.973 - 0.85(0.35)) = 131.4\,t$

$\therefore$ $A_{s\,max}$ ($\epsilon_t = 0.005$, $A_s' = 10\phi 25$) $= \frac{363.2 + 131.4}{4.2} = 117.8\,cm^2$

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b) (12 points)

$Mu = 100$ t.m

$Mn_{req} = \frac{100}{0.9} = 111.11$ t.m

C_s

$$111.11 \text{ t.cm} = \overbrace{49.1\left[\left(\frac{x-7}{x}\right)(6) - 0.85(0.35)\right]}^{C_s}(37-7)$$

a_c

$$+ \overbrace{0.85(0.35)(110)(0.80x)}^{C_c}\left(37 - \frac{0.80x}{2}\right)$$

$$= 1473\left(6 - \frac{42}{x} - 0.2975\right)$$

$5.7025 - \frac{42}{x}$

~~$+ 32.725(37$~~

$$+ 26.18x\,(37 - 0.40x)$$

$$= 8400 - \frac{61866}{x} + 969x - 10.472x^2$$

$$10.472x^2 - 969x + 2711 + \frac{61866}{x} = 0$$

$$x^3 - 92.53x^2 + 259x + 5908 = 0$$

$x = 10$	equation = 245
9.8	500
10.2	−15
10.19	−2.65

$\therefore x = 10.19 < x_{max}$ $\therefore \phi = 0.9$ ✓

Check $\varepsilon_s' = 1.878$ t/cm^2

$C_s = 77.62$ t

$C_c = 266.77$ t

$$A_{s\,req} = \frac{77.62 + 266.77}{4.2} = \underline{\underline{82.0 \text{ cm}^2}}$$

use 12 ϕ30 bars in one layer

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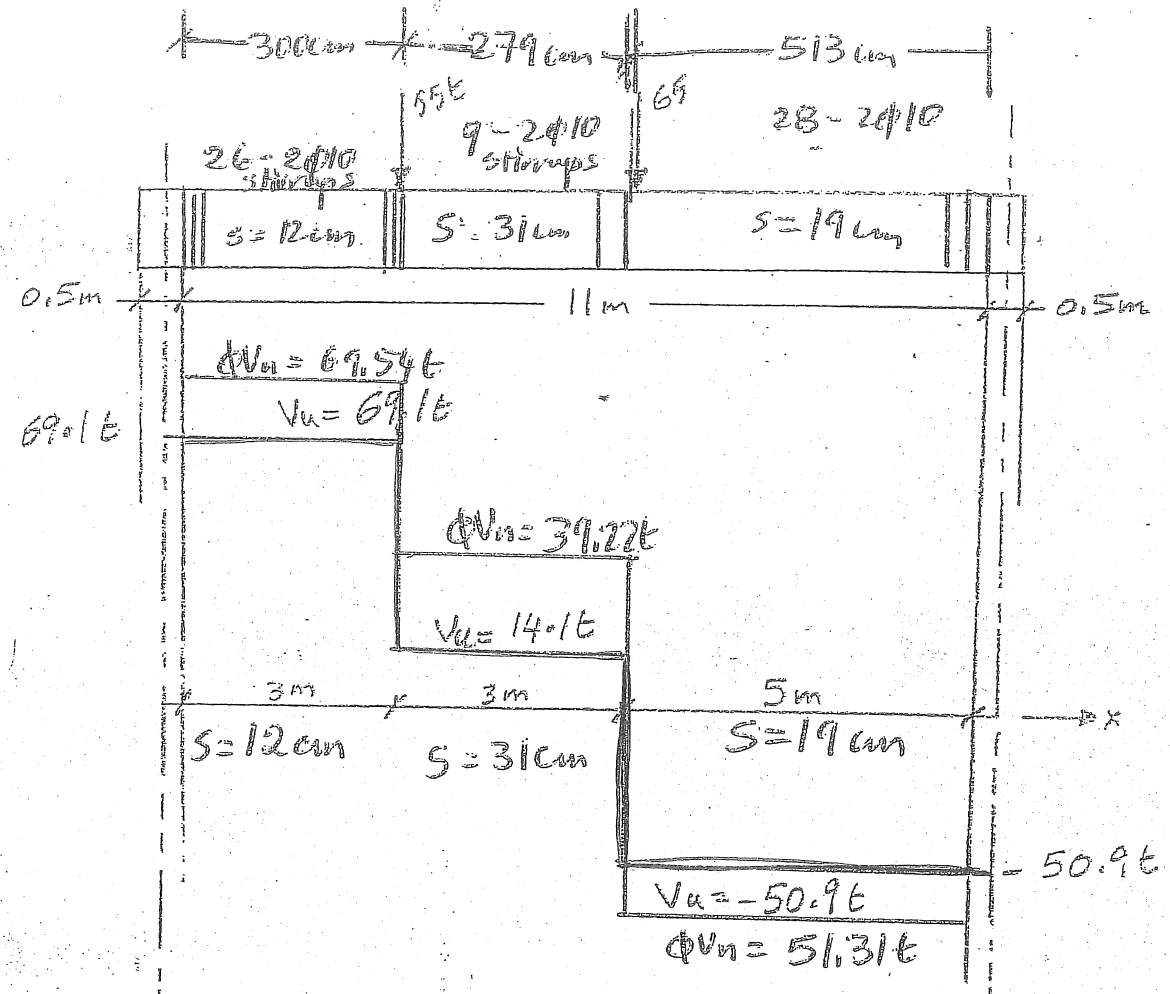
Q2. (12 points) A beam has b = 50 cm, d = 63 cm, fc' = 25 MPa, fy = 400 MPa, and Φ10 stirrups where necessary. The shear diagram is given. Draw a side view of the beam and show the distribution and number of stirrups required. Also, superimpose the ϕVn diagram on the Vu diagram.



Since b = 50cm, 2 stirrups are used, $A_v = 3.14\,cm^2$

$$\phi V_c = 0.75(0.17)\frac{(\sqrt{25})}{100} \times 50 \times 63 = 20.08\,t$$

$$\frac{\phi V_c}{2} = 10.04\,t$$

$3\phi V_c = 60.24\,t$, $5\phi V_c = 100.4\,t$

Middle Part of the Beam: Category II, No Exceptions

∴ Minimum reinforcement is required.

$$S_{max} = \frac{(3.14)(400)}{0.062\sqrt{25}\,(50)} = 81\,cm \qquad d/2 = 31.5\,cm$$

$$= \frac{(3.14)(400)}{0.35\,(50)} = 71.8\,cm \qquad 60\,cm$$

Smallest

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using $S = 31\,cm$,

$$\phi V_{s\,min} = \frac{0.75(3.14)(4)(63)}{31} = 19.14\,t$$

$$\phi V_n = 20.08 + 19.14 = \underline{39.22\,t}$$

Right-hand Part of the Beam: Category III or IV

$\phi V_{s\,req} = 50.9 - 20.08$
$= 30.82\,t$

Obviously - Category IV

$$S_{req} = \frac{0.75(3.14)(4)(63)}{30.82} = \underline{19.3\,cm}$$ smallest compared to S_{max}

using $S = 19\,cm$,

$$\phi V_s = \frac{0.75(3.14)(4)(63)}{19} = 31.23\,t$$

$$\phi V_n = 20.08 + 31.23 = \underline{51.31\,t}$$

Left-hand Part of the Beam: Category V

$\phi V_{s\,req} = 69.1 - 20.08 = 49.02\,t$

$$S_{req} = \frac{0.75(3.14)(4)(63)}{49.02} = \underline{12.1\,cm}$$

Compared to:
81 cm
71.8 cm
$d/4 = 15.75\,cm$
30 cm

using $S = 12\,cm$,

$$\phi V_s = \frac{0.75(3.14)(4)(63)}{12} = 49.46\,t$$

$$\phi V_n = 20.08 + 49.46 = \underline{69.54\,t}$$

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Name:_____

Part II – 2 pages

Q2. (30 points) Circle the appropriate letter, T for true or F for false.

1. T F According to the ACI-Code, every arithmetic average of any two consecutive strength tests must equal or exceed fc'.

2. T F According to the ACI-Code, a strength test is the average of two or three cylinder tests, depending on the age of the concrete at the time of the test.

3. T F Vibration is a method used to consolidate concrete.

4. T F Poor conveying of concrete may result in segregation.

5. T F Superplasticizers are used mainly to improve the workability of fresh concrete.

6. T F Air-entraining admixtures are used to protect concrete from freezing cycles.

7. T F Silica fume may be used to replace part of the mixing water in concrete mixes.

8. T F Epoxy-coating of bars may be used to minimize corrosion of reinforcement under severe environmental conditions.

9. T F In the working stress method, stresses resulting from service loads should not exceed allowable values.

10. T F In the ACI Code, ϕ is used to account for probability of understrength due to a situation in which several acceptable tolerances may combine.

11. T F Increasing the depth of a concrete section results in a relatively higher strength increase than increasing the width.

12. T F The ACI Code permits using $As_{actual} = As_{max(\varepsilon t = 0.004)}$ to reinforce a beam.

13. T F Excessive deflection and cracking are considered strength and safety problems.

14. T F The ACI Code permits using $As_{actual} \leq As_{balanced}$ to reinforce a beam.

15. T F The strength reduction and overload factors are considered among the safety provisions of the ACI code.

16. T F Under-reinforced sections do not have sufficient reinforcement to support the design moments.

17. T F The stress-strain relationship for concrete depends on its strength and age at loading.

18. T F Over-reinforced sections have more reinforcement than necessary to support the design moments and therefore are un-economical..

19. T F A tension-controlled section will exhibit a ductile failure mode with visible flexural cracks and deflection.

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Part I – 1 page **Total number of pages = 9**

Name: Key

Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335 Reinforced Concrete Design I
Mid-Term Exam **Tuesday, April 12, 2016**

Q1. (20 points) Write the exact section in the ACI Code that specifies the following:

1. The overload factors for dead and live loads _____
2. Strength reduction factor ϕ for bending moment if ε_t is less than 0.005 _____
3. Design requirements for one-way ribs are included with the requirements for beams _____
4. As_{min} for T-sections with the flange in tension _____
5. Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003 _____
6. As_{min} for T-sections with the flange in compression _____
7. Effective flange width b_E for interior T-beams _____
8. Minimum spacing for flexural reinforcement bars in one layer _____
9. Minimum spacing for flexural reinforcement bars in two layers _____
10. ε_t for beams shall be at least 0.004 _____
11. Minimum depth of non-prestressed beams _____
12. The critical negative moment for beams occurs at the face of support _____
13. The value of β_1 for determining "a" of the Whitney block _____
14. The design strength shall satisfy $\phi Mn \geq Mu$ _____
15. fc' for concrete shall be based on 28-day tests _____
16. Minimum bend diameters for stirrups _____
17. Formula for determining fr for concrete _____
18. The value of Es for ordinary (non-prestressed) bars _____
19. Concrete cover for beams not exposed to weather = 40 mm _____
20. Formula for determining Ec for normal-weight concrete _____

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Name:_____ Number_____

Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335 Reinforced Concrete Design I
Mid-Term Exam, Part III **Monday, August 1, 2016**

Q1. (20 points) Write the exact section in the ACI Code that specifies the following:

1. Load factors and combinations for determining U _____
2. Isolated T-beams must have $t_f \geq b_w / 2$ _____
3. The minimum beam depth if excessive deflection is not considered a problem _____
4. Location of the critical section for determining Vu _____
5. Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003 _____
6. fc' for concrete shall be based on 28-day tests. _____
7. Effective flange width b_E for interior T-beams _____
8. Strength reduction factor ϕ for shear = 0.75 _____
9. Tensile strength of concrete shall be neglected in flexural and axial strength calculations _____
10. ε_t for beams shall be at least 0.004 _____
11. The formula to calculate As_{min} for non-prestressed beams _____
12. Design strength for beams shall satisfy $\phi Sn \geq U$ _____
13. The value of β_1 for determining "a" of the Whitney block _____
14. The upper limit for category 5 for shear strength of beams _____
15. The formula for determining Vs for shear reinforcement _____
16. The formula for determining the shear strength Vc of non-prestressed members without axial force _____
17. Formula for determining fr for concrete _____
18. The value of Es for non-prestressed bars _____
19. Concrete cover for beams not exposed to weather = 40 mm _____
20. Formula for determining Ec for normal-weight concrete _____

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Total number of pages = 7

Name: Odai Saleh Hamdan 1080233

Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335 Reinforced Concrete Design I

Mid-Term Exam **Tuesday, November 13, 2012**

Q1. (10 points) A beam has b = 90 cm, and d = 35 cm. Determine the reinforcement required to support an ultimate moment, Mu = 70 t.m. (If the beam must be doubly reinforced, use as little reinforcement as possible, and let d' = 7 cm.)
Use fc' = 25 MPa, fy = 400 MPa, Φ 25 compression bars (if required), and Φ 30 tension bars. Select bars and provide a sketch of the x-section.

$a_{max} = \frac{3}{8}(35) = 13.125$ cm

$a = 0.85 \times 13.125 = 11.156$ cm

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

$M_u = \frac{70}{0.9} = 77.78$ t.m

$77.78 = 0.85(0.25)(90)(11.156)\left(35 - \frac{11.156}{2}\right) + C_s(35 - 7)$

$C_s = \frac{1543.665}{28} = 55.131$

$\varepsilon_s' = \left(\frac{x - d'}{x}\right)(0.003) = \left(\frac{13.125 - 7}{13.125}\right)(0.003) = 0.00014$

compression steel does not yield

$f_s' = \varepsilon_s' \times E = 0.00014 \times 200000 = 280$ MPa

$A_s' = \frac{C_s}{(f_s' - 0.85(f_c'))} = \frac{55.131}{28 - (0.85 \times 0.25)}$

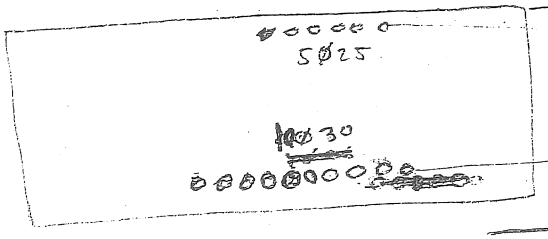
$A_s' = 21.31\ cm^2 \Rightarrow$ use $5\Phi 25 = 24.54\ cm^2$

$A_{s\,met} = \frac{C_s + C_c}{f_y} = \frac{24.54\left(2.8 - (0.85 \times 0.25)\right) + 0.85(0.25)(90)(11.156)}{4}$

$A_{s\,tens} = \frac{63.90 + 213.36}{4} = 69.27\ cm^2 \Rightarrow 10\Phi 30$

$10\Phi 30 = 70.69$ little more than what we need so accepted

Assumed = 68.93 given may be little bit less than required



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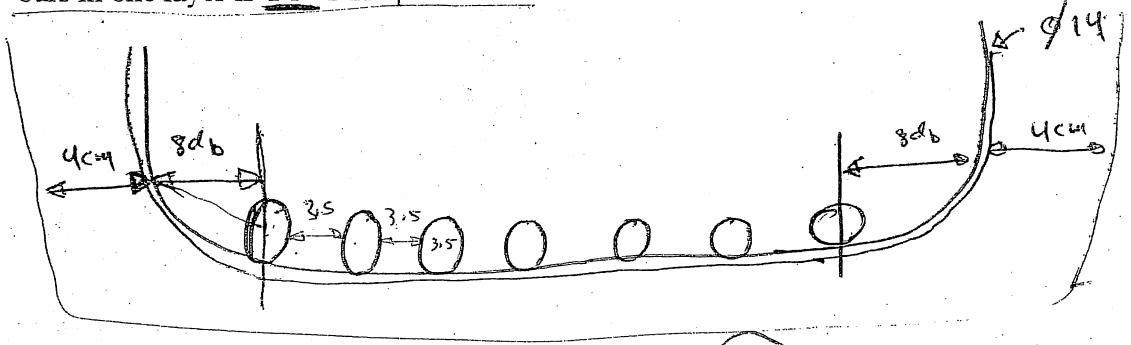
Q2. (3 points) Determine the exact minimum beam width required to fit 7 Φ 35 bars in one layer if Φ14 stirrups are used.



$b = 2\times4 + 2\times1.4 + 6\times3.5 + 6\times3.5 + 8d_b$

$b = 8 + 2.8 + 21 + 21 + 8d_b$

$= 52.8 + 8d_b$

$= 52.8 + 11.2$

$= 64$ cm

-2

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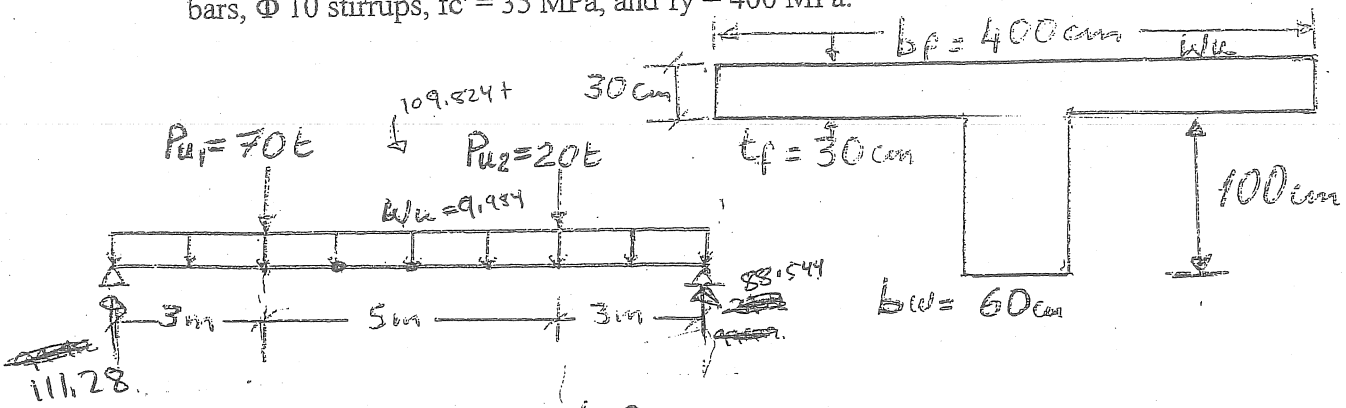
Q3. An isolated T-section supports a distributed factored load, Wu = 1.2 t/m^2 not including self-weight, in addition to two concentrated ultimate loads as shown. Use a concrete unit-weight of 2.4 t/m^3, d = 120 cm regardless of the number of layers, Φ 20 bars, Φ 10 stirrups, fc' = 35 MPa, and fy = 400 MPa.



Wu = 1.2 t/m^2
(per m^2)

a. (5 points) Determine the ultimate design moment Mu for the beam.

$W_u = 1.2\ t/m^2 \times 4 = 4.8\ t/m$

Self weight $= (4 \times 0.3 \times 1) \times 2.4\ t/m^3 + (0.6 \times \frac{1}{2} \times 1)(2.4)$

$= 2.88\ t/m + 1.44\ t/m$

$= 4.32\ t/m$

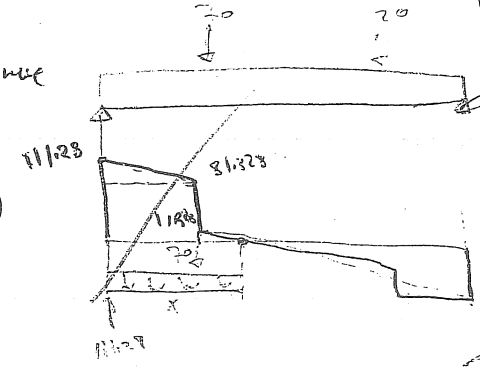
$W_u = 4.8 + 1.2(4.32) = 9.984\ t/m$

5.184

$m_1 = 254.868\ t.m$

$m_2 = 223.508\ t.m$

Moment = Area under curve



$M_u = \frac{1}{2}(249.852 \times 3) + (81.328 \times 3) + \frac{1}{2}(11.328 \times 1.136)$

$M_u = 295.135\ t.m$

$20 + 9.984x = 111.28$

$x = 9.136$

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b. (10 points) Determine As required to support a **positive** moment Mu = 75 t.m. Check $As_{max(\varepsilon t=0.005)}$ and As_{min}. Use Φ 20 bars and Φ 10 stirrups. Take the distance to the extreme tension steel to be 124 cm. Select bars and provide a sketch of the x-section.

$M_n = \frac{75}{0.9} = 83.33$ t.m

$t \geq \frac{b_w}{2} \Rightarrow 30 \geq 30$

$b_E \leq 4 b_w \leq b_f$

$\leq 240 \leq 400$

$b_E = 240$ cm

If $a = t \Rightarrow C = 0.85 \times 0.35 \times 240 \times 30$

$= 2142$ t

$M_n = 2142\left(\frac{124 - \frac{30}{2}}{100}\right) = 2334.78$ t.m

$M_n > M_{nmq} \Rightarrow a < t$

Same as rectangular

$b = b_E$

$8333 = 0.85 \times 0.35 \times 240 (a)\left(\frac{124 - \frac{a}{2}}{100}\right)$

$116.71 = 124a - a^2$

$a^2 - 248a + 233.42 = 0$

$a = 0.945$

$C = 67.473$ t

$A_s = \frac{C}{f_y} = 16.87\ cm^2$

$As_{max} \Rightarrow x = \frac{3}{5} \times 124 = 46.5$ cm

$a = 39.525$ cm

$a > t \Rightarrow C = C_1 + C_2 = 0.85 \times 0.35 \times (180)(30) + 0.85 \times 0.35 (60)($

$C = 1606.5 + 705.52 = 2312.021$ t

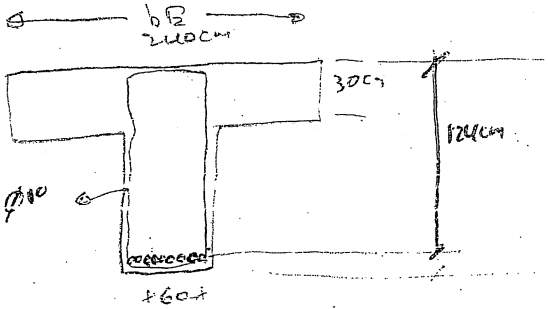
$As_{\varepsilon t=0.005} = \frac{2312.021}{f_y} = 578.005\ cm^2$

$As_{min} \Rightarrow \frac{0.25\sqrt{f'_c}}{f_y} b_w d \geq \frac{1.4 b_w d}{f_y}$

$4.65\sqrt{35} \geq 26.04$

$27.51 \geq 26.04$

Controls



the required is less than the minimum

So we use the min.

$As_{min} = 27.51 \Rightarrow 9\phi 20$

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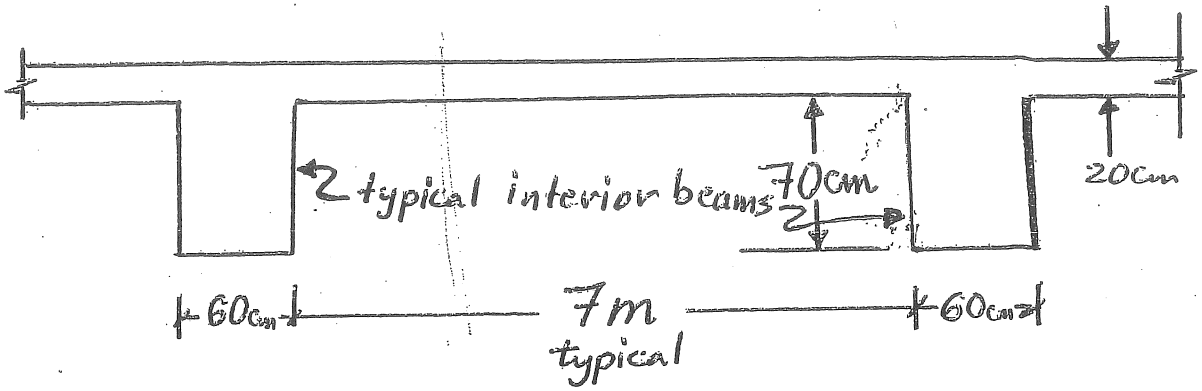
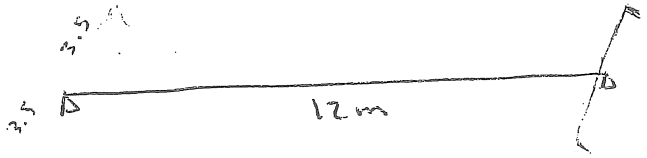
(5/4)

2. The following sketch shows a 20-cm thick solid slab supported on 70-cm deep drop beams. The slab carries a service live load = 0.35 t/m^2. The beams are simply supported on columns at a simple span of 12 m.
Use fc' = 25 MPa, fy = 400 MPa, concrete density $\gamma_{concrete}$ = 2.4 t/m^3, 4 cm clear cover, Φ 10 stirrups, and Φ 20 longitudinal bars.



a. (3 points) Determine the ultimate design moment Mu for a typical interior beam.



L.L = 0.35 t/m^2

D.L = 2.6 t/m^3 (12) = 28.8 t/m^2

L.L = 0.35(7) = 2.45 t/m

D.L = 201.6 t/m

w_u = 1.2(201.6) + 1.6(2.45) = 245.84 t/m

$M_u = \frac{wL^2}{8} = \frac{245.84(12)^2}{8}$

L.L = 0.35(3.5) = 1.225 t/m

D.L = 28.8(3.5) = 100.8 t/m

w_u = 1.2(100.8) + 1.6(1.225) = 122.92

$M_u = \frac{wL^2}{8}$ = 2212.56 t.m

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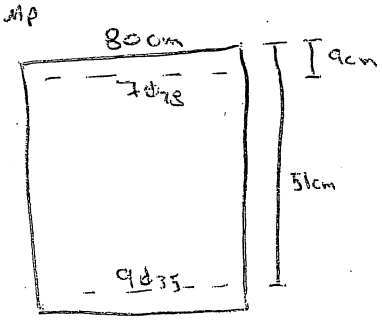
b. (5 points) If the beam is reinforced with As = 9Φ35 tension bars, determine ϕMn.

$f_c' = 40 MPa$
$f_y = 400 MP$



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

We assume that steel yeild → $f_s' = f_y = 4$

$C_s = 43.10 (4 - 0.85(0.4) = 157.766$ ton (7Φ28)

$C_c = 0.85(0.4)(80)(0.764)(x) = 20.781x$

$T = A_s \times f_y = 86.59 \times 4 = 346.36$ ton

$T = C_s + C_c$

$x = \frac{346.36 - 157.746}{0.85(0.4)(80)(0.764)} = 9.076$ cm

$\epsilon_s' = \frac{9.076 - 9}{9.076} 0.003 = 2.517 \times 10^{-5}$

∴ steel does not yeild

$346.36 = C_c + C_s = 0.85(0.4)(80)(x)(0.764) + 43.10(f_s' - 0.85(0.4))$

$f_s' = \frac{x - 9}{x}(0.003)(2000) = \frac{x-9}{x}(6) = 6 - \frac{54}{x}$

$346.36 = 20.781x + 43.10\left(6 - \frac{54}{x} - 0.34\right)$

$346.36 = 20.781x + 258.6 - \frac{2327.4}{x} - 14.654$

$346.36 = 20.781x + 243.946 - \frac{2327.4}{x}$

$346.36x = 20.781x^2 + 243.946x - 2327.4$

$20.781x^2 - 102.414x - 2327.4 = 0$

$\frac{102.414 \pm 452.54}{2(20.781)} =$

$x = 13.352$ cm

$a = 13.352(0.764) = 10.20$ cm

$\epsilon_t = \frac{51 - 13.352}{13.352}(0.003) = 0.00846 > 0.005 \rightarrow \phi = 0.9$

$\epsilon_s' = \frac{13.352 - 9}{13.352}(0.003) = 0.000978$ / $f_s' = 0.000978(2000) = 1.956$

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b. (6 points) If the ultimate design moment for an interior beam was determined to be Mu = 150 t.m., determine the required reinforcement in accordance with the ACI-318 Code (check appropriate limits.)

positive moment

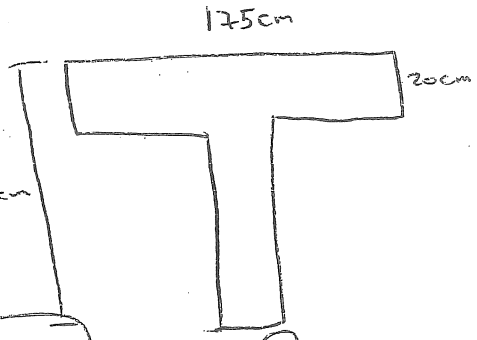
interior beam

b_E is the smallest of:-

$b_E = L/4 = \frac{700}{4} = 175\,cm \Longrightarrow$ control

$b_E = b_w + 16(t) = 60 + 16(20) = 380\,cm$

$b_E = c/c = 760\,cm$



$Mu = 150$

$Mn = \frac{150}{0.9} = 166.67\ t.m$

$Mn = C_{web}(d - a/2) + C_{flange}(d - t/2)$ $\quad a < t\ ?$

if bars in one layer

$d = 90 - 4 - 1 - 1 = 84\,cm$

$C_{web} = 0.85(0.25)(60)(a) = 12.75a$

$C_{flange} = 0.85(0.75)(175 - 60)(20) = 488.75$

$166.67 = 12.75a\left(\frac{84 - a/2}{100}\right) + 488.75\left(\frac{84 - 20/2}{100}\right)$

$166.67 = 10.71a - 0.06375a^2 + 361.675$

$0.06375a^2 - 10.71a - 195.005 = 0$

$a =$ $\quad 10.71 \pm 12.82$

As mat
As min
As req'd for
b = bE
dev
dium

-5

after determin a

we determin $T = C_{web} + C_{flange}$

from T we determine As required

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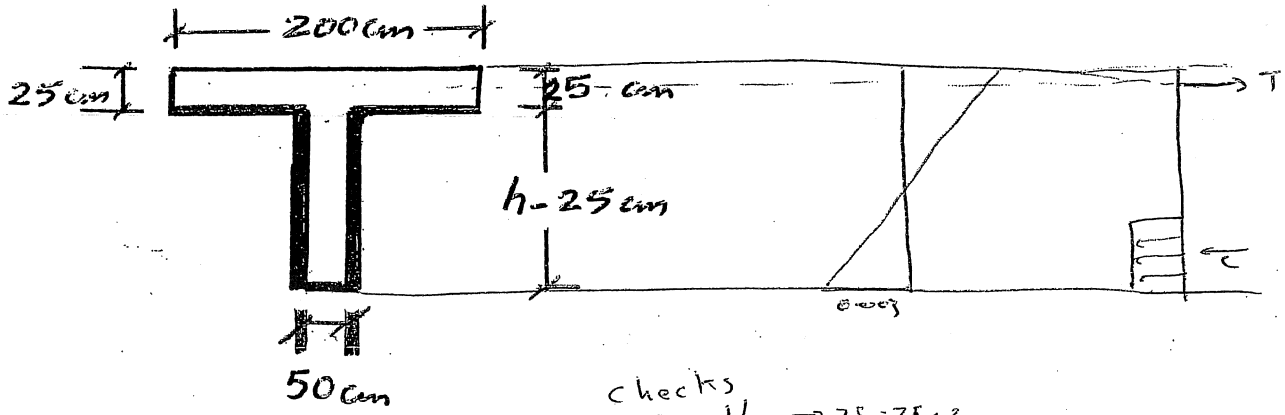
3. a. (6 points) Design the isolated T-beam shown to support a negative ultimate moment Mu = 110 t.m. Use fc' = 25 MPa, fy = 400 MPa, d = 73 cm, and Φ 20 longitudinal bars, in accordance with the ACI-318 Code.



checks
$25 \geq t/2 \rightarrow 25 = 25$ ✓
$b_E \leq 50 + 200 = 200$ $b_E = 200$ cm ✓

$Mu = 110$ t.m

$Mn = \frac{110}{0.9} = 122.22$ t.m

$Mn = C(d - a/2)$

$Rn = \frac{12222}{200(73)^2} = 0.01146$

$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mRn}{fy}}\right)$ $\quad m = \frac{fy}{0.85fc'} = 18.823$

$= 0.00295$

$As_{required} = \rho bd = 0.00295(200)(73) = 43.07\ cm^2$

$T = As \times fy = 43.07 \times 4 = 172.28$

$a = \frac{172.28}{0.85(0.25)(200)} =$

$C = 0.85(0.25)(50)(a) = 10.625a$

$Mn = C(d - a/2) = 10.625a\left(\frac{73 - a/2}{100}\right)$

$122.22 = 10.625a\left(\frac{73 - a/2}{100}\right)$

$1150.305 = 73a - a^2/2$

$a^2 - 146a + 2300.61 = 0$

$a = 17.97$ cm

$X = \frac{17.97}{0.85} = 21.14$

use $\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mRn}{fy}}\right)$ and save time and effort!

$146 = \frac{110.06}{2}$

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Name:_____ Number_____

Birzeit University
Faculty of Engineering
Department of Civil Engineering
ENCE 335 Reinforced Concrete Design I

Mid-Term Exam Tuesday, November 14, 2017

Part I

Q1. (10 points) Write the exact section in the ACI Code that specifies the following:

1. Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003 _____
2. Effective flange width b_E for interior T-beams _____
3. Tensile strength of concrete shall be neglected in flexural and axial strength calculations _____
4. The value of Es for non-prestressed bars _____
5. The upper limit for category 5 for shear strength of beams _____
6. The formula for determining Vs for shear reinforcement _____
7. Concrete cover for beams not exposed to weather = 40 mm _____
8. Critical section for shear in beams is located at a distance equal to "d" from the face of support _____
9. As_{min} for T-sections with the flange in compression _____
10. Strength reduction factor ϕ for bending moment if ε_t is less than 0.005 _____

Q2. **(10 points) Circle the appropriate letter, T for true or F for false.**

1. T F Prestressed concrete construction allows using very high strength concrete and steel with reduced deflection and cracking problems.
2. T F If development length requirements are not satisfied, the steel bars will not reach yielding before structural failure.
3. T F Under-reinforced sections are those that have less reinforcement than the balanced amount.

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4. T F The shear capacity of T-sections is based on the dimensions of the web without the flanges.

5. T F Over-reinforced sections have more reinforcement than necessary to support the design moments and therefore are uneconomical..

6. T F Flexural cracks are usually vertical.

7. T F Compression steel may be added to increase the deflection of beams under ultimate conditions.

8. T F If the compression reinforcement does not yield under ultimate load, the beam will not give a sufficient warning of imminent failure.

9. T F According to the ACI-Code, a strength test is the average of two or three cylinder tests, depending on cylinder size.

10. T F When the shear capacity ϕVn diagram is closest to the factored shear Vu diagram, the least amount of shear reinforcement will be required.

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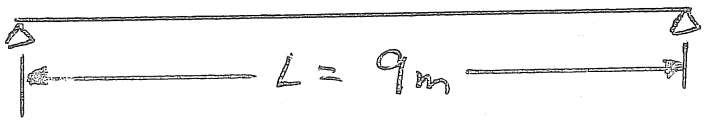
Name:_____

Part II

For all questions, use fc' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3). You must maintain four significant-digit-accuracy, for example: 132.4, 13.24, 1.324, and so on.

Q3. (30 points) A rectangular section has b = 50 cm, h = 50 cm, As' = 7 Φ 20, and As = 7 Φ 30. Assuming that the dead load is the self-weight only, determine the maximum service uniformly distributed live load that can be placed on the beam.



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Q4. (25 points) For the layout shown, a 15-cm solid one-way slab is used with drop beams. All columns are 60 cm x 60 cm. All beams have b_w = 60 cm and h = 80 cm (15 cm within the slab + 65 cm drop). Assume d = dt = 71 cm in all calculations. The total factored loads for beam B1 are $(Wu)_{DL}$ = 7.2 t/m including the weight of the beam, and $(Wu)_{LL}$ = 4.8 t/m.

1) For Beam B1, b_E is:
i) 185 cm ii) 205 cm iii) 170 cm iv) 210 cm v) 300 cm vi) none of the given answers

For Beam B1, and assuming b_E = 200 cm,

2) Asmax $_{\varepsilon t=0.005}$ for positive moment is:
i) 256.5 cm^2 ii) 280.5 cm^2 iii) 196.0 cm^2 iv) 211.9 cm^2 v) 76.95 cm^2 vi) none of the given answers

3) Asmax $_{\varepsilon t=0.005}$ for negative moment is:
i) 256.5 cm^2 ii) 196.0 cm^2 iii) 76.95 cm^2 iv) 211.9 cm^2 v) 280.5 cm^2 vi) none of the given answers

4) As min for positive moment is:
i) 26.84 cm^2 ii) 13.42 cm^2 iii) 142.0 cm^2 iv) 28.40 cm^2 v) 14.20 cm^2 vi) none of the given answers

5) As min for negative moment is:
i) 26.84 cm^2 ii) 13.42 cm^2 iii) 142.0 cm^2 iv) 28.40 cm^2 v) 14.20 cm^2 vi) none of the given answers

6) The exact amount of reinforcement $As_{required}$ calculated for a negative moment Mu = - 150 t.m is:
i) 55.49 cm^2 ii) 67.99 cm^2 iii) 75.74 cm^2 iv) 57.99 cm^2 v) 64.49 cm^2 vi) none of the given answers

7) The exact amount of reinforcement $As_{required}$ calculated for a positive moment Mu = + 150 t.m is:
i) 55.49 cm^2 ii) 67.99 cm^2 iii) 75.74 cm^2 iv) 57.99 cm^2 v) 64.49 cm^2 vi) none of the given answers

8) If a = t, Mn positive = :
i) 136.0 t.m ii) 405.6 t.m iii) 444.4 t.m iv) 453.4 t.m v) 162.0 t.m vi) none of the given answers

9) The factored self-weight of the drop underneath the slab is:
i) 1.123 t/m ii) 0.936 t/m iii) 1.152 t/m iv) 1.382 t/m v) 1.936 t/m vi) none of the given answers

10) For Beam B2, b_E is:
i) 66.67 cm ii) 330.0 cm iii) 96.67 cm iv) 150.0 cm v) 300.0 cm vi) none of the given answers

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Q5. (25 points) A rectangular beam is used over a simple span of 6 m measured center to center of columns. The columns are 60 cm x 60 cm. The total factored loads for the beam are $(Wu)_{DL}$ = 7.2 t/m including the weight of the beam, and $(Wu)_{LL}$ = 4.8 t/m.

1) Assume d = dt = 71 cm. At the critical section, Vu is:
i) 25.09 t ii) 21.49 t iii) 23.88 t iv) 32.4 t v) 28.33 t vi) none of the given answers

2) If the required reinforcement is to be exactly 80% of the maximum for εt = 0.005, the exact width "b" required to support Mu = 150 t.m would be (assume d = dt = 71 cm):
i) 66.47 cm ii) 62.44 cm iii) 72.43 cm iv) 52.62 cm v) 96.47 cm vi) none of the given answers

3) If the required reinforcement is to be exactly 80% of the maximum for εt = 0.005, the exact effective depth "d" required to support Mu = 150 t.m would be (assume b = 60 cm, and d = dt):
i) 66.47 cm ii) 62.44 cm iii) 72.43 cm iv) 52.62 cm v) 96.47 cm vi) none of the given answers

4) If the beam has b = 60 cm and d = 71 cm, and double Φ 10 stirrups (Av = 3.14 cm^2), the exact stirrup spacing required to support Vu = 80 t would be (you must check minimum requirements before choosing an answer):
i) 10.70 cm ii) 35.50 cm iii) 8.20 cm iv) 9.85 cm v) 13.70 cm vi) none of the given answers

5) If the beam has b = 60 cm and d = 71 cm, and double Φ 10 stirrups, the exact stirrup spacing required to support Vu = 100 t would be (you must check minimum requirements before choosing an answer):
i) 10.70 cm ii) 35.50 cm iii) 8.20 cm iv) 9.85 cm v) 13.70 cm vi) none of the given answers

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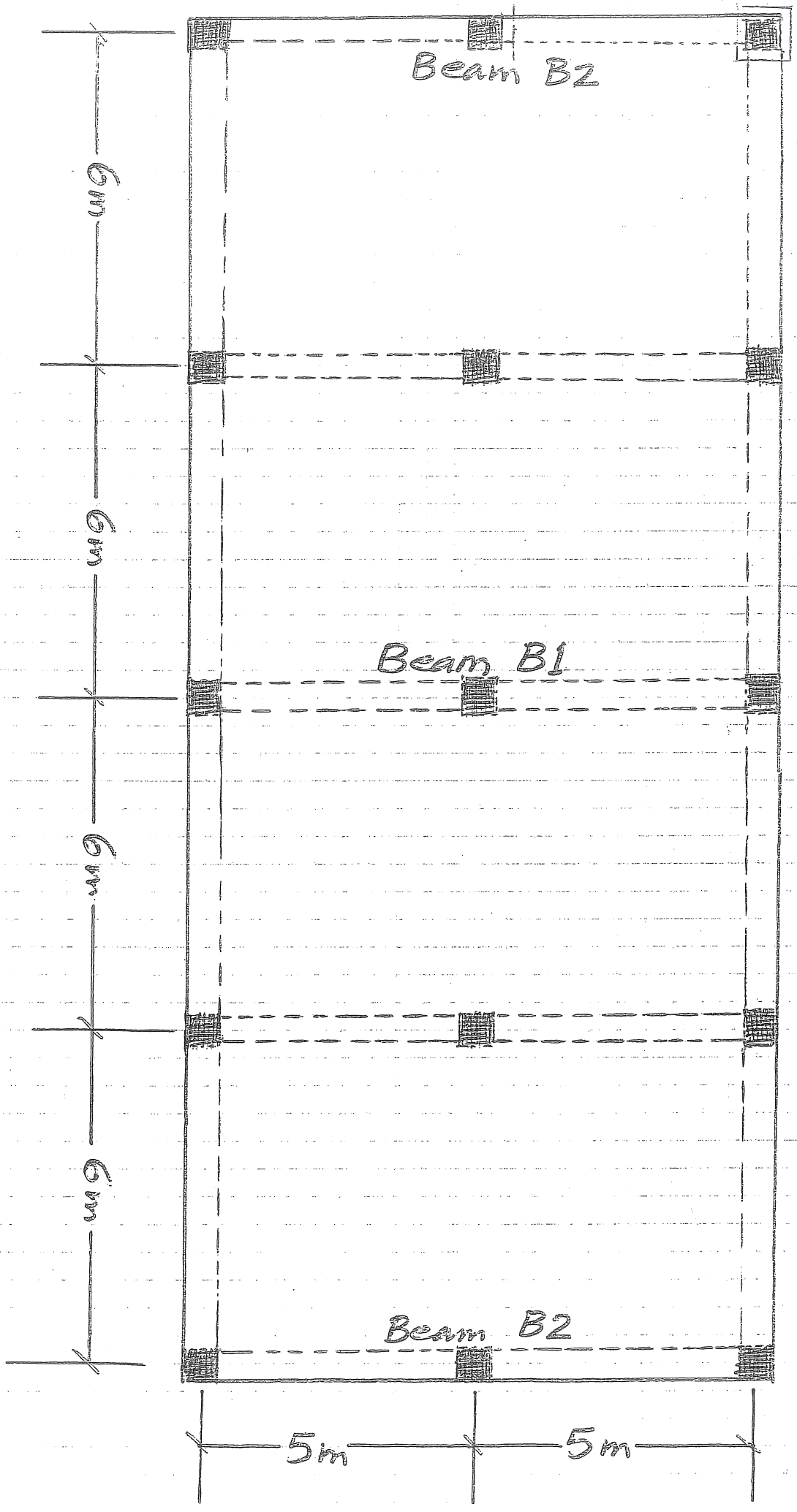

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b = 60 cm

2 stirrups (4 legs)

d = 73 cm

b = 60 cm

$A_v = 4(0.79) = 3.14\ cm^2$

$\phi V_c = 0.75(0.17)\frac{\sqrt{28}}{100}(60)(73) = 29.55\ t$

$\frac{\phi V_c}{2} = 14.78\ t$

$\phi V_c = 29.55\ t$

$3\phi V_c = 88.65\ t$

$5\phi V_c = 147.75\ t$

Geometry

$s \le \frac{73}{2} = 36.5\ cm$

$s \le 60\ cm$

$s \le \frac{3.14(420)}{0.062\sqrt{28}(60)} = 68.49\ cm$

$s \le \frac{3.14(420)}{0.35(60)} = 62.8\ cm$

$s = 36\ cm$

$\phi V_{s\,min} = \frac{0.75(3.14)(4.2)(73)}{36} = 20.05\ t$

$\phi V_n = 20.05 + 29.55 = 49.6\ t$

Minimum shear reinforcement

$x_1 = 1.92\ m = 192\ cm$

$\frac{192}{36} = 5.3$ spacing

$= 6 - 2\phi 10$ stirrup @ 36 c/c

$\phi V_{s\,req} = 80 - 29.55 = 50.45$

$s_{req} = \frac{0.75(3.14)(4.2)(73)}{50.45} = 14.3\ cm$

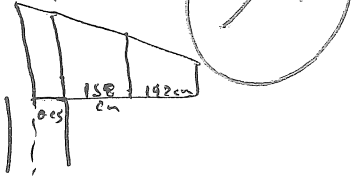
$\phi V_{s\,req} = 80 - 29.55 = 50.45\ t$

$s_{req} = \frac{0.75(3.14)(4.2)(77)}{50.45} = 14.3\ cm = 14$ Controls

$x_2 = 1.58\ m$

spacing $= \frac{158}{14} = 11.28$

11 - 2 ϕ 10 stirrups @ 14 c/c



$\phi V_{s\,req} = \frac{0.75(3.14)(4.2)(77)}{14} = 51.5\ t$

$\phi V_n = 51.5 + 29.55 = 81.\ t$

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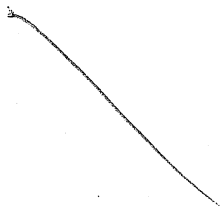

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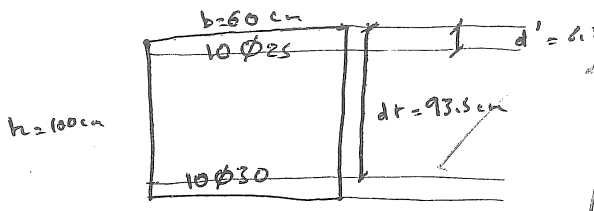
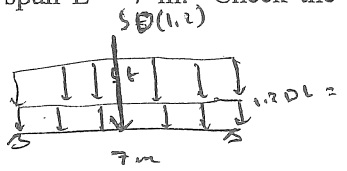
Q4. (25 points) A beam has b = 60 cm and h = 100 cm. The beam is reinforced with 10Φ30 tension bars and 10Φ25 compression bars, and supports a concentrated service dead load = 50 t. Determine the maximum distributed service live load that can be placed on the beam. Determine actual d_t, d, and d' for use in the calculations. The beam extends over a simple span L = 7 m. Check the maximum reinforcement limit. (You must add self-weight.)

DL = 50t L.L = ?? t/m L = 7m





10 Φ30 in two layers 2 above, 8 below

$\bar{y} = \frac{8(6.5) + 2(12)}{10} = 7.6$ cm

d = 92.4 cm

$A_{s'act} = 10(4.91) = 49.1\ cm^2$

$A_{sact} = 10(7.07) = 70.7\ cm^2$

$x_{max} = \frac{3}{8}(93.5) = 35.06$ cm

$a_{max} = 29.8$ cm

$C_{cmax} = 0.85(0.28)(60)(29.8) = 425.5$ t

$\epsilon_s' = \frac{35.06 - 6.25}{35.06}(0.003) \overset{?}{>} \epsilon_y = 0.0021$

$0.00246 > \epsilon_y = 0.0021$

$\therefore f_s' = f_y$

$C_{smax} = 49.1(4.2 - 0.85(0.28)) = 194.5$ t

$A_{smax} = \frac{194.5 + 425.5}{4.2} = 147.6\ cm^2$

Assume that compression steel yields $f_s' = f_y$

$C_s = 49.1(4.2 - 0.85(0.28) = 194.5$ t

$C_c = 0.85(0.28)(60)(0.85)\, x_{act} = 12.14 x_{act}$

$T = 70.7(4.2) = 296.94$ t

$296.94 = 12.14\, x_{act} + 194.5$

$x_{act} = 8.44$ cm

$a_{act} = 7.17$ cm

$\epsilon_{s'act} = \frac{8.44 - 6.25}{8.44}(0.003) > 0.0021$

$0.000778 < 0.0021$

Assumption is wrong

$C_s = 49.1\left(\frac{6(x - 6.25)}{x} - 0.85(0.28)\right)$

$C_s = \frac{294.6x - 1841.25}{x} - 11.68$

$C_s = 294.6 - \frac{1841.25}{x} - 11.68$

$C_c = 12.14x$

$T = 296.94$ t

$296.94 = 12.14x + 294.6 - \frac{1841.25}{x} - 11.68$

$13.48 = \frac{12.14x^2 - 184.25}{x}$

$13.48x = 12.14x^2 - 1841.25$

$12.14x^2 - 13.48x - 1841.25 = 0$

$x^2 - 1.11x - 151.67 = 0$

$x = +1.11 \pm \frac{\sqrt{(1.11)^2 + 4(151.67)}}{2}$

$x_{act} = 12.88$ cm

$a_{act} = 10.95$ cm

$\epsilon_{s'act} = \frac{93.5 - 12.88}{12.88}(0.003) > 0.005$

$0.0187 > 0.005$

$\phi \Rightarrow 0.9$

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$C_{cact} = 12.14(12.88) = 156.36$ t

$C_{sact} = 139.96$ t

$$M_n = 156.36\left[\frac{92.4 - \frac{10.95}{2}}{100}\right] + 139.96\left[\frac{92.4 - 6.25}{100}\right]$$

$$= 135.9 + 120.57$$

$M_n = 256.5$ t.m

$\phi M_n = (0.9)(256.5) = 230.8$ t.m

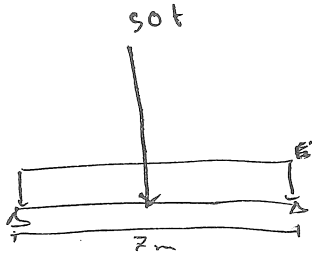
Now

$\phi M_n = M_u$

$$230.8 = 105 + \frac{(1.728 + 1.6L.L)(7)^2}{8}$$

$20.534 = 1.728 + 1.6L.L$

$L.L = 11.75$ t/m



D.L = 0.6 * 1 * 2.4 = 1.44 t/m

1.2D.L = 1.728 t/m

$W_u = 1.2D.L + 1.6L.L$

$W_u = 1.728 + 1.6L.L$

$$M_u = \frac{50(7)(1.2)}{4} + \frac{(1.728 + 1.6L.L)(7)^2}{8}$$

$$M_u = 105 + \frac{(1.728 + 1.6L.L)(7)^2}{8}$$

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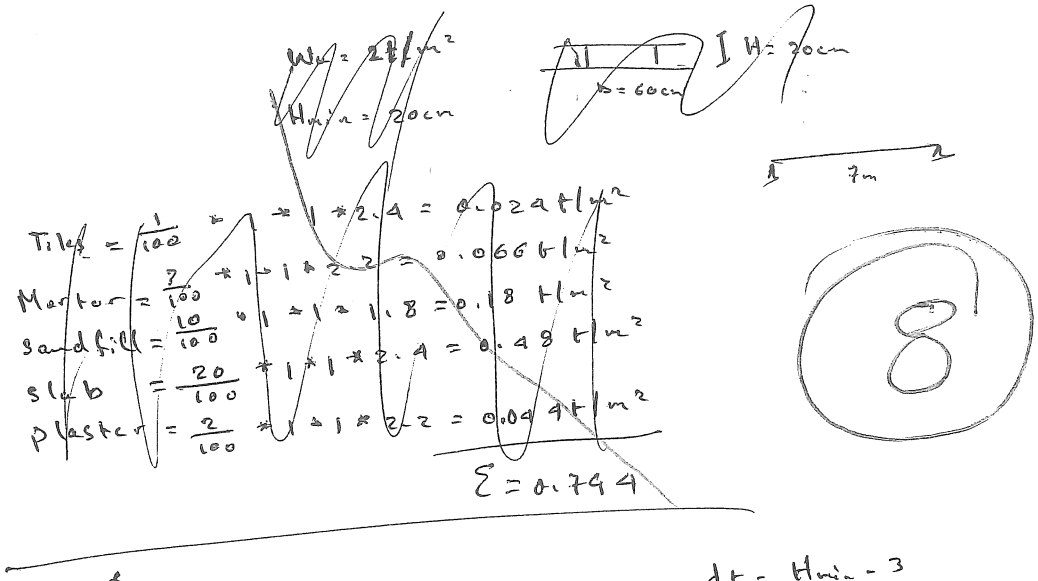
Q5. (15 points) A solid slab supports a factored load Wu = 2 t/m^2 (includes self-weight) over a simple span of 7.0 m. The slab is 20 cm thick and is supported on 60 cm wide beams. Design the slab for flexure.



$d_t = H_{min} - 3$
$= 20 - 3 = 17\text{cm}$

$M_u = \frac{2(7)^2}{8} = 12.25$ t.m

$M_{u\,req} = \frac{12.25}{0.9} = 13.61$ t.m

$R_{u\,req} = \frac{13.61 * 100}{60(17)^2} = 0.07849$

$m = 17.65$

$\rho_{req} = \frac{1}{17.65}\left[1 - \sqrt{1 - \frac{2(17.65)(0.07849)}{4.2}}\right]$

$\rho_{req} = 0.0236$

$\rho_{max} = 0.31875\frac{(28)}{420}(0.85) = 0.018062$

$\frac{\rho_{req}}{\rho_{max}}$ so large $= \frac{0.0236}{0.018062} = 1.3$ high

H should be More than 20 cm

take H = 23 cm

$d_t = 23 - 3 = 3$ cm

then $\rho_{req} = 0.0156$

$\frac{\rho_{req}}{\rho_{max}} = \frac{0.0156}{0.01806} = 0.86$ ok

$A_{s\,req} = 0.0156\,(60)(20) = 18.07$ cm^2

$A_{s\,max} = 0.01806\,(60)(20) = 21.67$ cm^2

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$H = 23\,cm$

$d = 20\,cm$

V_u check shear

$V_u = \frac{\not{2}(7 - 0.4)}{\not{2}} = 7.6\,t$

$\phi V_c = 0.75(0.17)\frac{\sqrt{28}}{100}(60)(20)$

$= 8.9\,S$

$\phi V_c > V_u$ ✓

Assume $\phi 20$

Area $= 3.14\,c$

$\#$ of bars $= \frac{18.07}{3.14} = 5.75$ bars

$S = \frac{100}{5.75} = 17.3\,cm$ $\quad S = 3h = 3(23) = 69\,cm$

$= 45\,cm$

$S = 17\,cm$

$1\phi 20$ @ 17 cm c/c

take $S = 17\,cm$

controls

$A_{sact} = 6(3.14) = 18.84\,cm^2$

$T = 18.84(4.2) = 79.128\,t$

$a = \frac{79.128}{0.85(0.28)(60)} = 5.54\,cm$

$X = \frac{5.54}{0.85} = 6.52\,cm$

$\frac{20 - 6.52}{6.52}(0.003) > 0.0005$

$0.0062 > 0.005$ ✓

$\phi \Rightarrow 0.9$

$M_n = 79.128\left[\frac{20 - \frac{5.54}{2}}{100}\right] = 13.6\,t.m$

$\phi M_n = 0.9(13.63) = 12.27\,t.m > M_u$

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3. a. (2 points) Use a simple strain versus time diagram to explain the change in strain of a loaded and drying specimen. Consider elastic, creep, and shrinkage strains.

It is about time you start to do some reading !!

b. (2 points) What are the two requirements specified by the ACI code for adequate control of strength.

c. (1 points) Explain the difference between f_c' and f_{cr}'.

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b. (7 points) Determine As_{max} and As_{min} for negative moment.

– Ve moment,

$$A_{s\,max}\ (\epsilon_t = 0.005) = 0.31875\left(\frac{20}{420}\right)(0.85)(40 \times 91)$$

$$= 46.96\ cm^2$$

$$A_{s\,min} = \frac{0.25\sqrt{20}\,(700)(91)}{420} \leq \frac{0.5\sqrt{20}\,(40)(91)}{420}$$

$$= 169.57\ cm^2 \leq 19.38\ cm^2$$

controls

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c. (7 points) Determine As_{max} and As_{min} for positive moment.

+ve moment

$b_E = \frac{900}{4} = 225$ cm

$= 40 + 16(20) = 360$ cm

$= 400$ cm

X_{max} ($\epsilon_t = 0.005$) $= \frac{3}{8} \times 91 = 34.125$ cm

$a_{max} = 0.85(34.125) = 29.0$ cm

$\therefore C_{max} = 0.85(0.2)(225 - 40)(20) + 0.85(0.2)(40)(29)$

$= 629 + 197.2 = 826.2$ t

A_{smax} ($\epsilon_t = 0.005$) $= \frac{826.2}{4.2} = 196.7$ cm^2

$A_{smin} = \frac{0.25\sqrt{20}}{420}(40)(91) \geq \frac{1.4}{420}(40)(91)$

$= 9.69 \geq 12.13$ cm^2

Controls

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d. (12 points) Design the beam to support an ultimate positive moment = Mu = 300 t.m. Determine As required but do not select reinforcement.

+ve moment, $Mu = 300$ t.m , $Mn_{req} = \frac{300}{0.9} = 333.3$ t.m

if $a = t$,

$C = 0.85(0.2)(225)(20) = 765$ t

$M = \frac{765\left(91 - \frac{20}{2}\right)}{100} = 619.7$ t.m

$\therefore a < t$, the beam behaves as a rectangular section with $b = 225$ cm

$R_{n_{req}} = \frac{333.3 \times 100}{(225)(91)^2} = 0.01789$ t/cm²

$m = \frac{420}{0.85(20)} = 24.71$

$\rho_{req} = \frac{1}{24.71}\left(1 - \sqrt{1 - \frac{2(24.71)(0.0\quad)}{4.2}}\right)$

$= 0.00451$

$A_{s_{req}} = 0.00451 \times 225 \times 91 = 92.36$ cm²

$A_{s_{min}} = 12.13$ cm²

$A_{s_{max}} = 196.7$ cm² $\Rightarrow \phi = 0.9$ ✓

$\therefore A_{s_{req}} = \underline{92.36 \text{ cm}^2}$

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Name: Key

Part III – 6 pages

For all questions, use fc' = 35 MPa ($\beta_1 = 0.80$), fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3).

Q3. (10 points) For an ultimate moment Mu = 130 t.m that includes self-weight, design a beam with b = h. Determine the required dimensions to the nearest 5 cm using ρ approximately equal to 0.75($\rho_{max\varepsilon t=0.005}$). Use Φ25 tension bars and Φ10 stirrups. Provide a final sketch of the section.

$\rho_{max\varepsilon t=0.005} = 0.31875\left(\frac{35}{420}\right)(0.80) = 0.02125$

(1) $\rho_{sel} = 0.75(0.2125) = 0.015\,94$

$m = \frac{420}{0.85(35)} = 14.12$

(1) $R_{n\,sel} = (0.01594)(4.2)\left(1 - \frac{1}{2}(0.01594)(14.12)\right) = 0.05941$

$M_{nreq} = \frac{130}{0.9} = 144.4$ t.m

$\frac{14440}{b^3} = 0.05941 \Rightarrow b = 62.4$ cm

Note: Take b = h = 65 cm, not 60 cm, because h was used instead of d

If h = 65 cm, d_t = 58.75 cm

(2) $R_n = \frac{14440}{(65)(58.75)^2} = 0.06436$ t/cm^2

$\rho_{revised} = \frac{1}{14.12}\left(1 - \sqrt{1 - \frac{2(14.12)(0.06436)}{4.2}}\right) = 0.01748 \sim 0.82\rho_{max}$

$A_{sreq} = 0.01748 \times 65 \times 58.75 = 66.76$ cm^2 → 13.6 bars

use 14 Φ 25 bars

(2) 11 in one layer + 3 in the second layer

$A_{sprovided} = 68.74$ cm^2 ~ $0.85\,A_{smax}$

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20. T F Under-reinforced sections have $As_{actual} < As_{min}$.

21. T F The use of high-strength materials in the design of ordinary reinforced concrete sections results in relatively reduced deflections under ordinary loading conditions.

22. T F Prestressed concrete construction allows using very high strength concrete and steel with reduced deflection and cracking problems.

23. T F Folded plate roof construction may be used to cover spans of more than 50 m.

24. T F Even if the compression reinforcement does not yield under ultimate load, the beam may still provide the necessary warning at failure.

25. T F Reductions are often permitted in live loads for members supporting large areas.

26. T F The maximum reinforcement limit may be exceeded if an appropriate amount of compression steel is used.

27. T F Live loads may be either fully or partially in place or not present at all.

28. T F Compression steel will result in a notable increase in the capacity of beams, but only if additional tension steel is used.

29. T F Compression steel may be added to reduce the deflection of beams in service.

30. T F Compression steel may be added to increase the deflection of beams under ultimate conditions.

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Name: [redacted] 1091720

Birzeit University

Faculty of Engineering

Department of Civil Engineering

ENCE335 Reinforced Concrete Design I

Mid-Term Exam Sunday, March 25, 2012

39/50

Q1. (2 points) a. Explain the difference between fc' and fcr'.

fc' is the Specified compressive Strength of Concrete whereas fcr' is the required average compressive strength of concrete as the basis for Selection of concrete Proportions

b. Explain the basic principle of the working stress method.

The working Method is concerned with finding the Stresses resulting from Service loads or what is known as (working loads). It relies on the elastic Mechanics and the stress f has limits where f ≤ fallow is found from flexure formula $f = \frac{Mc}{I}$

Q2. (6 points) Explain the meaning of:

Plain concrete: is made from cement, water and aggregate to form solid mass and it doesn't include or contain reinforcing bars.

Hydraulic cements: is a cohesive and adhesive matter that consists of lime, Shale and clay mixed together and heated in a kiln to form the Silicate aluminates which make the hydraulic Cement.

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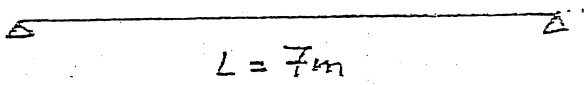
4.. (4 points) Determine the maximum service live load for this beam in tons per meter.



Self weight $= 1.2\,(1 \times 0.7)(2.4) = 2.016\ t/m$

$\phi M_n = 157\ t.m$

$$\frac{W_u\,(7^2)}{8} = (0.9)(174.6)$$

$W_u = 25.66\ t/m$

$25.66 = 1.2(15) + 2.016 + 1.6\,LL$

$1.6\,LL = 5.64\ t/m$

$\therefore\ LL = \underline{\underline{3.52\ t/m}}$

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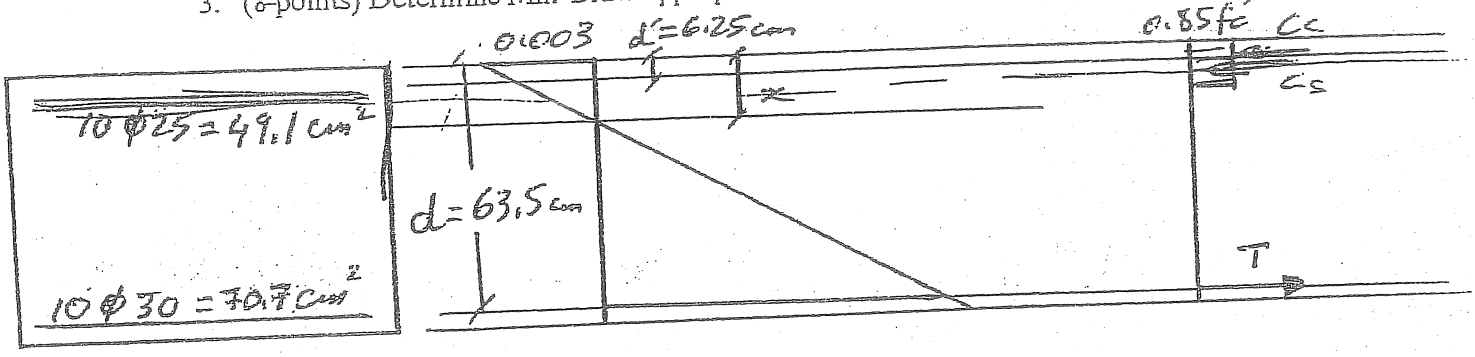
2. (2 points) Determine As_{min}

$$As_{min} = \frac{0.25\sqrt{30}}{420}(100)(63.5) \geq \frac{1.4(100)(63.5)}{420}$$

$$20.70\ cm^2 \geq \underline{21.17\ cm^2} \quad \text{Controls}$$

3. (8-points) Determine Mn. Draw appropriate stress and strain diagrams.



$T = 70.7 \times 4.2 = 297\ t$

Assume compression steel yields, $C_s = 49.1 \times (4.2 - 0.85 \times 0.3) = 194\ t$

$C_c = 0.85(0.3)(100)(0.836x) = 21.32x$

$297 = 194 + 21.32x \Rightarrow x = 4.83\ cm \Rightarrow \therefore$ assumption is wrong

$$\varepsilon_s' = \frac{x - 6.25}{x}(0.003) \Rightarrow f_s' = 2000\varepsilon_s' = 6 - \frac{37.5}{x}$$

$$297 = 49.1\left[\left(6 - \frac{37.5}{x}\right) - 0.85(0.3)\right] + 21.32x$$

$$297 = 282.1 - \frac{1841}{x} + 21.32x$$

$$21.32x^2 - 14.9x - 1841 = 0 \qquad x = 9.65\ cm \qquad a = 8.07\ cm$$

Check calculations, $C_c = 205.7\ t$, $C_s = 91.3\ t$, $C_c + C_s = 297\ t$ ✓

$$M_n = 205.7\left[\frac{63.5 - \frac{8.07}{2}}{100}\right] + 91.3\left[\frac{63.5 - 6.25}{100}\right]$$

$$= 122.3 + 52.3 = \underline{174.6\ t.m}$$

Note: $\varepsilon_t = \frac{63.5 - 9.65}{9.65}(0.003) = 0.01674 \Rightarrow \phi = 0.9$

$\varepsilon_s' = \frac{9.65 - 6.25}{9.65}(0.003) = 0.001057 < \varepsilon_y$, so f_s' is already known

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Name: Desin Design Key

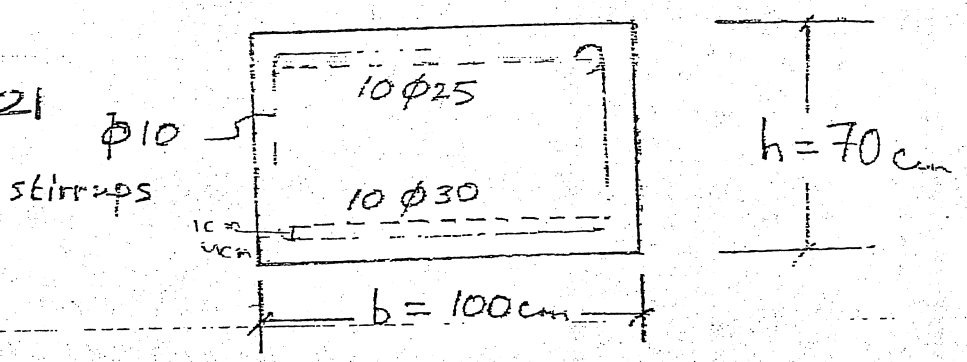
Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335, Reinforced Concrete Design I

Quiz **Monday, November 5, 2012**

The beam shown supports a service dead load of 15 t/m, not including self-weight. Use fc' = 30 MPa, fy = 420 MPa, $\gamma_{concrete}$ = 2.4 t/m^3.

$\epsilon_y = \frac{420}{200{,}000} = 0.0021$



1. (6 points) Determine $A_{s\,max(et=0.005)}$. Draw appropriate stress and strain diagrams.

Distance to the bottom layer = 70 − 4 − 1 − 1.5 = 63.5 cm

$x_{max\ \epsilon_t=0.005} = \frac{3}{8}(63.5) = 23.81$ cm

$\beta_1 = 0.85 - \frac{30-28}{7}(0.05) = 0.836$

$a_{max\ \epsilon_t=0.005} = 0.836 \times 23.81 = 19.90$ cm

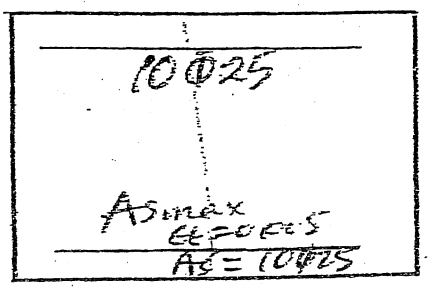
$\epsilon_s' = \left(\frac{23.81 - 6.25}{23.81}\right)(0.003) = 0.00221 > \epsilon_y \Rightarrow f_s' = f_y$

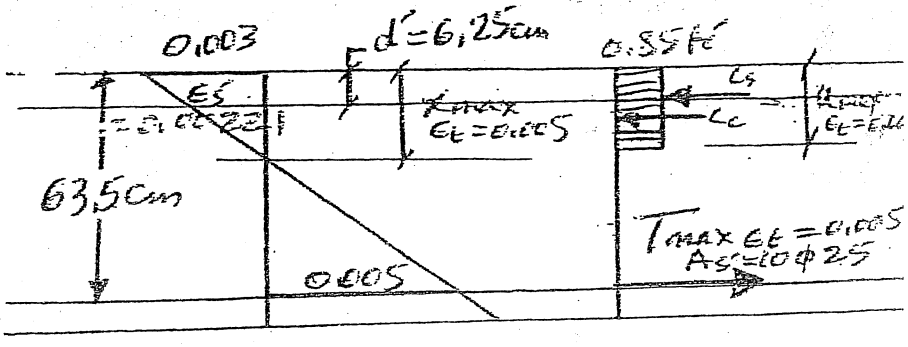
$C_c = 0.85(0.3)(100)(19.90) = 507.5$ t

$C_s = (10 \times 4.91)(4.2 - 0.85 \times 0.3) = 193.7$ t

$A_{s\,max\ \epsilon_t=0.005} = (507.5 + 193.7)/4.2 = 167.0$ cm^2

$A_s = 10\phi25$





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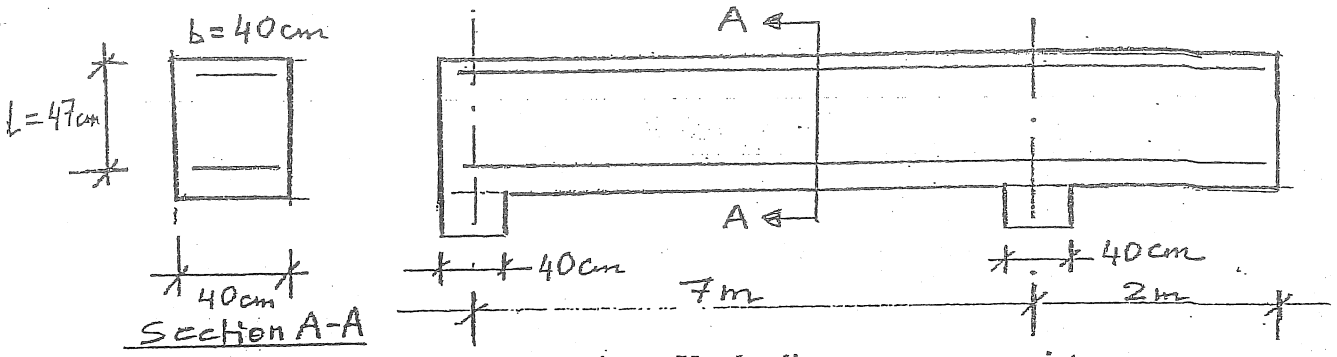
2. For the beam shown, the factored loads are W_{DL} = 70 kN/m (7 t/m) and W_{LL} = 120 kN/m (12 t/m). Use fc' = 35 MPa, and fy = 280 MPa.



a. (5 points) Draw the shear envelope. Use loading cases as appropriate.

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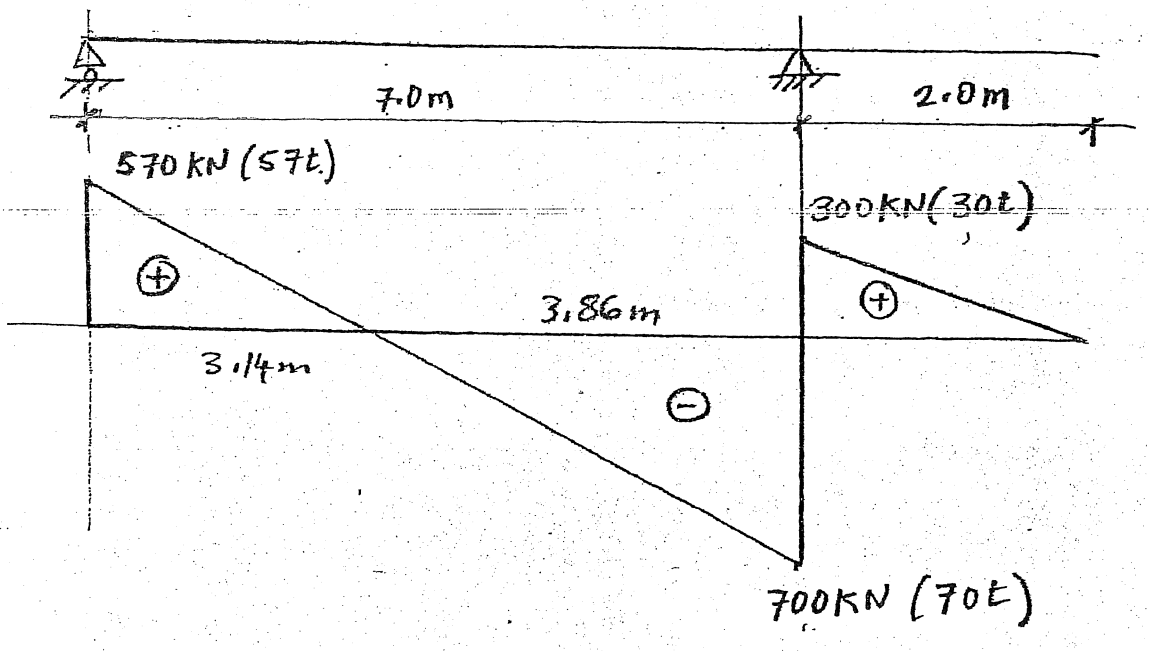
b. (7 points) The shear diagram for a similar beam is shown. For the purposes of this part, use the given diagram. Determine the required stirrups for span AB of the beam using Φ10 stirrups only.



$$\phi V_c = 0.75(0.17)(\sqrt{35})\left(\frac{10}{1000}\right)(40 \times 47) = 14.18t$$

$$\frac{\phi V_c}{2} = 7.09t \;,\quad 3\phi V_c = 42.54t \;,\quad 5\phi V_c = 70.90t$$

$S_{max} =$

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At the critical section:

$3\phi V_c = 95.1\,t < V_u = 121.3\,t < 5\phi V_c = 158.5\,t$ ∴ Category V

ϕV_s required $= 121.3 - 31.7 = 89.6\,t$

$$S_{required} = \frac{0.75\,(3.16)(4)(83)}{89.6} = 8.78\,cm$$

$S_{max} \leq 68\,cm$, $60\,cm$; $d/4 = 20.75\,cm$, $30\,cm$

∴ Unless the size or the number of the stirrups is changed, the required spacing = 8cm controls.

$\phi V_s = 0.75\,(3.16)(4)(83)/8 = 98.4\,t$, $\phi V_n = 130.1\,t$

$$\frac{336\,cm}{8} = 42 \text{ spaces}$$

∴ 43 (2φ10) stirrups are required

$$\frac{64}{41} = 1.6 \text{ spaces}$$

∴ 2 (2φ10) stirrups are required

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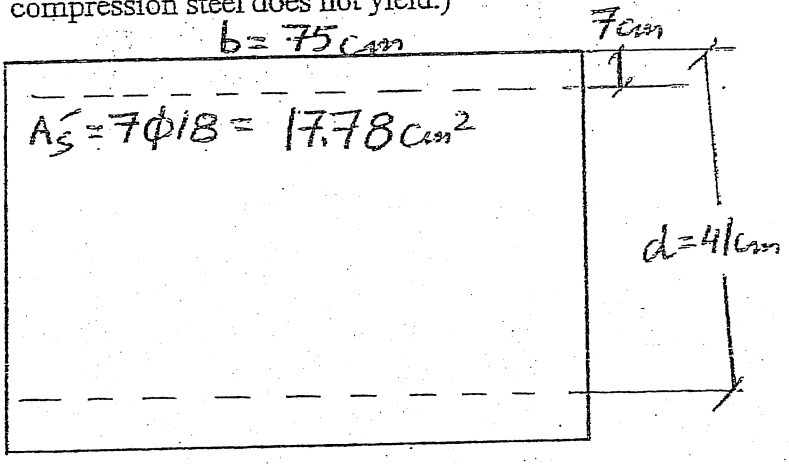
4. (10 points) Determine the exact As required for a beam having b = 75 cm, d = 41 cm, and d' = 7 cm. The ultimate moment Mu = 70 t.m. The beam is reinforced with 7 Φ18 compression bars. Use fc' = 25 MPa, fy = 400 MPa. (Hint: under the given conditions the compression steel does not yield.)



$Mu = 70$ t.m

$Mn_{req} = 77.8$ t.m

$\epsilon_s' = \left(\frac{x-7}{x}\right)(0.003)$ $\quad f_s' = \left(\frac{x-7}{x}\right)(0.003)(2000) = 6 - \frac{42}{x}$

$C_s = \left(6 - \frac{42}{x} - 0.85(0.25)\right)(17.78) = 106.7 - \frac{746.8}{x} - 3.8 = 102.9 - \frac{746.8}{x}$

$C_c = 0.85(0.25)(75)(0.85x) = 13.55x$

$7780 = 13.55x\left(41 - \frac{0.85x}{2}\right) + \left(102.9 - \frac{746.8}{x}\right)(41-7)$

$= 556x - 5.76x^2 + 3499 - \frac{25391}{x}$

$4281x + 5.76x^3 - 556x^2 + 25391 = 0$

$x^3 - 96.5x^2 + 743x + 4408 = 0$ $\quad \therefore x = 12.97$ cm

note: for $x = 12.97$ cm, $\epsilon_t = 0.00648 > 0.005$ $\quad \therefore \phi = 0.9$ ✓

$\epsilon_s' = 0.00138 < \epsilon_y$ (see the hint above)

$\therefore C_c = 176$ t, $\quad C_s = 45.1$ t $\quad \Rightarrow T = 221$ t

$A_{s\,req} = \frac{221}{4} = 55.25$ cm²

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56

a. (5 points) Determine the most appropriate length for bars "B".

for 6φ20 , $a = \frac{6 \times 3.14 \times 4}{(0.85)(0.25)(50)} = 7.09\ cm$

$M_n = (18.84)(4)\left(73 - \frac{7.09/2}{100}\right) = 52.34\ t.m$

$\phi M_n = 0.9\,(52.34) = 47.11\ t.m$

$d = 73cm$, $12\,d_b = 24cm$

$\therefore Length = 2 + 2(2.86) + 2(0.73) = \underline{9.18\ m}$

Note:

$a_{max} = \beta_1 x$

$\varepsilon_t = 0.005$

$= 0.85\left(\frac{3}{8}\right)(73)$

$= 23.27\ cm$

$\therefore \phi = 0.9$

b. (3 points) Check if bars "A" are properly embedded at the ends.

$\frac{1.3\,(52.34)}{22} + 0.15 \geq L_d$ = for 6φ20 ⇒ Category A

$= \frac{400(1.0)(1.0)}{1.7\sqrt{25}}(2.0) = 94.1\ cm$

$= 3.09 + 0.15$

$= \underbrace{3.24\ m}_{available} > \underbrace{0.94\ m}_{required}$ ∴ OK

c. (3 points) Use proper sketches of a bar and surrounding concrete to explain acting forces (and their components) and bond failure mechanisms.

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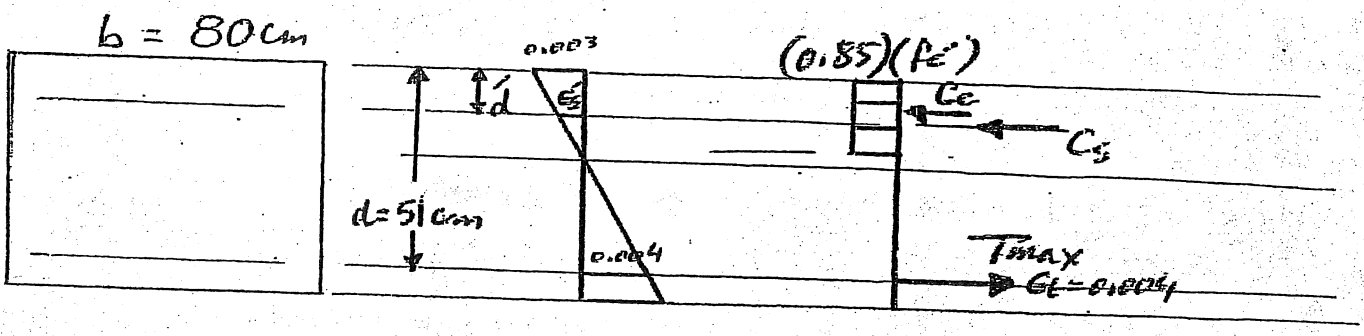
Name: Key

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

First Exam **March 26, 2009**

1. A doubly reinforced beam has b = 80 cm, d = 51 cm, d' = 9 cm, As' = 7Φ28 bars, fc' = 40 MPa, fy = 400 MPa.
   a. (4 points) Determine As_{max} for the $\varepsilon_t = 0.004$ limit.



x_{max} ($\varepsilon_t = 0.004$) $= \frac{3}{7}(51) = 21.86$ cm ✓

$\beta_1 = 0.85 - \left(\frac{40-28}{7}\right)(0.05) = 0.764$

$\therefore a_{max}$ ($\varepsilon_t = 0.004$) $= (0.764)(21.86) = 16.71$ cm

$C_c = 0.85(0.4)(80)(16.71) = 454.4$ t

$\varepsilon_s' = \frac{21.86-9}{21.86}(0.003) = 0.00176 < \varepsilon_y = 0.002$

$\therefore f_s' = 0.00176 \times 2000\ t/cm^2 = 3.53\ t/cm^2$

$C_s = 43.10\ cm^2\ (3.53 - 0.85(0.4)) = 137.5$ t

$\therefore T_{max} = 454.4 + 137.5 = 591.9$ t

$A_{s\,max}$ ($\varepsilon_t = 0.004$, 7Φ28 comp) $= \frac{591.9}{4} = 148.0\ cm^2$

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b. (2 points) Asmin for positive moment.

$$A_{s\,min} = \frac{0.25\sqrt{25}(40)(144)}{400} \geq \frac{1.4(40)(144)}{400}$$

$$= 18\ cm^2 \geq 20.16\ cm^2$$

controls

c. (5 points) Bars required for a positive moment of Mu = 160 t.m.

$M_{n\,req} = 177.8$ t.m

if $a = t$, $M_n = 0.85(0.25)(325)(30)\left(\frac{144 - 30/2}{100}\right) = 2672.7$ t.m

$\therefore a < t$

$$R_{n\,req} = \frac{177.8 \times 100}{(325)(144^2)} = 0.00264\ t/cm^2$$

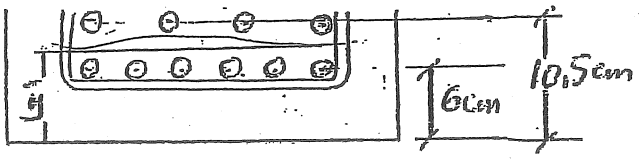
$$m = \frac{400}{0.85(25)} = 18.82$$

$$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.00264)}{4}}\right)$$

$\therefore \rho_{req} = 0.0006643$

$A_{s\,req} = 0.0006643 \times 325 \times 144 = 31.09\ cm^2$

$\frac{31.09}{3.14} = 9.9 \Rightarrow 10\ \phi 20 \Rightarrow$ two layers



$\acute{y} = \frac{6 \times 6 + 4 \times 10.5}{10} = 7.8$ cm

$d_{revised} = 150 - 7.8 = 142.2$ cm

$R_{n\,rev} = 0.002714\ t/cm^2$, $\rho_{rev} = 0.000681$, $A_{s\,rev} = 31.5\ cm^2$

$10\ \phi 20 = 31.42\ cm^2$

$\Rightarrow a = \frac{31.42 \times 4}{0.85(0.25)(325)} = 1.82$ cm

$M_n = 31.42 \times 4\left(\frac{142.2 - 1.82/2}{100}\right)$

$M_n = 177.6$ t.m

$\phi M_n = 0.9 \times 177.6 = 159.8$ t.m $\approx$ Mu (obvious)

$\therefore$ OK

use $10\ \phi 20$ bars, $A_{s\,provided} = 31.42\ cm^2$

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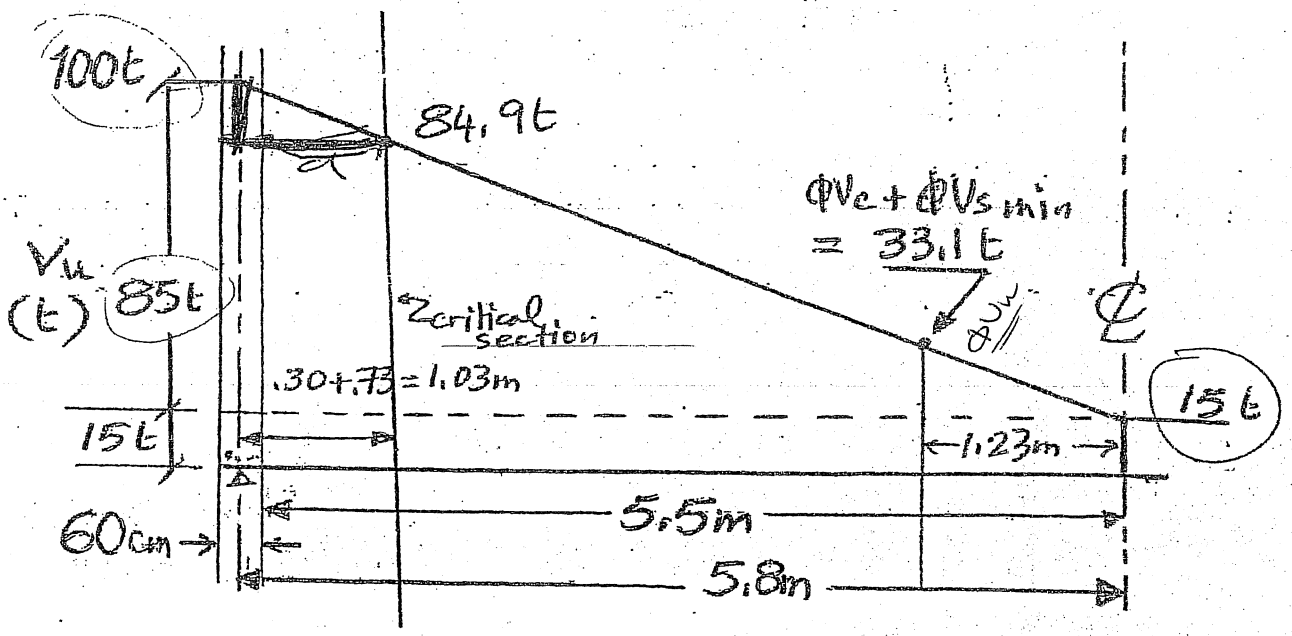
2. A beam has b = 50 cm, d = 73 cm, f_c' = 25 MPa, f_y = 400 MPa, and Φ 10 stirrups. The shear envelope for half of the span is provided. Determine:



a. (4 points) The distance "A" for which no or only minimum stirrup reinforcement is required.

$\phi V_{s\,min}$: $s_{max} = \dfrac{(1.57)(400)}{(0.062)\sqrt{25}(50)} = 40.5$ cm

$\leq \dfrac{(1.57)(400)}{0.35(50)} = 35.9$ cm controls

$\leq 73/2 = 36.5$ cm

≤ 60 cm

for $s = 35$ cm,

$\phi V_{s\,min} = \dfrac{(0.75)(1.57)(4)(73)}{35} = 9.82$ t

$\phi V_c = (0.75)(0.17)\dfrac{\sqrt{25}}{100}(50)(73) = 23.27$ t

$\phi V_c + \phi V_{s\,min} = 9.82 + 23.27 = 33.1$ t

$\dfrac{(33.1-15)}{85}(5.8) = 1.23$ m

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b. (2 points) Is the beam expected to show objectionable deflection under service conditions?

Based on $\rho = 0.7\,\rho_{max}$ ($\epsilon_t = 0.005$)

or $A_s = 0.7\,(61.81) = 43.27\ cm^2$

$A_{s\,req} = 47.74\ cm^2 > 43.27\ cm^2$

or

$$\frac{A_{s\,req}}{A_{s\,max}\ (\epsilon_t = 0.005)} = \frac{47.74}{61.81} = 0.77$$

Objectionable deflection is possible since the ratio is larger than 0.7

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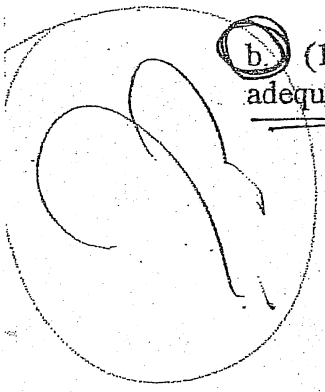
For the structural concrete (as a material):

4. a. (2 points) Use a simple strain versus time diagram to explain the change in strain of a loaded and drying specimen. Consider elastic, creep, and shrinkage strains.



b. (1 points) What are the two requirements specified by the ACI code for adequate control of strength.

c. (1 points) Explain the difference between fc' and fcr'.

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(1/7)

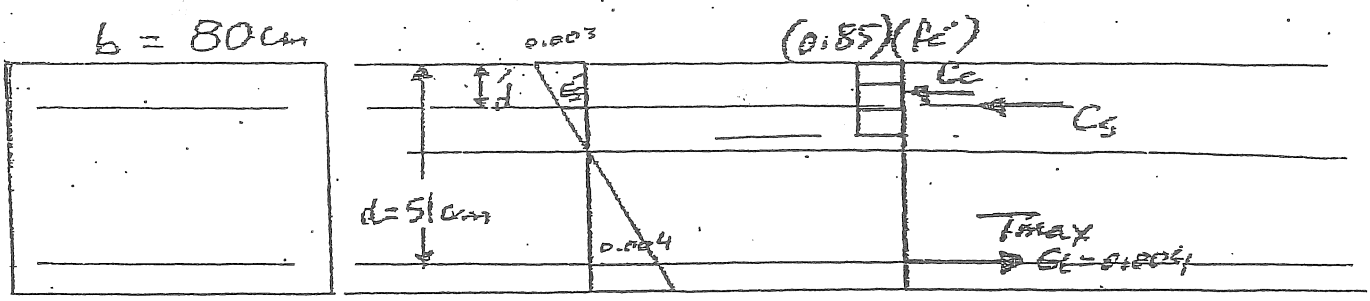
Name: Key

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

First Exam March 26, 2009

1. A doubly reinforced beam has b = 80 cm, d = 51 cm, d' = 9 cm, As' = 7Φ28 bars, fc' = 40 MPa, fy = 400 MPa.
   a. (4 points) Determine As_{max} for the $\varepsilon_t = 0.004$ limit.



~~$c_{max} = \frac{3}{7}(51) = 21.86$ cm~~

$\varepsilon_t = 0.004$

$$\beta_1 = 0.85 - \frac{(40-28)}{7}(0.05) = 0.764$$

$$\therefore a_{\substack{max \\ \varepsilon_t = 0.004}} = (0.764)(21.86) = 16.71 \text{ cm}$$

$$C_c = 0.85(0.4)(80)(16.71) = 454.4 \text{ t}$$

$$\varepsilon_s' = \frac{21.86-9}{21.86}(0.003) = 0.00176 < \varepsilon_y = 0.002$$

$$\therefore f_s' = 0.00176 \times 2000 \text{ t/cm}^2 = 3.53 \text{ t/cm}^2$$

$$C_s = 43.10 \text{ cm}^2 (3.53 - 0.85(0.4)) = 137.5 \text{ t}$$

$$\therefore T_{max} = 454.4 + 137.5 = 591.9 \text{ t}$$

$$A_{s\,\substack{max \\ \varepsilon_t = 0.004}} = \frac{591.9}{4} = \underline{148.0 \text{ cm}^2}$$

7 Φ 28 Comp

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b. (2 points) Is the beam expected to show objectionable deflection under service conditions?

Based on $\rho = 0.7\,\rho_{max}$ ($\epsilon_t = 0.005$)

or $A_s = 0.7\,(61.81) = 43.27\ cm^2$

$A_{s\,req} = 47.74\ cm^2 > 43.27\ cm^2$

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$$\frac{A_{s\,req}}{A_{s\,max}\ (\epsilon_t = 0.005)} = \frac{47.74}{61.81} = 0.77$$

Objectionable deflection is possible since the ratio is larger than 0.7

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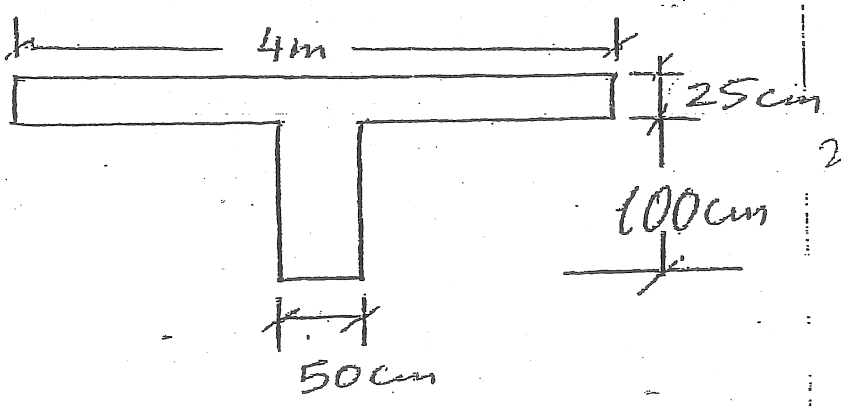
Flowing concrete: is Concrete

Sand replacement: is a light weight concrete made from light coarse aggregates but the the lightweight fine aggregates are replaced with natural sand

Modulus of rupture: is a measurement of the tensile force of concrete from flexure

Creep: is the continuous deformation of concrete after it has hardened and its the deflection due to time passing. sustained load

Q3. (6 points) For the isolated T-section shown, the service live load = 500 kg/m^2, while the dead load consists of self-weight only. Use $\gamma_{concrete}$ = 2400kg/m^3.



$4(0.25)2400 + (0.5)(1)(2400)$

$500(4)(1.67)$

$2400[4(0.25)+(0.5)(1)]$

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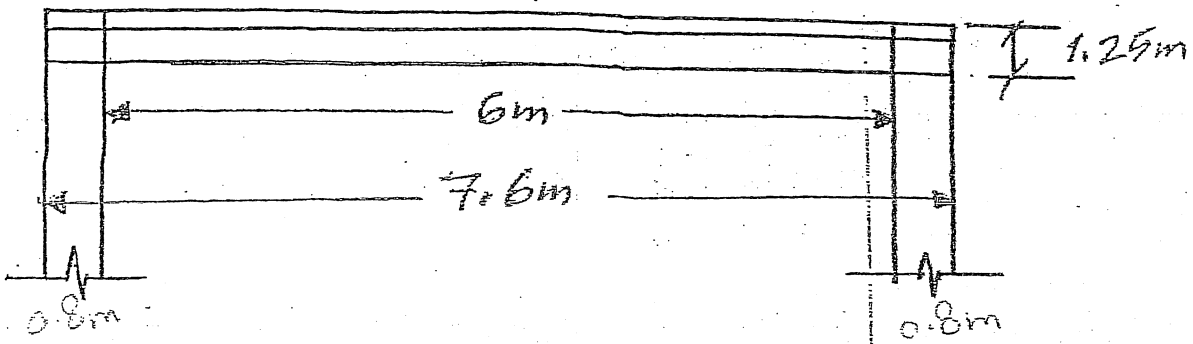

a. The effective flange width, b_E =

i) 400 cm (ii) 200 cm iii) 170 cm iv) 150 cm v) other

b. The factored live load in kg/m =

i) 2800 ii) 3000 (iii) 3200 iv) 3600 v) other

c. The service dead load in kg/m =

i) 2800 ii) 3000 iii) 3200 (iv) 3600 v) other

a. Isolated

$b_E \leq 4 b_w$

$t \geq \frac{1}{2} b_w$

$b_E = 4 \leq 4(0.5)$

$4 \leq 2$ m = 200 cm

b. L.L $= (1.6)\left(500 \frac{kg}{m^2}\right)(4m) = 3200 \frac{kg}{m}$

c. D.L $= (4)(0.25)[2400) + (1)(0.5)(2400)$

$= 3600$ kg/m

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Q4. For a T-section, the span length = 10 m, d = 92 cm, bw = 50 cm, fc' = 20 MPa, fy = 400 MPa, b_E = 240 cm, t_f = 25 cm, b_f = 300 cm, and Wu = 2.5 t/m. Determine:

a. (2 points) Asmax(εt=0.005) for positive bending moment.

$a > t$

$X = \frac{3}{8}(92) = 34.5\text{cm}$ $a = (0.85)(34.5) = 29.33\text{cm} > 25\text{cm}$

$C_1 = 0.85(0.2)(240 - 50)(25) = 807.5\ t$

$C_2 = 0.85(0.2)(25)(29.33) = 124.65\ t$

$T = C_1 + C_2 \Rightarrow As_{max} = \frac{807.5 + 124.65}{4}$

$= 233.04\ cm^2$

b. (2 points) Asmax(εt=0.004) for negative bending moment.

$X = \frac{3}{7}(92) = 39.43\text{cm}$ $a = 0.85(39.43) = 33.51\text{cm}$

$C_{max} = 0.85(0.2)(50)(33.51) = 284.84\ t$

$T = C \Rightarrow As_{max} = \frac{284.84}{4}$

$= 71.21\ cm^2$.

c. (2 points) Asmin for positive bending moment.

$0.25\frac{\sqrt{20}}{400}(50)(92) \geq \frac{1.4}{400}(50)(92)$

$12.86\ cm^2 \geq 16.1\ cm^2$

Controls.

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$$\epsilon_s' = \left(\frac{x-6}{x}\right)(0.003)$$

$$f_s' = \left(\frac{x-6}{x}\right)(0.003)\left(2000 \frac{t}{cm^2}\right)$$

$$f_s' = 6 - \frac{36}{x}$$

$$384.84 = 0.85(0.2)(100)(0.85)X + (35.34)\left(\left(6 - \frac{36}{x}\right) - 0.85(0.2)\right)$$

$$X * \left[384.84 = 14.45x + (35.34)\left(5.83 - \frac{36}{x}\right)\right]$$

$$14.45x^2 - 178.8x - 1272.24 = 0$$

$$x = 17.43 \text{ cm} \qquad a = 14.82$$

$$f_s' = \left(\frac{17.43-6}{17.43}\right)(0.003)(2000) = 3.93 \text{ t}$$

Check ϕ

$\phi \times C_n =$

Mn on same page question →

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d. (2 points) Asmin for negative bending moment.

$0.5\frac{\sqrt{20}}{400}(50)(92) \le 0.25\frac{\sqrt{20}}{400}(300)(92)$

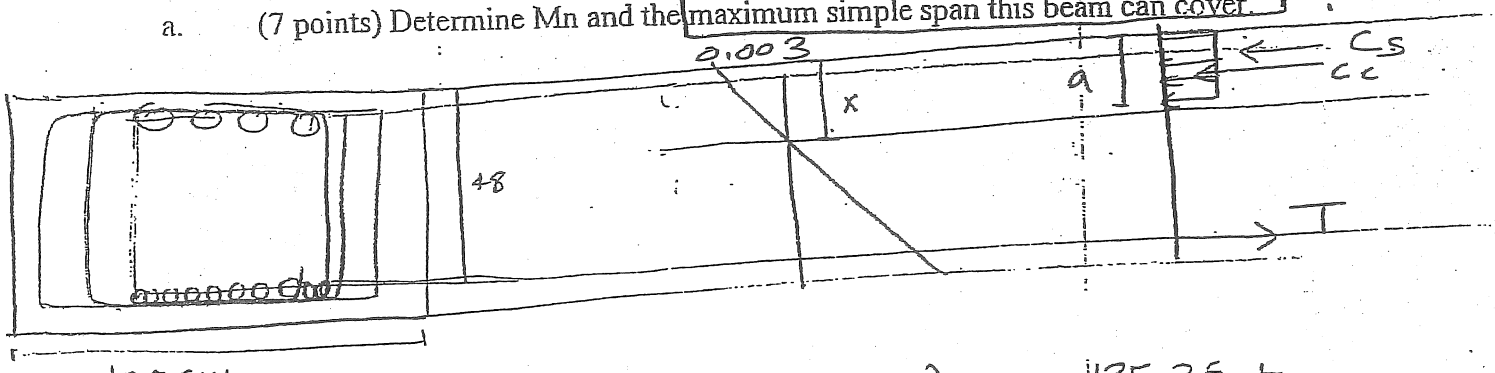
$25.71\ cm^2 \le 77.14\ cm^2$

controls.

Q5. A doubly reinforced beam has d = 48 cm, d' = 6 cm, fc' = 20 MPa, fy = 400 MPa, b = 100 cm, As' = 5Φ30 bars, As = 10Φ35bars, 3Φ10 stirrups where required, and Wu = 2.5 t/m.

$A_s = 96.21$ $A_s' = 35.34$

a. (7 points) Determine Mn and the maximum simple span this beam can cover.



Assume comp. steel yields

$C_s = 35.34(4 - 0.85(0.2)) = 135.35\ t$

$C_c = 0.85(0.2)(100)a = 17a$

$T = (96.21)(4) = 384.84\ t$

$T = C_s + C_c$

$384.84 = 135.35 + 17a$

$a = 14.68\ cm$

$x = \frac{14.68}{0.85} = 17.3\ cm$

$\varepsilon_s' = \left(\frac{17.3 - 6}{17.3}\right)(0.003)$

$= 0.00195 < 0.002$

this is not valid.

for New x:

$M_n = \left[(17)(14.82)\left(48 - \frac{14.82}{2}\right)\right]/100 + 135.35(48 - 6)$

$M_n = 102.3 + 56.85$

$M_n = 159.15\ t.m$

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$A_V = 6\,(0.79) = 4.74$ from Table 4.

b. (5 points) For Vu = 20t, select s.

$\phi V_c = (0.75)(0.17)\frac{\sqrt{20}}{100}(48)(100)$

$= 27.4\ t$

$\frac{\phi V_c}{2} = 13.7\ t$ $\quad 3\phi V_c = 82.2\ t$ $\quad 5\phi V_c = 137\ t$

Since $13.7 < V_u \leq 27.4$ $\therefore$ Vu in category II

Geom. Strength

$S_{max}: \frac{48}{2} = 24\ cm$ $\quad \frac{(4.71)(400)}{(0.0052)\sqrt{20}(100)} = 79.5$

60 cm

this controls

$\frac{(4.71)(400)}{0.35\,(100)} = 53.8$

OK!

c. (5 points) For Vu = 90t, select s.

$\phi V_c = (0.75)(0.17)\frac{\sqrt{20}}{100}(100)(48) = 27.4\ t$

Vu

$3\phi V_c = 82.2 < 90 < 5\phi V_c = 137\ t$ $\therefore$ category V

$\phi V_{s\,req} = 90 - 27.4 = 62.6\ t$

$S_{req} = \frac{(0.75)(4.71)(4)(48)}{62.6} = 10.83\ cm$

this controls.

$S_{max}: \leq \frac{d}{4} = 12\ cm$ $\quad 79.5$

$\leq 30\ cm$ $\quad 53.8$

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Name: Design Key

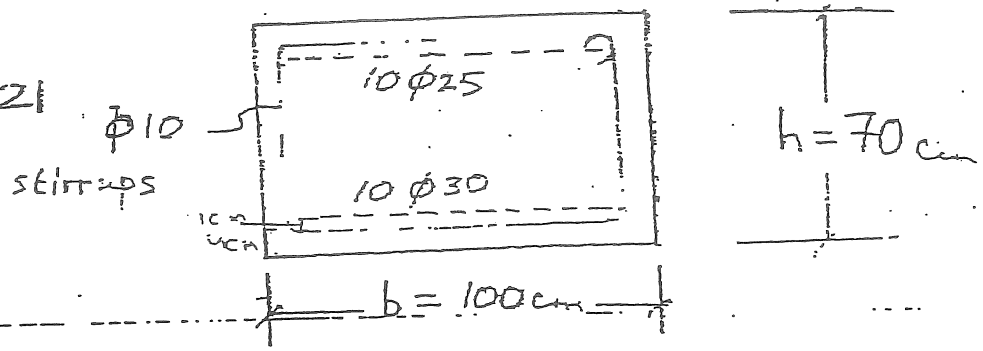
Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335, Reinforced Concrete Design I

Quiz — Monday, November 5, 2012

The beam shown supports a service dead load of 15 t/m, not including self-weight. Use fc' = 30 MPa, fy = 420 MPa, $\gamma_{concrete}$ = 2.4 t/m^3.

$\epsilon_y = \frac{420}{200{,}000} = 0.00221$



1. (6 points) Determine $A_{s\,max(\epsilon_t=0.005)}$. Draw appropriate stress and strain diagrams.

Distance to the bottom layer = 70 − 4 − 1 − 1.5 = 63.5 cm

x_{max} (ϵ_t=0.005) $= \frac{3}{8}(63.5) = 23.81$ cm

$\beta_1 = 0.85 - \frac{30-28}{7}(0.05) = 0.836$

a_{max} (ϵ_t=0.005) $= 0.836 \times 23.81 = 19.90$ cm

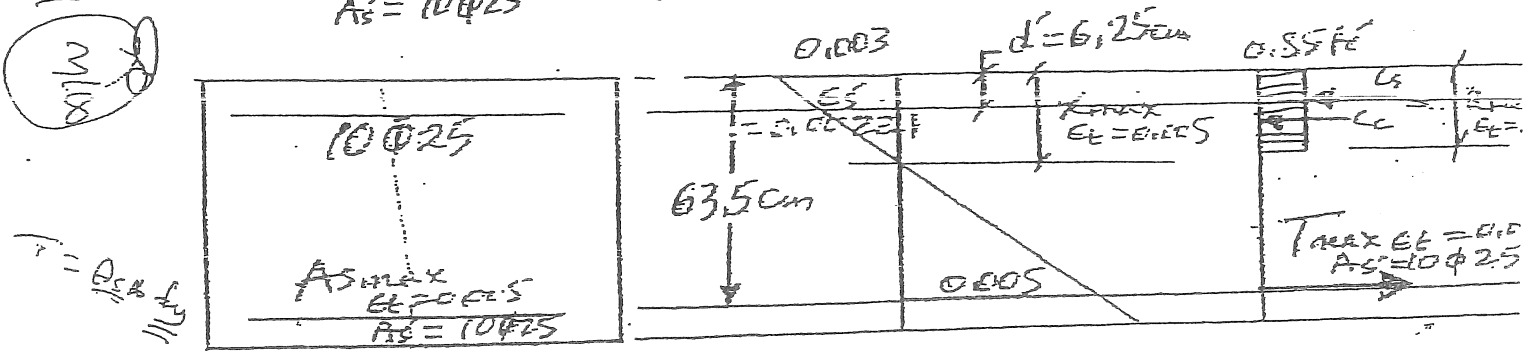
$\epsilon_s' = \left(\frac{23.81 - 6.25}{23.81}\right)(0.003) = 0.00221 > \epsilon_y \therefore f_s' = f_y$

$C_c = 0.85(0.3)(100)(19.90) = 507.5$ t

$C_s = (10 \times 4.91)(4.2 - 0.85 \times 0.3) = 193.7$ t

$A_{s\,max\,\epsilon_t=0.005} = (507.5 + 193.7)/4.2 = 167.0$ cm^2

A_s = 10 ϕ25



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(7/7)

For the structural concrete (as a material):

4. a (2 points) Use a simple strain versus time diagram to explain the change in strain of a loaded and drying specimen. Consider elastic, creep, and shrinkage strains.

b. (1 points) What are the two requirements specified by the ACI code for adequate control of strength.

c. (1 points) Explain the difference between f_c' and f_{cr}'.

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17/30

Name: [redacted]

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

First Exam **March 26, 2009**

1. A doubly reinforced beam has b = 80 cm, d = 51 cm, d' = 9 cm, As' = 7Φ28 bars, fc' = 40 MPa, fy = 400 MPa.
   a. (4 points) Determine As_{max} for the $\varepsilon_t = 0.004$ limit.

$$\frac{X_{max}}{0.003} = \frac{d}{0.007}$$

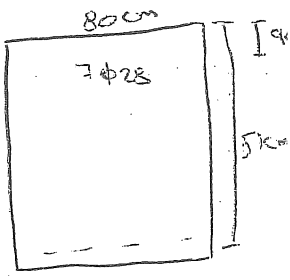
$$X_{max} = 21.86 \text{ cm}$$

for $f_c' = 40$ MPa

$\beta = 0.85 - 0.05\left(\frac{40-28}{7}\right)$

$\beta_1 = 0.764$

a_{max} at $\varepsilon_t = 0.004$ $= 21.86(0.764) = 16.70$ cm



$$\varepsilon_s' = \frac{21.86 - 9}{21.86}(0.003) = 0.00176 < 0.002$$

$$\therefore f_s' = 0.00176(2000) = 3.529 \text{ t/cm}^2$$

$$C_s = A_s'(f_s' - 0.85 f_c') = 43.10(3.529 - 0.85 f_c') = 137.446 \text{ ton}$$

$$C_c = 0.85(0.4)(80)(16.70) = 454.268 \text{ ton}$$

$$T_{max} = C_s + C_c = 137.446 + 454.268 = 591.714 \text{ ton}$$

$$A_{s,max} = \frac{T_{max}}{f_y} = \frac{591.714}{4} = 147.9285 \text{ cm}^2$$

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10. T F The modulus of rupture gives lower values for tensile strength than the split-cylinder test.

11. T F The modulus of elasticity of concrete, like that of steel, varies with strength.

12. T F Shrinkage is the property of concrete by which it continues to deform with time under sustained loads.

13. T F The main cause of creep is the loss of water as the concrete dries and hardens.

14. T F Welded wire fabric may be used as the main reinforcement for thin slabs.

15. T F In the ACI Code, ϕ is used to account for probability of understrength due to a situation in which several acceptable tolerances may combine.

16. T F In the working stress method, stresses resulting from ultimate loads and computed by mechanics of elastic members should not exceed allowable values.

17. T F The ACI Code allows using bar sizes that differ by more than 4 mm in diameter, together in the same layer, for beam reinforcement.

18. T F An economical rectangular beam proportion is one in which the overall depth-to-width ratio is between about 1.5 to 2.0.

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c. (10 points) Determine As required to support a **negative** moment Mu = 15 t.m. Check $As_{max(\varepsilon t=0.005)}$ and As_{min}. Use Φ 20 bars and Φ 10 stirrups. Take the distance to the extreme tension steel to be 124 cm. Select bars and provide a sketch of the x-section.

$$Mu = \frac{15}{0.9} = 16.67 \text{ t.m}$$

$$\frac{Mu}{bd^2} = Rn_{req} = \frac{1667}{(60)(124)^2} = 0.001807$$

$$m = \frac{fy}{0.85f'c} = \frac{400}{0.85 \times 35}$$

$$m = 13.45$$

d = 124

$$\rho = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mRn}{fy}}\right)$$

$$\rho = \frac{1}{13.45}\left(1 - \sqrt{1 - \frac{2 \times 13.45 \times Rn}{4}}\right)$$

$$\rho = 0.00045231$$

$$As_{req} = \rho bd = 3.37 \text{ cm}^2$$

$As_{max} \Rightarrow$ $x = \frac{3}{8}d = 46.5$ cm

$a = 39.525$ cm

$$C = 0.85 \times 0.35 \times 60 \times 39.525 = 705.521 \text{ t}$$

$$As_{\varepsilon t=0.005} = \frac{C}{fy} = 1766.38 \text{ cm}^2$$

$As_{min} \Rightarrow$ $\frac{0.5\sqrt{f'c}}{fy} bd \leq \frac{0.25\sqrt{f'c}}{fy} bpd$

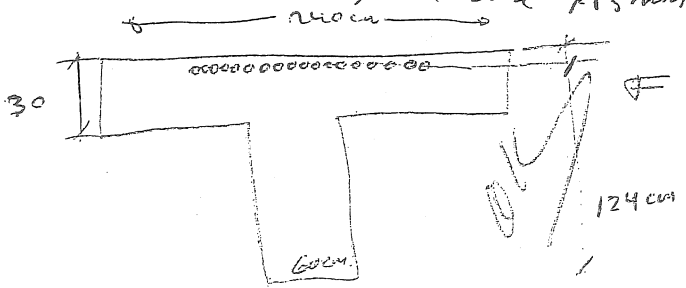
$$\frac{0.5\sqrt{35}}{400} \times 60 \times 124 \leq \frac{0.25\sqrt{35}}{400} \times 400 \times 124$$

$55.02 \leq 183.340$

Controls

$As_{req} < As_{min}$

Some use $As_{min} \Rightarrow \frac{55.02}{3.14} = 17.52 \Rightarrow 18\ \Phi 20$



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Q4. (4 points) Answer with no more than two lines!

a. What is "high performance" concrete?

Concrete with high workability

b. What is a balanced strain condition?

c. What is the purpose of using bolsters and chairs (bar supports) in construction?

to support tension and compression bars for construction uses.

d. Why does the ACI Code require a minimum concrete cover for reinforcing bars (for example, a clear cover of 4 cm for beams and columns)?

Q5. (18 points) Circle the appropriate letter, T for true or F for false.

1. T (F) Under-reinforced sections do not have sufficient reinforcement to support the design moments.

2. T (F) Over-reinforced sections have more reinforcement than necessary to support the design moments and therefore are un-economical..

3. (T) F Steel and concrete have similar rates of thermal expansion.

4. (T) F Proper concrete mixes provide adequate impermeability of the concrete against water intrusion and bar corrosion.

5. (T) F Concrete ordinarily requires about 14 days to attain adequate strength so that forms can be removed and construction and dead loads carried.

6. (T) F A tension-controlled section will exhibit a ductile failure mode with visible flexural cracks and deflection.

7. T (F) The nominal maximum size of coarse aggregate may not exceed 1/3 the narrowest dimension between sides of forms.

8. (T) F The nominal maximum size of coarse aggregate may not exceed 3/4 the minimum clear spacing between reinforcing bars.

9. (T) (F) As an average, the 15 x 30 cm cylinder strength is 80 % of the 15-cm cube strength.

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b. (2 points) Is the beam expected to show objectionable deflection under service conditions?

$\frac{A_{s\,actual}}{A_{s\,max}} = 0.7 - 0.8$

$\frac{x_{max}}{0.003} = \frac{73}{0.008}$ $\quad x_{max} = 27.375$

a_{max} (at $\varepsilon_t = 0.005$) $= 23.268$

$C_{max} = 0.85(0.25)(30)(23.268) = 247.22$

$A_{s\,max} = \frac{247.22}{4} = 61.80\ cm^2$

$\frac{50.24}{61.80} = 0.8$ (yes the beam expected to show objectionable deflection)

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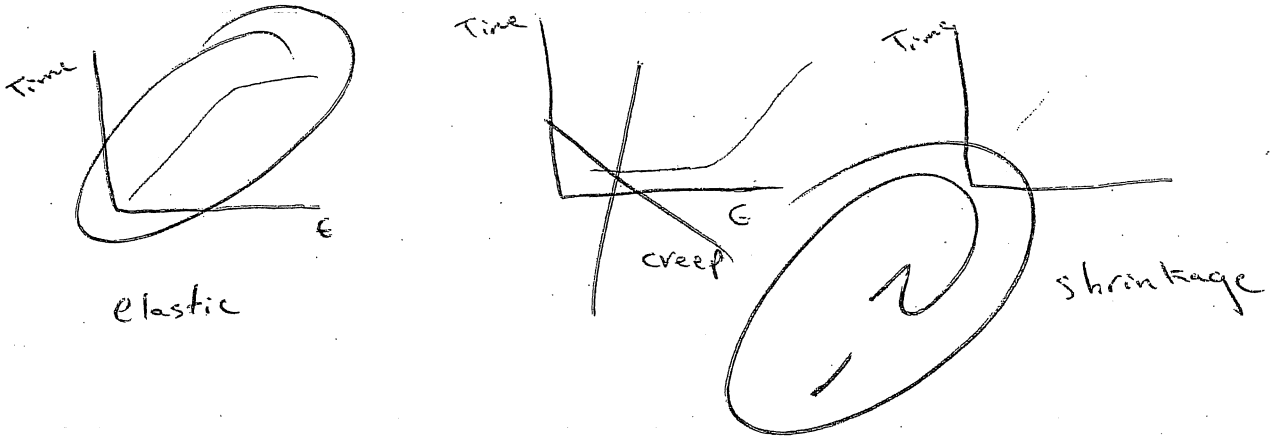
For the structural concrete (as a material):

4. a. (2 points) Use a simple strain versus time diagram to explain the change in strain of a loaded and drying specimen. Consider elastic, creep, and shrinkage strains.



b. (1 points) What are the two requirements specified by the ACI code for adequate control of strength.

Design strength ≥ required strength

ϕ (Nominal strength) > U (ultimate)

c. (1 points) Explain the difference between fc' and fcr'.

f_c' = compressive strength of concrete

f_{cr}' = required average compressive strength of concrete used as the basis for selection of concrete proportions

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Total Number of Pages = 10

Name: Key

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

Final Exam May 30, 2009

1. The sketch on the following page shows a ribbed slab supported on hidden beams. Use $f_c' = 25$ MPa and $f_y = 400$ MPa. Use d = 23 cm for Rib 1 everywhere.

a. (1 point) Determine the maximum load Wu for Rib 1.

$$W_u = 1.7 \frac{t}{m^2} \times 0.75 m = 1.275 \ t/m$$

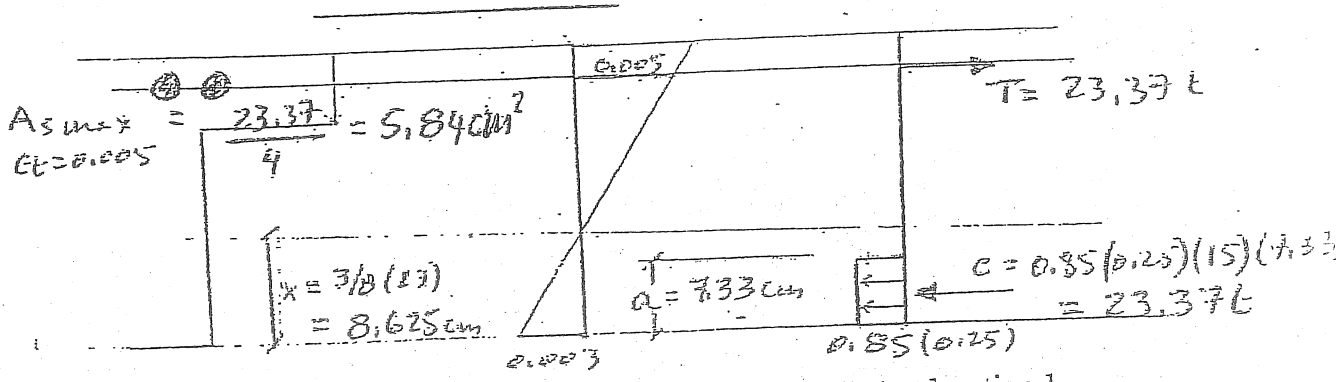
b. (2 points) Determine $A_{s\,max\text{-}et=0.005}$ for Rib 1 at location 1.

location 1 = -ve moment

$b = b_w = 15$ cm

$$A_{s\,max} = 0.31875 (0.85)\left(\frac{25}{400}\right)(15)(23)$$

$$= 5.84 \ cm^2$$



c. (2 points) Determine the minimum reinforcement for Rib 1 at location 1.

$$A_{s\,min} = 0.5 \frac{\sqrt{25}}{400}(15)(23) \leq \frac{0.25\sqrt{25}}{400}(75)(23)$$

$$= 2.16 \ cm^2 \leq 5.39 \ cm^2$$

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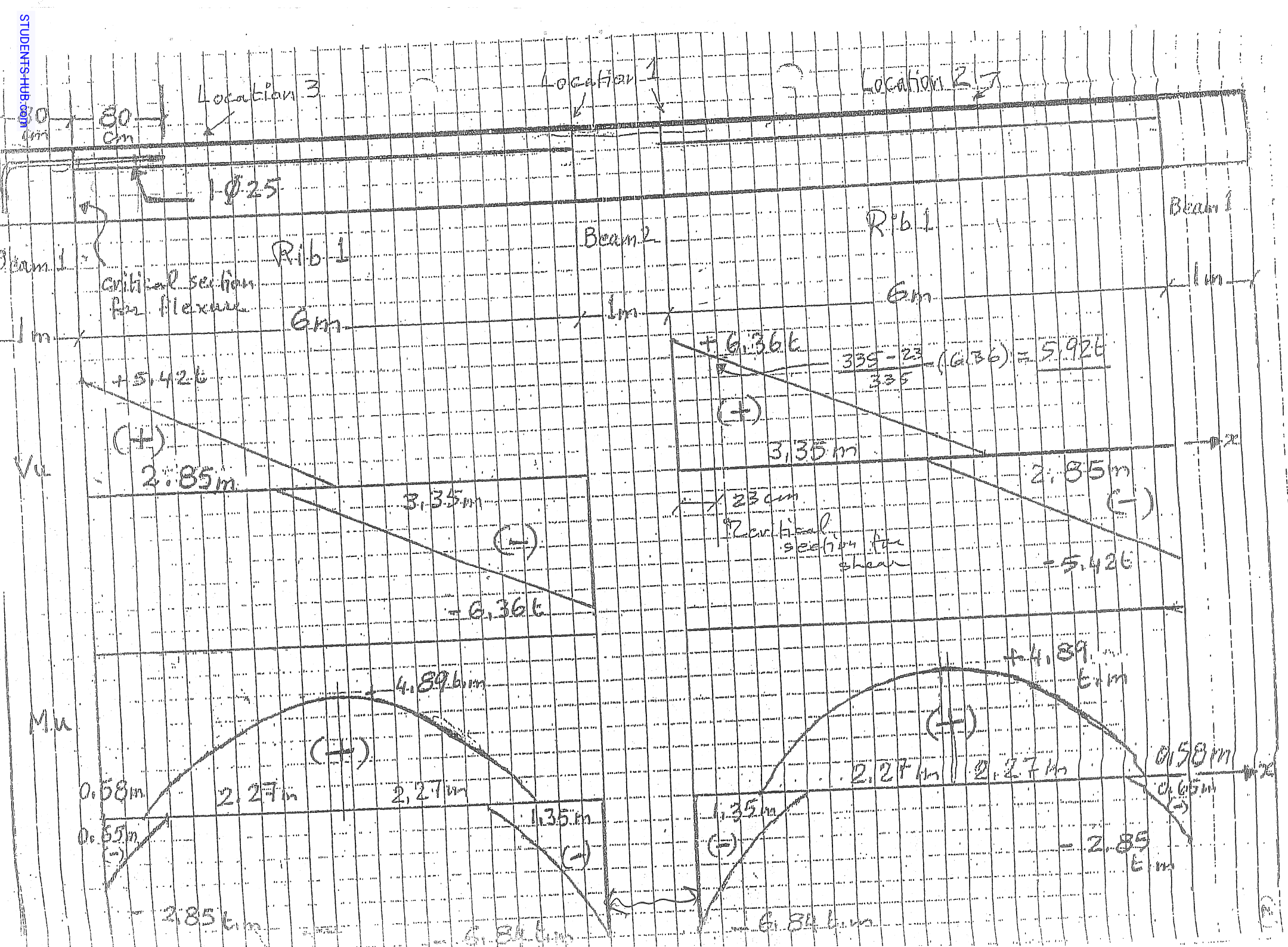

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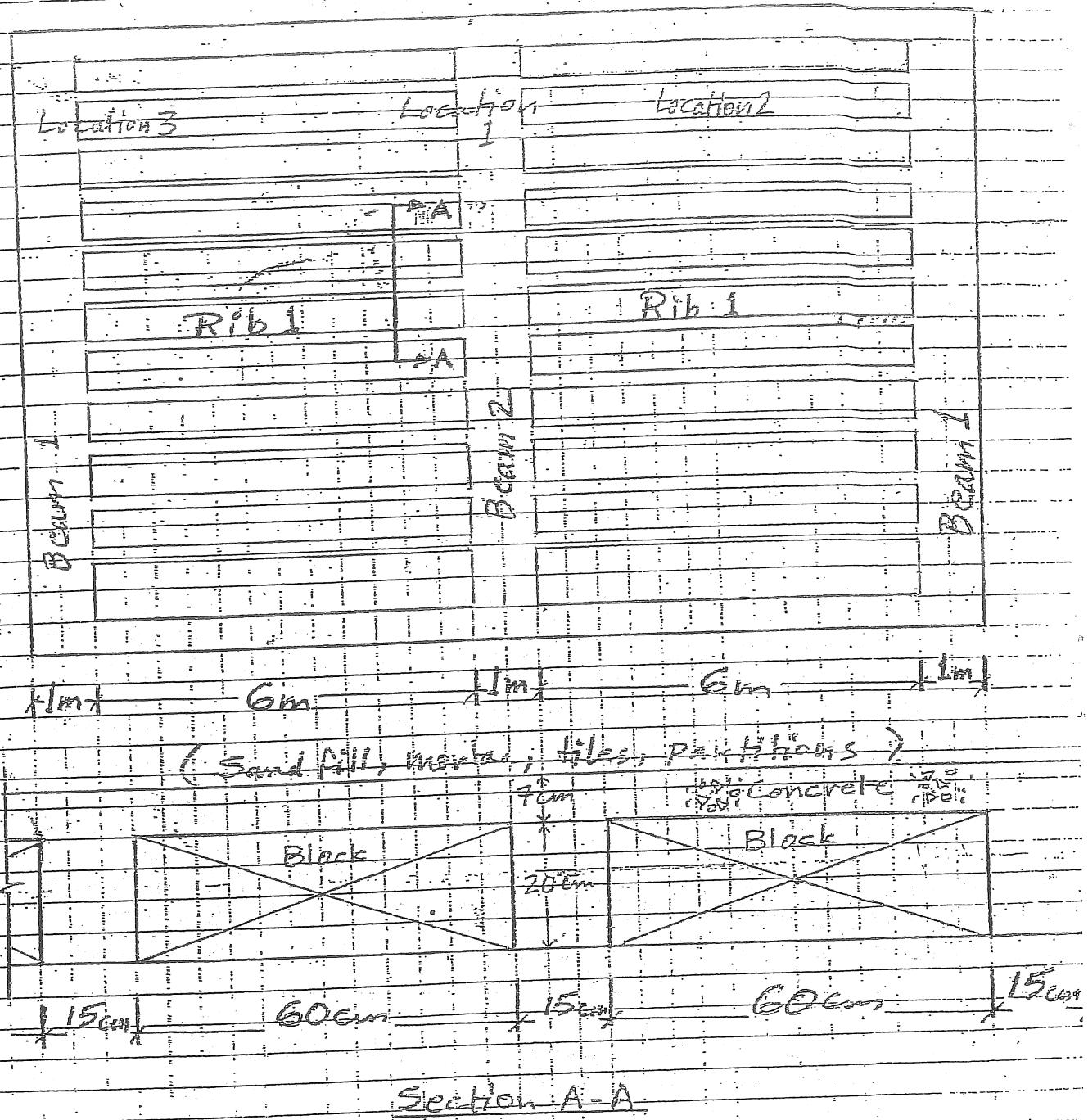
Wu for the slab = 1.7 t/m² for part (a)



Section A-A

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d. (3 points) Using the envelope provided, determine the required flexural reinforcement at location 1. Select bars.

$M_u = -6.84$ t.m, $M_{n\,req} = \frac{6.84}{0.9} = 7.60$ t.m ; $m = \frac{400}{0.85(25)} = 18.82$

$R_{n\,req} = \frac{760\ t.cm}{(15)(23)^2} = 0.0958\ t/cm^2$; $\rho_{req} = \frac{1}{18.82}\left(1-\sqrt{1-\frac{2(18.82)(0.0958)}{4}}\right) = 0.03$

$A_{s\,req} = 0.0364 \times 15 \times 23 = 12.57\ cm^2 > A_{s\,max}$ ⇒ Doubly Reinforced

at $A_{s\,max}$, $M_{n\,c} = 23.37\left(\frac{23-7.33/2}{100}\right) = 4.52$ t.m

$M_{n\,s\,req} = 7.60 - 4.52 = 3.08$ t.m (C) Moment, $f_s' = \frac{8.625-4}{8.625}(0.003)(2000) = 3.217$

$\frac{d-d'}{d}$

for $d' = 4$ cm, 3.08 t.m $= A_s'(3.217 - 0.85\times0.25)(23-4) = 3A_s'(19)$

$C_s = 3.0A_s' = \frac{308}{19} = 16.21$ t ⇒ $A_{s\,req}' = 5.39\ cm^2$ ⇒ use $2\phi20$ $(6.28\ cm^2)$

$A_{s\,req} = \frac{23.37+16.21}{4} = 9.89\ cm^2$ ⇒ use $2\phi25$ $(=9.82\ cm^2)$

Check: $T = 39.28$ t $= 0.85(0.25)(15)(0.85x) + 6.28\left(5.79 - \frac{24}{x}\right)$

⇒ $x_{act} = 8.02$ cm, $a = 6.82$ cm, $C_c = 21.73$ t, $C_s = 17.54$ t

$M_n = 21.73\left(\frac{23-6.82/2}{100}\right) + 17.54\left(\frac{23-4}{100}\right) = 7.60$ t.m

(note $H_n\ \phi = 0.9$) because $x_{act} < x_{max\ \varepsilon_t=0.005}$

e. (2 points) Determine $A_{s\,max\text{-}\varepsilon_t = 0.005}$ for Rib 1 at location 2.

Location 2 : +ve moment

$b_E = \frac{6+0.5+0.5}{4} = 1.75$ cm

$= 15 + 16(7) = 127$ cm

$= 75$ cm controls

x_{max} $\varepsilon_t = 0.005$ $= \frac{3}{8}(23) = 8.625$ cm, $a_{max} = 7.33$ cm

$C_{max} = 0.85(0.25)\left[(75\times7)+(15\times0.33)\right] = 112.6$ t

$A_{s\,max}$ $\varepsilon_t = 0.005$ $= \frac{112.6}{4} = 28.15\ cm^2$

$\left(\frac{4.6}{x} = 0.85\phi\right.$

$\left(\frac{x-4}{x}\right)0.003$

$1-\frac{4}{x}$

f. (2 points) Determine the minimum reinforcement for Rib 1 at location 2.

$A_{s\,min} = \frac{0.25\sqrt{25}}{400}(15)(23) \geq \frac{1.4}{400}(15)(23)$

$= 1.078\ cm^2 \geq 1.208\ cm^2$

Controls

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g. (3 points) Use the loads and the envelope provided to determine the required flexural reinforcement at location 2. Select bars.

$M_u = +4.89$ t.m , $M_{n\,req} = \frac{4.89}{0.9} = 5.43$ t.m

if $a = t$, $M_n = 0.85(0.25)(75)(7)\left(23 - \frac{7/2}{100}\right) = 21.75$ t.m

$\therefore \quad a < t \Rightarrow b = b_E = 75$ cm

$R_{n\,req} = \frac{543 \text{ t.cm}}{(75)(23)^2} = 0.0137 \text{ t/cm}^2$

$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.0137)}{4}}\right) = 0.00354$

$A_{s\,req} = 0.00354 \times 75 \times 23 = 6.10 \text{ cm}^2$ $> A_{s\,min}$ $< A_{s\,max}$

use $2\phi 20$ bars in one layer

A_s provided $= 6.28 \text{ cm}^2$

h. (3 points) Use the loads and the envelope provided to design the rib for shear at location 1. Use Φ8 stirrups if needed. $2\phi 8 = 1.0 \text{ cm}^2$

$V_u = \frac{335 - 23}{335}(6.36) = 5.92$ t

$\phi V_c = 0.75(0.17)\frac{\sqrt{25}}{100}(15)(23) = 2.20$ t

$1.1\,\phi V_c = 2.42$ t

Check minimum requirements:

$s_{max} = \frac{(1.0)(400)}{0.062\sqrt{25}(15)} = 86.02$ cm

$= \frac{(1.0)(400)}{0.35(15)} = 76.19$ cm

$= d/2 = \frac{23}{2} = 11.5$ cm controls minimum

$= 60$ cm

$\phi V_{s\,min} = \frac{0.75(1.0)(4.00)(23)}{11.5} = 6$ t

$\phi V_c + \phi V_{s\,min} = 8.20$ t ∴ use 1φ8 @ 11.5 cm

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i. (4 points) Examine the hook provided at location 3. Check if the hook is embedded properly to the left and to the right of the critical section for flexure.

1 Φ25 hooked bar — Category A

cover = 2cm + 0.8 = 2.8cm

$$l_d = \frac{(400)(1)(1)}{1.7(1)\sqrt{25}}\, d_b$$

$$= 47.06\, d_b = 117.6\ cm$$

d = 23cm

$12 d_b = 30\ cm$

$\frac{L_n}{16} = \frac{600}{16} = 37.5cm$ controls

To the right:

Required length = (65 + 37.5) = 102.5 cm < l_d = 117.6 cm

Provided (available) = 80 cm ∴ Not Good

To the left:

$$l_{db} = \frac{0.24(1.0)(400)}{(1.0)\sqrt{25}}(2.5) = 48\ cm$$

$$A_{s\,req}: \quad R_{u\,req} = \frac{285}{(0.9)(15)(23)^2} = 0.040\ t/cm^2$$

$$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.040)}{4}}\right) = 0.0111, \quad A_{s\,req} = 3.84\ cm^2$$

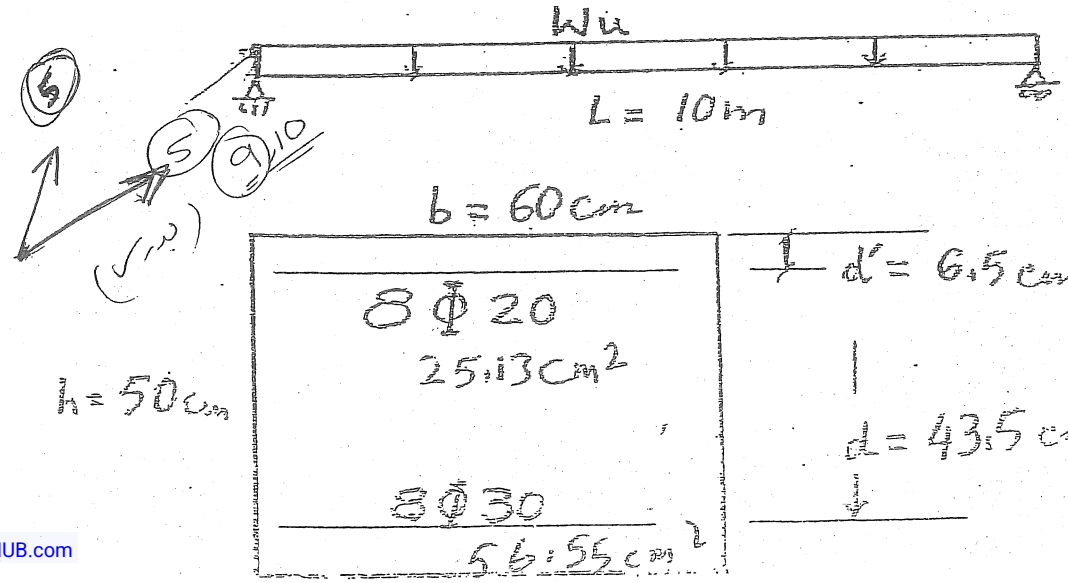
A_s provided = 4.91 cm^2 (4Φ25)

Note that the available cover within the flange is very large >>

$$\therefore l_{dh} = (48)(0.7)\left(\frac{3.84}{4.91}\right) = 26.3cm \text{ controls} > 8d_b = 20cm,\ 15cm$$

Provided length = 80cm > 26.3cm ∴ Good

2. For the beam shown, use fc' = 25 MPa and fy = 400 MPa.



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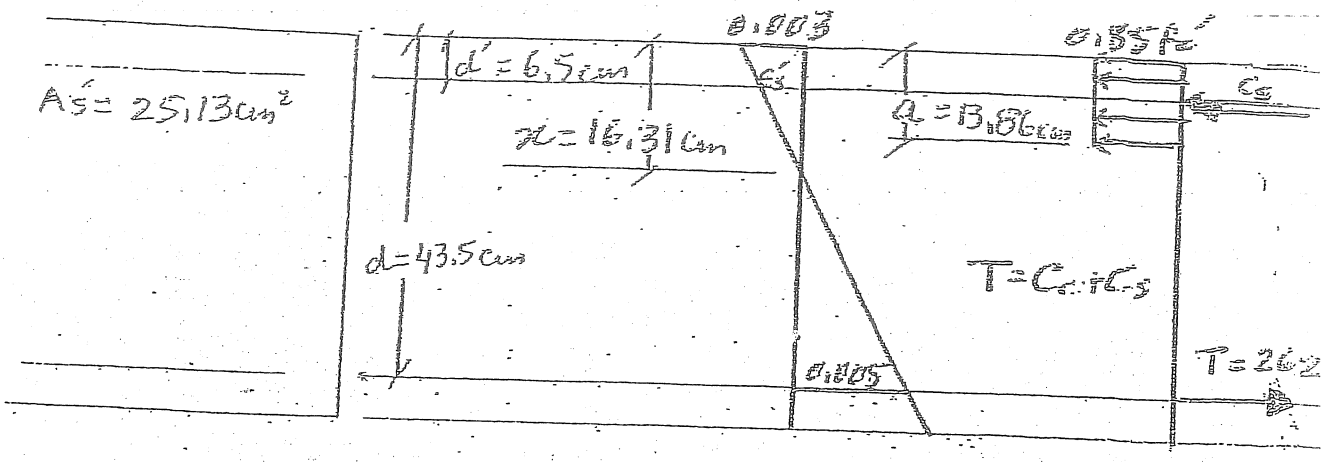
a. (3 points) Determine $As_{max-et=0.005}$ for this doubly reinforced beam.



$c_{max} = \frac{3}{8}(43.5) = 16.31\ cm$ ($\varepsilon_t = 0.005$)

$a_{max} = 13.86\ cm$

$C_{1max} = 0.85(0.25)(60)(13.86) = 176.8t$ ($\varepsilon_t = 0.005$)

$f's = 0.00180 \times 2800 = 3.61\ t/cm^2$

$C's_{max} = 25.13(3.61 - 0.85(0.25)) = 85.3t$

$As_{max} = \frac{176.8}{4} + \frac{85.3}{4}$ ($\varepsilon_t = 0.005$)

$= \frac{262.1}{4} = 65.52\ cm^2$

b. (1 points) Determine As_{min} for this beam.

$As_{min} = \frac{0.25\sqrt{25}}{4200}(60)(43.5) \geq \frac{1.4}{4200}(60)(43.5)$

$= 8.16\ cm^2 \geq 9.14\ cm^2$

Controls

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c. (5 points) Determine the maximum load Wu permitted on this beam if it is reinforced as shown.

Note that the compression steel will not yield since it did not yield at the maximum level as in part a)

$$C_s = 25.13\left(6\left(\frac{x-6.5}{x}\right) - 0.85(0.25)\right) = 25.13\left(5.79 - \frac{39}{x}\right)$$

$$= 145.4 - \frac{980.1}{x}$$

$$C_c = 0.85(0.25)(60)(0.85x) = 10.84x$$

$$T = 56.55 \times 4 = 226.2\ t$$

$$226.2 = 145.4 - \frac{980.1}{x} + 10.84x$$

$$10.84x^2 - 80.8x - 980.1 = 0$$

$$x^2 - 7.45x - 90.4 = 0$$

$$x = 13.44\ cm,\ a = 11.85\ cm$$

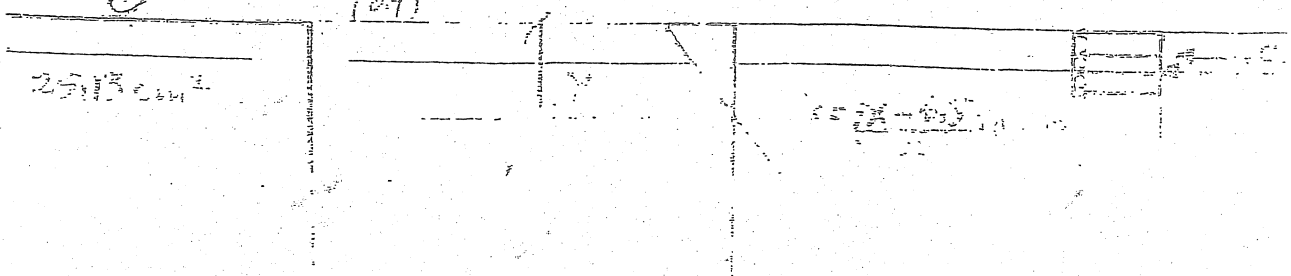
$$C_c = 151.1\ t,\ C_s = 75.1\ t$$

Check: $C_c + C_s = 151.1 + 75.1 = 226.2\ t$

Note: $\varepsilon_s' = \frac{13.94 - 6.5}{13.94}(0.003) = 0.00160 < \varepsilon_y$

$$M_n = 151.1\left(\frac{43.5 - 11.85/2}{100}\right) + 75.1\left(\frac{43.5 - 6.5}{100}\right) = 84.57$$

$$\frac{(w_u)(10^2)}{8} = (0.9)(84.56) \Rightarrow w_u = 6.09\ t/m$$



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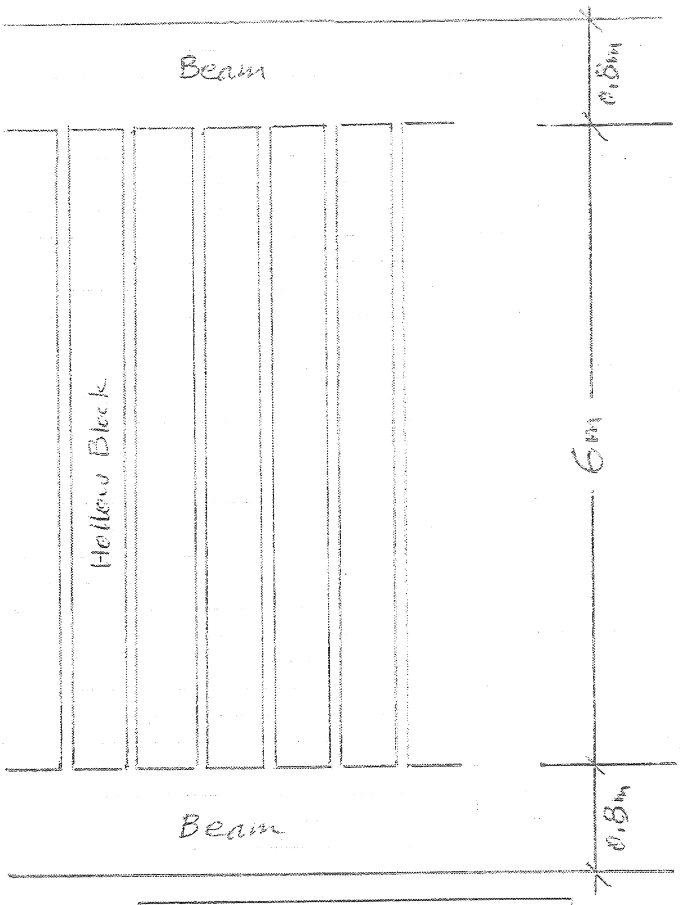
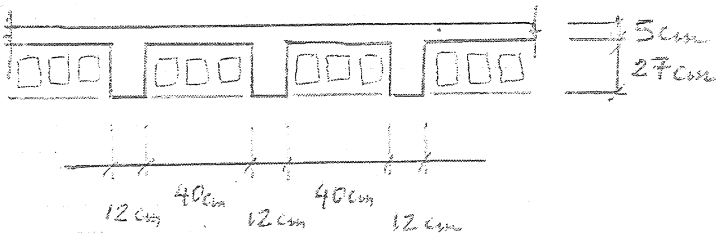


Use $d_t = d = 29$ cm



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b. (10 points) If the slab is reinforced with 2Φ12 tension bars, determine the maximum positive and maximum negative ultimate moment that can be supported in each case.

$2\phi 12 = 2.26\ cm^2$ ($< A_{s\,max}$ for +ve and -ve moments)

+ve Moment:

$T = 2.26 \times 4.2 = 9.492\ t$

$a = \frac{9.492}{0.85(0.35)(52)} = 0.614\ cm < 5\ cm \Rightarrow b = 52\ cm$ ✓

$M_n = 9.492\left(\frac{29 - 0.614/2}{100}\right) = 2.72\ t.m$

(5) $\phi M_n = 0.9(2.72) = \underline{2.45\ t.m}$

-ve Moment:

$T = 9.492\ t$

$a = \frac{9.492}{0.85(0.35)(12)} = 2.66\ cm$

$M_n = 9.492\left(\frac{29 - 2.66/2}{100}\right) = 2.63\ t.m$

(5) $\phi M_n = 0.9(2.63) = \underline{2.36\ t.m}$

(Note that the main difference between the two cases is the maximum reinforcement limit.)

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$\phi M_n = 90.45$ t.m

$\frac{1.6(LL)(5^2)}{8} = 90.45 - 3.65 - 30 = 56.8$

$1.6(LL) = 18.18$ t/m

3 $LL = 11.36$ t/m

---

2 $A_{s\,max}$ is checked by $\epsilon_{t\,actual} = 0.00798$
or by direct calculation

2 $A_{s\,min} = \frac{0.25\sqrt{35}}{420}(90)(35.5) \geq \frac{1.4}{420}(90)(35.5)$

$12.20\ cm^2 \geq 11.55\ cm^2$

$\therefore A_{s\,min} < A_{s\,actual} < A_{s\,max}$

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Q5. A ribbed one-way slab has 40 cm hollow blocks between ribs, a topping slab = 5 cm, and 12 cm-wide ribs. The slab extends over a clear span of 6 m between 80 cm wide beams. Provide sketches as appropriate.

a. (10 points) Determine the maximum positive and negative reinforcement limits for a rib.

$d_t = d = 29\,cm$

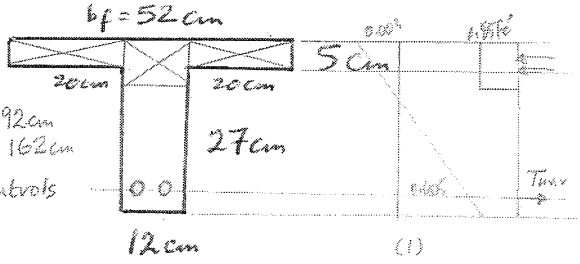
$L = 6.8\,m$

$L_n = 6\,m$

$b_f \le 12 + 16(5) = 92\,cm$

$\le 12 + \frac{600}{4} = 162\,cm$

$\le 52\,cm$ controls



Maximum +ve:

(3) $\underset{\varepsilon_t = 0.005}{x_{max}} = \frac{3}{8}(29) = 10.875\,cm$, $a_{max} = 8.7\,cm$

$C_{max} = \overset{99.50}{0.85(0.35)(52-12)(5)} + \overset{31.06}{0.85(0.35)(12)(8.7)} = 90.56\,t$

$\therefore \underset{\varepsilon_t = 0.005}{A_{s\,max}}\,(+ve) = \frac{90.56}{4.2} = 21.56\,cm^2$

(22.62 for $\varepsilon_t = 0.004$)

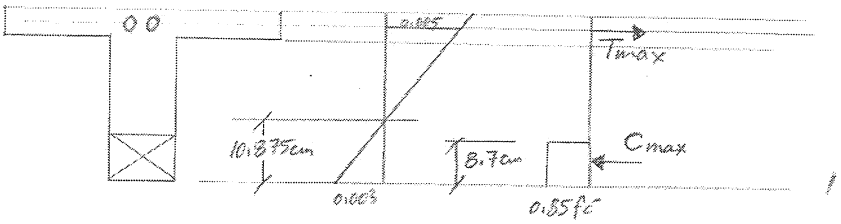
Maximum −ve:

(3) $\underset{\varepsilon_t = 0.005}{A_{s\,max}} = 0.31875\left(\frac{35}{420}\right)(0.8)(12)(29) = 0.02125(12)(29)$

$= 7.40\,cm^2$

(3.45 for $\varepsilon_t = 0.004$)

$OR = \frac{0.85(0.35)(12)(8.7)}{4.2} = 7.40\,cm^2$



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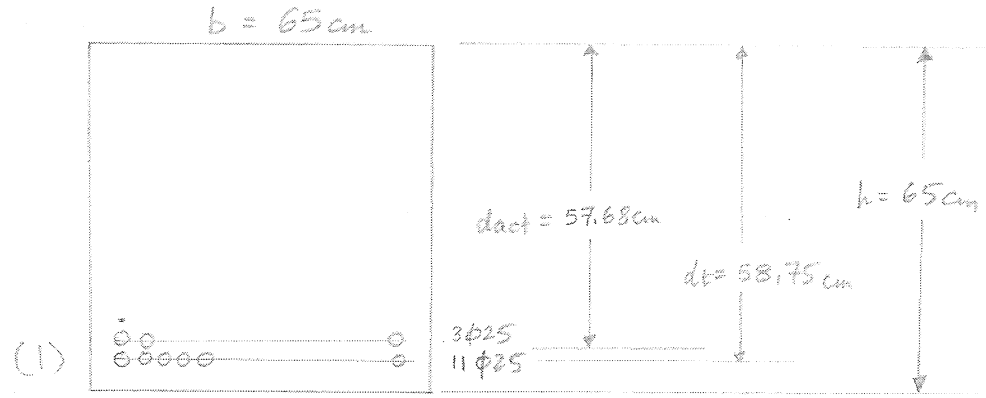

$$\bar{y} = \frac{11 \times 6.25 + 3 \times 11.25}{14} = 7.32 \text{ cm}$$

(1) $d_{act} = 57.68$ cm

(1) $a = \dfrac{14 \times 4.91 \times 4.2}{0.85\,(0.35)(65)} = 14.93$ cm

$$M_n = 288.7 \text{ t} \left(\frac{57.68 - 14.93/2}{100} \right) = 145.0 \text{ t.m}$$

(1) $\phi M_n = 130.5$ t.m $> M_u = 130$ t.m ∴ OK

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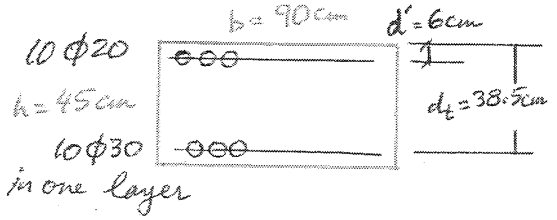
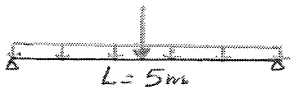
Q4. (20 points) A beam has b = 90 cm and h = 45 cm. The beam is reinforced with 10Φ30 tension bars and 10Φ20 compression bars, and supports a concentrated service dead load = 20 t placed at midspan, not including self-weight. Determine the maximum distributed service live load that can be placed on the beam. Determine actual d_t, d, and d' for use in the calculations. The beam extends over a simple span L = 5m. Check the maximum and minimum reinforcement limits. (You must add self-weight.) Provide sketches as appropriate.

$A_s' = 31.42\ cm^2$

$A_s = 70.69\ cm^2$





Self-weight, $w_o = 0.9 \times 0.45 \times 2.4 = 0.972$, $(w_o)_{factored} = 1.2 \times 0.972 = 1.166\ t/m$

2 · $(M_o)_{factored} = \frac{(1.166)(5^2)}{8} = 3.645\ t.m$

2 $(M_{DL})_{factored} = \frac{(1.2 \times 20)(5)}{4} = \frac{(24)(5)}{4} = 30\ t.m$

Assume that the compression steel yields,

$C_c = 0.85(0.35)(90)(0.8x) = 21.42x$

$C_s = 31.42(4.2 - 0.85(0.35)) = 122.6\ t$

$T = 70.69 \times 4.2 = 296.9\ t$

4 · $296.9 = 122.6 + 21.42x \Rightarrow x = 8.14$, $\varepsilon_s' = 0.000788 < \varepsilon_y$

∴ assumption is wrong,

$C_s = 31.42\left(6\left(\frac{x-6}{x}\right) - 0.85(0.35)\right) = \left(179.2 - \frac{1131}{x}\right)$

$296.9 - 21.42x - 179.2 + \frac{1131}{x} = 0$

$21.42x^2 - 117.7x - 1131 = 0$

$x^2 - 5.495x - 52.8 = 0$ $\quad x = 10.52cm$, $a = 8.41\ cm$

$\varepsilon_t = 0.00798 \Rightarrow \phi = 0.9$

5 $C_c = 225.2\ t$, $C_s = 71.7\ t$

$M_n = 225.2\left(\frac{38.5 - 8.41/2}{100}\right) + 71.7\left(\frac{38.5 - 6}{100}\right) = 100.5\ t.m$ /

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Name: [redacted] Number [redacted]

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Birzeit University
Faculty of Engineering
Department of Civil Engineering
ENCE 335 Reinforced Concrete Design I
Mid-Term Exam **Wednesday, April 11, 2018**

13/15

Part I – 1 page

Q1. (5 points) Write the exact section in the ACI Code that specifies the following:

1. Tensile strength of concrete shall be neglected in flexural and axial strength calculations — 22.2.2.2
2. Strength reduction factor ϕ for bending moment if ε_t is less than 0.005 — 21.2.2
3. As_{min} for T-sections with the flange in compression — 9.6.1.2
4. ε_t for beams shall be at least 0.004 — 9.3.3.1
5. The value of β_1 for determining "a" of the Whitney block — 22.2.2.4.3

Q2. (10 points) Circle the appropriate letter, T for true or F for false.

1. (T) (F) The use of high-strength materials in the design of ordinary reinforced concrete sections results in relatively reduced (increase) deflections under ordinary loading conditions.
2. (T) (F) Poor conveying of concrete results in honeycombing.
3. (T) F Compression steel may be added to increase the deflection of beams under ultimate conditions.
4. T (F) Even if the tension reinforcement does not yield under ultimate load, the beam may still provide the necessary warning at failure.
5. T (F) The ACI Code bases the design of members on the strength obtained from testing cubes at the age of 28 days.
6. (T) F The modulus of rupture measures the tensile strength of concrete.
7. (T) (F) Increasing the depth of a concrete section results in a relatively higher strength increase than increasing the width.
8. (T) F Air-entraining admixtures are used mainly to improve the freeze-thaw resistance of concrete.
9. (T) (F) Superplasticizers are used mainly to reduce the shrinkage of concrete.
10. (T) F Prestressed concrete construction allows using very high strength concrete and steel with reduced deflection and cracking problems.

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Name: Shaymaa Mohammed Al-Shanti. 1152202.

Part II – 6 pages

For all questions, use fc' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3). You must maintain four significant-digit accuracy, for example: 132.4, 13.24, 1.324, 0.1324 and so on.

Q3. (32 points) A simply supported beam extends over a simple span of 10 m. The beam has a width b = 50 cm.

1) To support an ultimate moment Mu = 100 t.m at a reinforcement ratio $\rho = 0.8\ \rho_{max(\varepsilon t=0.005)}$ the exact "d" required would be:
i) 70.79 cm ii) 71.99 cm iii) 58.39 cm (iv) 64.79 cm v) 65.99 cm vi) 57.39 cm
vii) none of the given answers

2) If the total depth h = 60 cm, the service DL = 12 t/m, and the service LL = 8 t/m, the design load w_u equals (you must add the self-weight):
i) 27.20 t/m ii) 27.92 t/m iii) 29.10 t/m iv) 28.80 t/m (v) 29.66 t/m vi) 28.06 t/m
vii) none of the given answers

3) If the total depth h = 60 cm and the beam is reinforced with 12 Φ 20 bars in tension, the effective depth "d" would be exactly:
i) 52.88 cm ii) 51.88 cm iii) 52.21 cm iv) 51.21 cm (v) 47.50 cm (vi) 47.88 cm
vii) none of the given answers

4) If the total depth h = 60 cm and the beam is reinforced with 12 Φ 30 bars in tension and12 Φ 20 bars in compression, the effective depth "d" would be exactly:
i) 52.88 cm ii) 51.88 cm iii) 52.21 cm iv) 51.21 cm (v) 47.50 cm vi) 47.88 cm
vii) none of the given answers

5) If the effective depth d = 68 cm and the beam is required to support an ultimate moment Mu = 100 t.m, the exact area of steel required would be:
i) 40.40 cm^2 (ii) 43.91 cm^2 iii) 42.42 cm^2 iv) 39.39 cm^2 v) 48.41 cm^2 vi) 47.42 cm^2
vii) none of the given answers

6) If the effective depth d_t = 68 cm, $As_{max(\varepsilon t=0.005)}$ is exactly:
i) 68.91 cm^2 ii) 60.60 cm^2 iii) 62.62 cm^2 iv) 59.39 cm^2 (v) 61.41 cm^2 vi) 57.42 cm^2
vii) none of the given answers

7) If the effective depth d_t = 68 cm, As_{min} is exactly:
i) 10.71 cm^2 ii) 11.71 cm^2 (iii) 11.33 cm^2 iv) 13.79 cm^2 v) 12.58 cm^2 vi) 14.42 cm^2
vii) none of the given answers

8) If the total depth h = 60 cm and the beam is reinforced with 7 Φ 20 bars, the ultimate load w_u that can be supported by the beam (including self-weight) is:
i) 3.33 t/m ii) 8.34 t/m iii) 6.28 t/m (iv) 5.28 t/m v) 3.70 t/m vi) 9.06 t/m
vii) none of the given answers

-16

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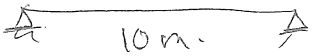
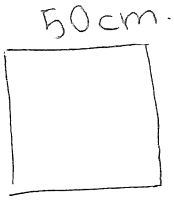




$M_u = 100\ t.m.$

$P = 0.8\ P_{max}$.

$P_{max} = 031875 \frac{f_c}{f_y} (B_1)$.

0.01806

$P = 0.9445$

$R_n = 0.003552$

$b(d)^2 = \frac{111.11 \times 100}{}$

$0.003552 = \frac{111.11 \times 100}{bd^2}$

$R_n =$

0.06068

$DL = 12 + 0.6 \times 0.5 \times 2.4$

12.72.

$1.4(DL) =$

$1.4(12.72) + 1.6(8)$

92.316

$q =$

$W_u = 1.4DL + 1.6LL + 1.4DL$

$\times 1.008$

$T = 92.316$

$d = 54$

$q = 7.7$

$91.66 = \frac{wL^2}{8}$

$6.5 \times 10 +$

7.4.

$\frac{(6.5 \times 10) + (2 \times 12)}{12}$

7.4

$q = 32.05$

$X = 37.7$

$6 \times 10 +$

6.75

$h = 60$

$12\phi 20$

$T = 37.68$

$= 158.3$

$q = \frac{T}{0.8 \times 0.28 \times T}$

$q = 13.38$

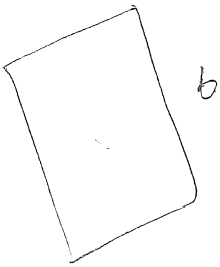
$X = 15.65$

$X = \frac{3}{8} d$

$d = \frac{}{8} X$

$As = 43.9$

d ?



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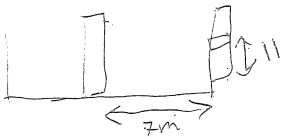
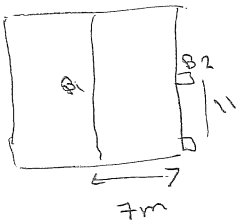


Q4. An interior simply supported T-section (note: positive moment) has bw = 50 cm. The slab has a thickness t = 20 cm. The beam drop below the slab = 65 cm (total beam depth = 85 cm). The center-to-center spacing of the beams = 7 m. The center-to-center spacing of the columns = 11 m. The columns are all 60 cm x 60 cm. Assume Φ 28 tension bars and Φ 10 stirrups are used. Determine:

a) (8 points) $As_{max(\varepsilon t=0.005)}$.



bw = 50 cm drop = 65 cm.

t = 20 cm

bf = 7m = 700 cm.

$b_E = 50 + 16(20) = 370$

$= 50 + \frac{640}{4} = 210$

310

= 700

~~$b_E = 210$~~

$b_E = 310$

As max for positive moment

$d = 85 - (4 + 1 + \frac{2.8}{2}) = 78.6$ cm.

$x = \frac{3}{8}(d) = \frac{3}{8}(78.6) = 29.475$ cm

$a = 0.85(29.475) = 25.054$ cm.

$a > t$

$25.054 > 20$ cm.

$C = 0.85 f'_c (b_E - b_w)(t) + 0.85 f'_c b_w (a)$

$= 0.85(0.28)(310 - 50)(20) + 0.85(0.28)(50)(25.054)$

$= 1237.6 + 298.143$

$C = 1535.7426\ t$

$As = \frac{C}{f_y} = 365.653\ cm^2$ (As max)

b) (3 points) As_{min}.

~~$x = \frac{3}{8}(d) = 29.475$ cm~~

$a = 25.054$

$C =$

$\frac{0.25\sqrt{f'_c}\,(b_w)(d)}{f_y}$? $\frac{1.4(b_w)(d)}{f_y}$

$12.37\ cm^2$? $13.1\ cm^2$

larger controls.

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c) (12 points) The exact reinforcement required to support an ultimate moment Mu = + 120 t.m. Perform all the necessary checks.

$$M_n = \frac{120}{0.9} = 133.33 \text{ t.m.}$$

if $a = t$

$C = 0.85(0.28)(310)(20)$

$C = 1475.6$ t

$$M_n = C\left(\frac{d - t/2}{100}\right) \Rightarrow 1012.26 \text{ t.m}$$

if $a < t$ it behaves as rectagular section.

$b = b_E = 310$ cm.

$d = 78.6$ cm.

$$R_n = \frac{133.33 \times 100}{310 \times (78.6)^2} = 0.006962$$

$$\rho_{req} = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2 \times m \times R_n}{f_s}}\right) = 0.00168$$

$$A_{s\,req} = \rho_{req}(b_E)d = 40.98 \text{ cm}^2$$

# of bars $= 6.65$

$\Rightarrow 7\phi 28$

$T = A_{s\,actual} f_y$

$= 43.08 \times 4.2$

$= 180.94$ t.

$$a = \frac{180.94}{0.85 \times 0.28 \times b_E} = 2.45 \text{ cm.}$$

$x = 2.88$ cm

Check

$$\epsilon_t = \left(\frac{78.6 - 2.45}{2.45}\right)$$

$0.09 > 0.005$

$\Rightarrow \phi = 0.9$.

$a < t$

$C = 0.85(0.28)(310)(2.45)$

$= 180.94$ t.

$$M_n = 180.94\left(\frac{78.6 - a/2}{100}\right) = 140.002$$

$\phi M_n > M_u$

$0.9(140.002)$ 120 t.m

$126.002 > 120$ ✓

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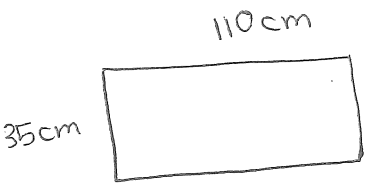
Q5. (30 points) A rectangular beam has b = 110 cm, and h = 35 cm. Determine the required reinforcement to support an ultimate moment, Mu = + 58 t.m. The reinforcement ratio used (actual) must be between 0.72 and 0.82 of the maximum. Use Φ 30 tension bars, and Φ 20 compression bars if needed. You must provide a check of the capacity and the reinforcement ratio.



$d = 35 - (4 + 1 + \frac{3}{2}) = 28.5$ cm.

$M_n = \frac{58}{0.9} = 64.44$ t.m

$R_n = \frac{64.44 \times 100}{110 \times (28.5)^2} = 0.0721$ t/cm^2

$d' = 1 + 4 + \frac{2}{2} = 6$

$\rho = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2 \times 17.65 \times 0.0721}{4.2}}\right)$

$= 0.0211$

$\frac{\rho_{req}}{\rho_{max}} = \frac{0.0211}{0.01806} > 0.82$

$\rho_{req} >> \rho_{max} \Rightarrow$ doubly reinforcement compression steel yeild.

$X = \frac{3}{8}(d) = 10.68$ cm

$a = 9.08$ cm.

$C_c = 0.85 f'_c \times b \times a$

$= 237.7$ t

$M_{nc} = C_c\left(\frac{d - a/2}{100}\right)$

$= 56.95$ t.m

$M_{ns} = M_{nreq} - M_{nc}$

$= 64.44 - 56.95 = 7.487$ t.m.

$C_{sreq} = \frac{M_{ns}}{d - d'} = \frac{7.487 \times 100}{28.5 - 6} = 33.276$ t.

$A_s' = \frac{33.276}{4.2 - 0.85 \times 0.28} = 8.39$ cm^2 $\Rightarrow$ 2.67 bars

3 Φ 20

$A_s = \frac{237.7 + 33.276}{4.2} = 64.5$ cm^2 $\Rightarrow$ 9.13 bars

10 Φ 30

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4 Φ20

$A_s = 12.56\,cm^2$

$C_s = 12.56(4.2 - 0.85 \times 0.28)$

$C_s = 49.76$

$$M_n = 55.93 + 49.76\left(\frac{28.5 - 6}{100}\right)$$

$55.93 + 11.196$

$M_n = 67.126$

ϕM_n

$60.4 > M_u = 58$

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10Φ30

$T = A_{actual} \times 4.2$

$70.69 \times 4.2 = 296.898$ t.

$C_s = A_s' (F_y - 0.85 F_c')$

$= 9.42 (4.2 - 0.85 \times 0.28)$

$C_s = 37.32$ t

$C_c = 26.18\, a$ $= 232.47$

$296.898 = 37.32 + 26.18 a$

$a = 8.88$ cm.

$x = 10.45$ cm

$x = \beta_1 a$.

$\epsilon_s' = \left(\frac{10.45 - 6}{10.45}\right) \times (0.003) = 0.00127 \leq 0.0021$

Compression steel not yeild.

$f_s' = \epsilon_s \times 2000$

$= \left(6 - \frac{636}{x}\right)$

$296.898 = 9.42 \left(\left(6 - \frac{36}{x}\right) - 0.85 \times 0.28\right) + 22.253x$

$296.898 = 56.52 - \frac{339.12}{x} - 2.24196 + 22.253x$

$242.62 =$

$M_n = 232.47 \left(\frac{28.5 - 8.88/2}{100}\right) + 37.32 \left(\frac{28.5 - 6}{100}\right)$

$M_n = 55.93 + 8.397$

$M_n = 64.327$

$M_u = 58$ t.m.

$\phi M_n \quad < 58$

$57.89 \simeq 58,$

add one bar.

turn the page.

$\epsilon_t =$

$\epsilon_t = 0.00518 < 0.005$

$\Rightarrow \phi = 0.9$

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96/100

Name: شريف عبد الرحيم Number 1131068

Birzeit University
Faculty of Engineering
Department of Civil Engineering
ENCE 335 Reinforced Concrete Design I

Mid-Term Exam Tuesday, November 14, 2017

Part I

Q1. (10 points) Write the exact section in the ACI Code that specifies the following:

18/78

1. The formula for determining Vs for shear reinforcement — 22.5.10.5.3
2. Concrete cover for beams not exposed to weather = 40 mm — 20.6.1.3.1
3. Critical section for shear in beams is located at a distance equal to "d" from the face of support — 9.4.3.2
4. As_{min} for T-sections with the flange in compression — 9.6.1.2.
5. Strength reduction factor ϕ for bending moment if ε_t is less than 0.005 — 21.2.2
6. Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003 — 22.2.2.1
7. Effective flange width b_E for interior T-beams — 6.3.2.1
8. Tensile strength of concrete shall be neglected in flexural and axial strength calculations — 22.2.2.2.
9. The value of Es for non-prestressed bars — 20.2.2.2
10. The upper limit for category 5 for shear strength of beams — 22.5.1.2.

Q2. (10 points) Circle the appropriate letter, T for true or F for false.

1. (T) F Flexural cracks are usually vertical.
2. (T) F Compression steel may be added to increase the deflection of beams under ultimate conditions.
3. T (F) If the compression reinforcement does not yield under ultimate load, the beam will not give a sufficient warning of imminent failure.

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4. T F — According to the ACI-Code, a strength test is the average of two or three cylinder tests, depending on cylinder size.

5. T F — When the shear capacity ϕVn diagram is closest to the factored shear Vu diagram, the least amount of shear reinforcement will be required.

6. T F — Prestressed concrete construction allows using very high strength concrete and steel with reduced deflection and cracking problems.

7. T F — If development length requirements are not satisfied, the steel bars will not reach yielding before structural failure.

8. T F — Under-reinforced sections are those that have less reinforcement than the balanced amount.

9. T F — The shear capacity of T-sections is based on the dimensions of the web without the flanges.

10. T F — Over-reinforced sections have more reinforcement than necessary to support the design moments and therefore are uneconomical..

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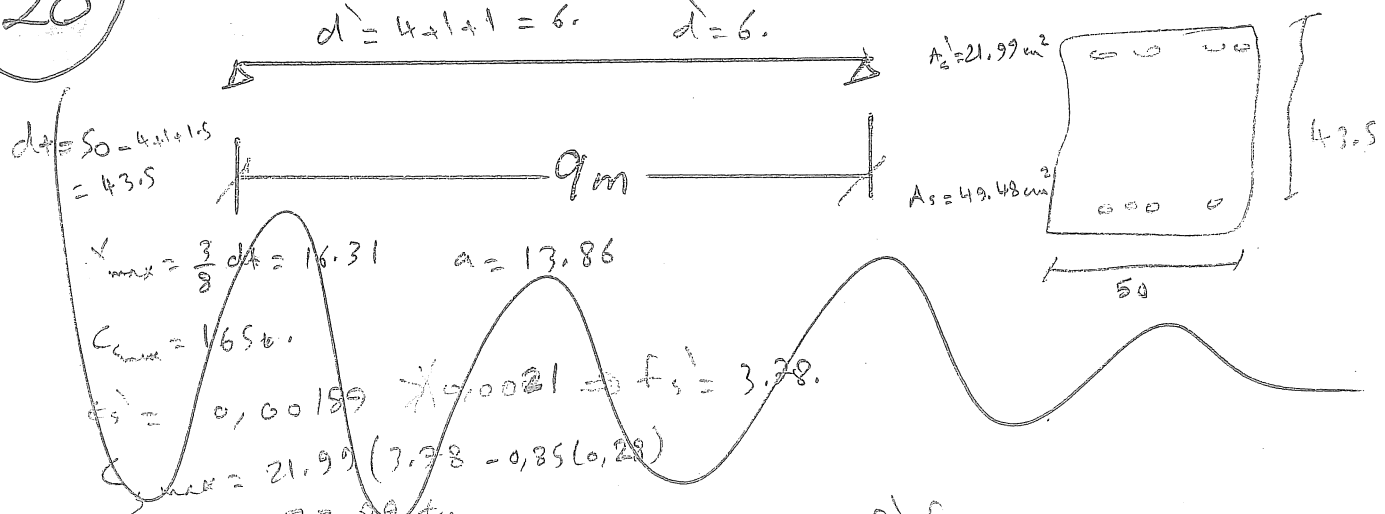
Name: شرف كبه الزايد

Part II 113068.

For all questions, use fc' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3). You must maintain four significant-digit-accuracy, for example: 132.4, 13.24, 1.324, and so on.

Q3. (30 points) A rectangular section has b = 50 cm, h = 50 cm, As' = 7 Φ 20, and As = 7 Φ 30. Assuming that the dead load is the self-weight only, determine the maximum service uniformly distributed live load that can be placed on the beam.

28



$d = 50 - 4+1+1.5 = 43.5$

$x_{max} = \frac{3}{8} d = 16.31$ $\quad a = 13.86$

$C_{c\,max} = 165\,t.$

$\epsilon_s' = 0.00189 > 0.0021 \Rightarrow f_s' = 3.78.$

$C_{s\,max} = 21.99(3.78 - 0.85(0.28)$

$= 77.28\,t.$

* Assumpe that the compression steel yeild $f_s' = f_y.$

$C_s = 21.99(4.2 - 0.85(0.28)) = 87.12\,t.$

$C_c = 10.12x$

$T = 207.8 \Rightarrow 207.82 = 10.12x + 87.12 \Rightarrow x = 11.93.$

$\epsilon_{s\,act}' = 0.00149 > 0.0021$

Assumption is wrong.

$f_s' = 6\left(\frac{x-6}{x}\right)$

$C_s = 21.99\left(6\left(\frac{x-6}{x}\right) - 0.85f_c\right) = 131.94\left(\frac{x-6}{x}\right)$

$207.8 = 131.94\left(\frac{x-6}{x}\right) + 10.12x.$

$207.8x = 131.94x - 791.64 + 10.12x^2$

$10.12x^2 - 207.8x + 131.94x - 791.64 = 0$

$10.12x^2 - 75.86x - 791.64 = 0$

$x = 13.35\,cm$

$C_s = 72.68\,t.$

$C_c = 135.10\,t.$

194.42

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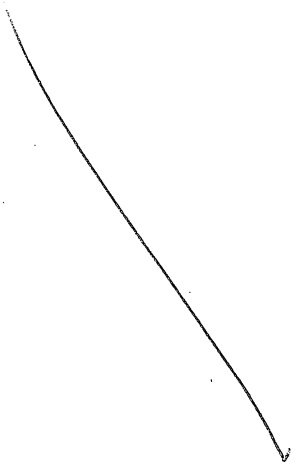

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$\epsilon_{t,act} = \left(\frac{43.35 - 18.35}{3.7}\right) 0.003$ $\Rightarrow \phi = 0.9$.

$0.00675 > 0.005$ ✓.

$M_n = 135.10 \left(\frac{43.5 - \frac{11.35}{2}}{100}\right) + 22.68\left(\frac{43.5 - 6}{100}\right)$

$= 51.10 + 27.25$

$M_n = 78.355$.

$\phi M_n = 70.52$.

S.w = D.L = $0.5 * 0.5 * 2.4 = 0.6$

D.L = 0,6.

$\phi M_n = \frac{wL^2}{8}$.

$70.52 = \frac{w*(9)^2}{8} \Rightarrow w = 6.96$ t/m.

$6.96 = 1.2 * D.L + 1.6 L.L$

$6.96 = 1.2(0.6) + 1.6\ L.L \Rightarrow L.L = 3.9$ t/m.

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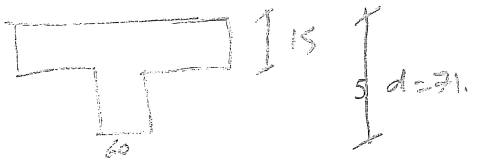

25

Q4. (25 points) For the layout shown, a 15-cm solid one-way slab is used with drop beams. All columns are 60 cm x 60 cm. All beams have b_w = 60 cm and h = 80 cm (15 cm within the slab + 65 cm drop). Assume d = dt = 71 cm in all calculations. The total factored loads for beam B1 are $(Wu)_{DL}$ = 7.2 t/m including the weight of the beam, and $(Wu)_{LL}$ = 4.8 t/m.

Wu = 7.2 + 4.8 = 12.

1) For Beam B1, b_E is:
i) 185 cm ii) 205 cm iii) 300 cm iv) 210 cm v) 170 cm vi) none of the given answers

60 + 16×15 = 300
= 600
= 170

For Beam B1, and assuming b_E = 200 cm,

2) Asmax $_{\varepsilon t=0.005}$ for positive moment is:
i) 256.5 cm^2 ii) 196.0 cm^2 iii) 280.5 cm^2 iv) 211.9 cm^2 v) 76.95 cm^2 vi) none of the given answers

110.95 195.99.

3) Asmax $_{\varepsilon t=0.005}$ for negative moment is:
i) 256.5 cm^2 ii) 196.0 cm^2 iii) 280.5 cm^2 iv) 211.9 cm^2 v) 76.95 cm^2 vi) none of the given answers

4) As min for positive moment is:
i) 26.84 cm^2 ii) 13.42 cm^2 iii) 14.20 cm^2 iv) 28.40 cm^2 v) 142.0 cm^2 vi) none of the given answers

5) As min for negative moment is:
i) 26.84 cm^2 ii) 13.42 cm^2 iii) 14.20 cm^2 iv) 28.40 cm^2 v) 142.0 cm^2 vi) none of the given answers

6) The exact amount of reinforcement $As_{required}$ calculated for a negative moment Mu = - 150 t.m is:
i) 55.49 cm^2 ii) 67.99 cm^2 iii) 75.74 cm^2 iv) 64.49 cm^2 v) 57.99 cm^2 vi) none of the given answers

7) The exact amount of reinforcement $As_{required}$ calculated for a positive moment Mu = + 150 t.m is:
i) 55.49 cm^2 ii) 67.99 cm^2 iii) 75.74 cm^2 iv) 64.49 cm^2 v) 57.99 cm^2 vi) none of the given answers

8) If a = t, Mn positive = :
i) 136.0 t.m ii) 405.6 t.m iii) 453.4 t.m iv) 444.4 t.m v) 162.0 t.m vi) none of the given answers

9) The factored self-weight of the drop underneath the slab is:
i) 1.123 t/m ii) 0.936 t/m iii) 1.152 t/m iv) 1.382 t/m v) 1.936 t/m vi) none of the given answers

10) For Beam B2, b_E is:
i) 66.67 cm ii) 330.0 cm iii) 96.67 cm iv) 150.0 cm v) 300.0 cm vi) none of the given answers

323.17.

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25

Q5. (25 points) A rectangular beam is used over a simple span of 6 m measured center to center of columns. The columns are 60 cm x 60 cm. The total factored loads for the beam are $(Wu)_{DL}$ = 7.2 t/m including the weight of the beam, and $(Wu)_{LL}$ = 4.8 t/m.

1) Assume d = dt = 71 cm. At the critical section, Vu is:
i) 25.09 t ii) 21.49 t iii) 23.88 t iv) 32.4 t v) 28.33 t vi) none of the given answers

2) If the required reinforcement is to be exactly 80% of the maximum for εt = 0.005, the exact width "b" required to support Mu = 150 t.m would be (assume d = dt = 71 cm):
i) 62.44 cm ii) 66.47 cm iii) 72.43 cm iv) 52.62 cm v) 96.47 cm vi) none of the given answers

3) If the required reinforcement is to be exactly 80% of the maximum for εt = 0.005, the exact effective depth "d" required to support Mu = 150 t.m would be (assume b = 60 cm, and d = dt):
i) 62.44 cm ii) 66.47 cm iii) 72.43 cm iv) 52.62 cm v) 96.47 cm vi) none of the given answers

4) If the beam has b = 60 cm and d = 71 cm, and double Φ 10 stirrups ($Av = 3.14\ cm^2$), the exact stirrup spacing required to support Vu = 80 t would be (you must check minimum requirements before choosing an answer):
i) 10.70 cm ii) 35.50 cm iii) 8.20 cm iv) 13.70 cm v) 9.85 cm vi) none of the given answers

5) If the beam has b = 60 cm and d = 71 cm, and double Φ 10 stirrups, the exact stirrup spacing required to support Vu = 100 t would be (you must check minimum requirements before choosing an answer):
i) 10.70 cm ii) 35.50 cm iii) 8.20 cm iv) 13.70 cm v) 9.85 cm vi) none of the given answers

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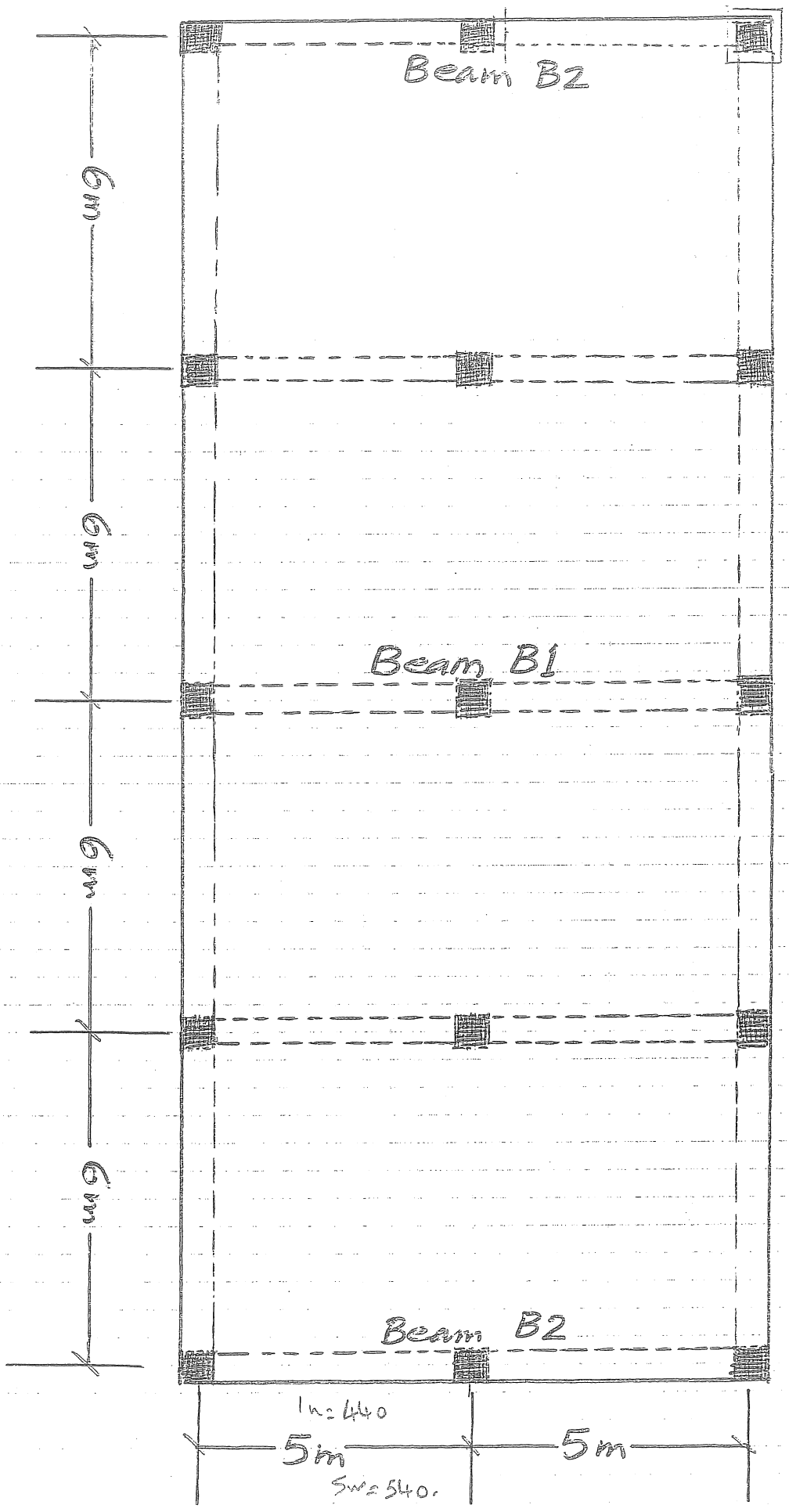

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Name: نبيل ابو غنايمة Number 1138124

7.7 / 100

Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335 Reinforced Concrete Design I

Mid-Term Exam **Tuesday, April 18, 2017**

32

Part I – 2 pages

Q5. (20 points) Circle the appropriate letter, T for true or F for false.

1. (T) F The use of high-strength materials in ordinary reinforced concrete results in large deflections under ordinary loading conditions.

2. T (F) If the compression reinforcement does not yield under ultimate load, the beam will not give sufficient warning of imminent failure.

3. (T) (F) The ACI Code bases the design of members on the strength obtained from testing cylinders, and not cubes..

4. T (F) The modulus of rupture measures the stiffness of concrete.

5. (T) F Creep is the property of concrete by which it continues to deform with time under sustained loads.

6. (T) F The main cause of shrinkage is the loss of water as the concrete dries and hardens.

7. T (F) In the working stress method, stresses resulting from factored loads and computed by mechanics of elastic members should not exceed allowable values.

8. (T) F If drop beams can be used, slabs (ribbed or solid) must be used along the short direction.

9. T (F) Properly designed sections fail in shear before flexure.

10. (T) F If drop beams may not be used such as for architectural reasons, one-way ribbed slabs, rather than solid slabs, must be used.

11. T (F) Shear cracks are usually inclined at 45 degrees and occur near the midspan of beams.

12. (T) (F) The design strength of concrete is reached at 28 days.

13. T (F) Under-reinforced sections do not have sufficient reinforcement to support the design moments.

14. T (F) Over-reinforced sections have more reinforcement than necessary to support the design moments and therefore are un-economical..

15. (T) F A tension-controlled section will exhibit a ductile failure mode with visible flexural cracks and deflection.

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16. (T) F The ACI Code requires minimum shear reinforcement for beams even if Vu does not exceed ϕVc.

17. (T) F Beams can support some additional moment even after the tension steel yields.

18. (T) F Cylindrical tanks are often pre-stressed circumferentially.

19. (T) F Reductions are often permitted in live loads for members supporting large areas.

20. (T) (F) The ACI Code requires double stirrups for beams with a width of 41 to 80 cm.

Q2. (15 points) Write the exact section in the ACI Code that specifies the following:

1. Strength reduction factor ϕ for shear = 0.75 — 21.2.1 b
2. Minimum thickness of ribbed one-way slabs — 9.3.1.1
3. Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003 — 22.2.2.1
4. As_{min} for one-way solid slabs — 7.6.1.1
5. Effective flange width b_E for interior T-beams — 6.3.2.1
6. Tensile strength of concrete shall be neglected in flexural and axial strength calculations — 22.2.2.2
7. ε_t for beams shall be at least 0.004 — ~~9~~ 9.3.3.1
8. Critical section for shear in beams is located at a distance equal to d from the face of support — 9.4.3.2
9. The value of β_1 for determining a of the Whitney block — 22.2.2.4.3
10. The upper limit for category 5 for shear strength of beams — 22.5.1.2
11. The formula for determining Vs for shear reinforcement — 22.5.10.5.3
12. The formula for determining the shear strength Vc of non-prestressed members without axial force — 22.5.5.1
13. The value of Es for non-prestressed bars — 20.2.2.2
14. Concrete cover for beams not exposed to weather = 40 mm — 20.6.1.3.1
15. Formula for determining Ec for normal-weight concrete — 19.2.2.1

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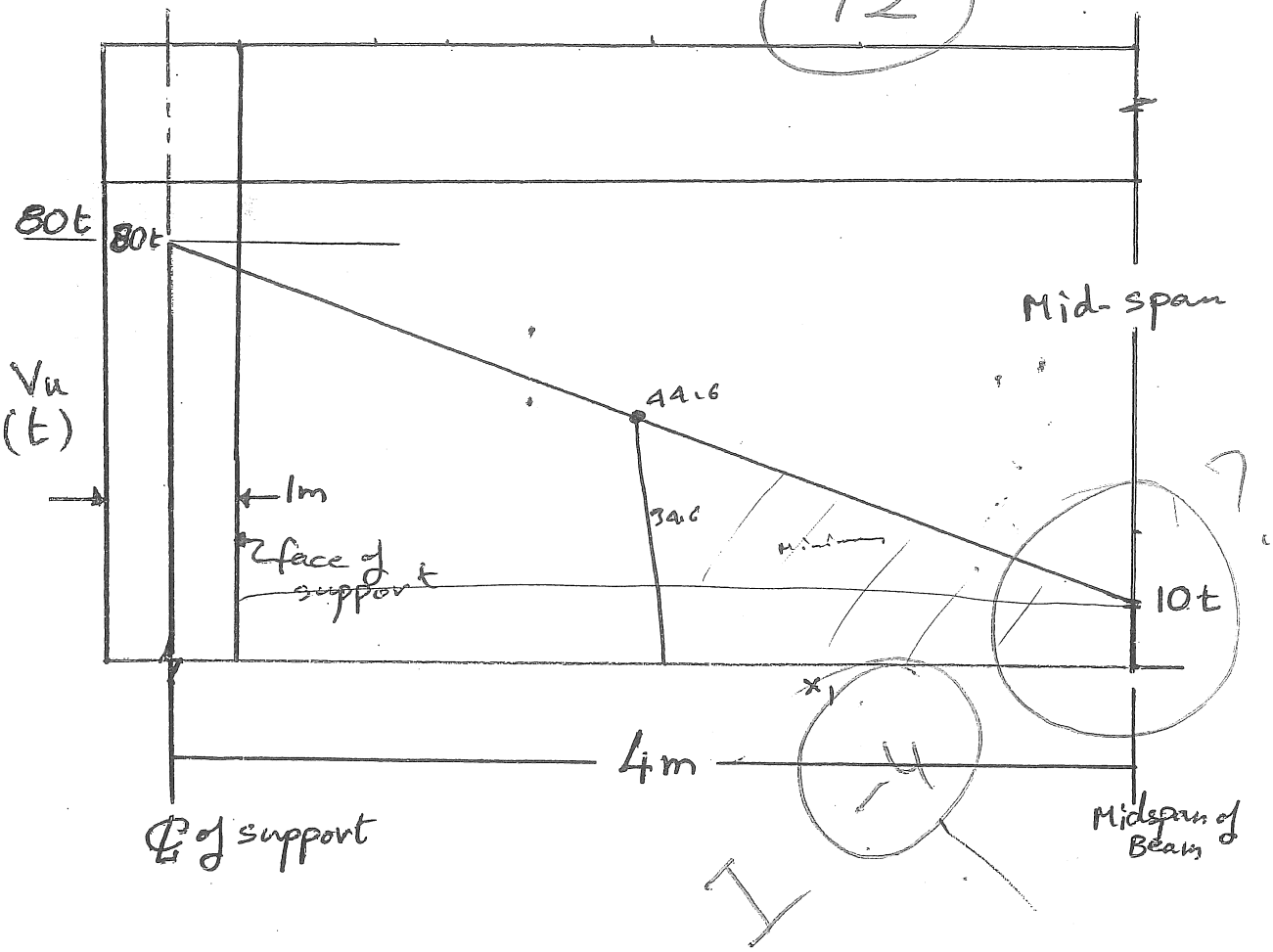
Name: نسل ابو غياضة 43

Part II– 5 pages

For all questions, use fc' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3).

Q3. (25 points) The shear envelope for half the span of a simply supported beam is shown. The beam has b = 60 cm and d = 73 cm. Design the beam for shear.

12



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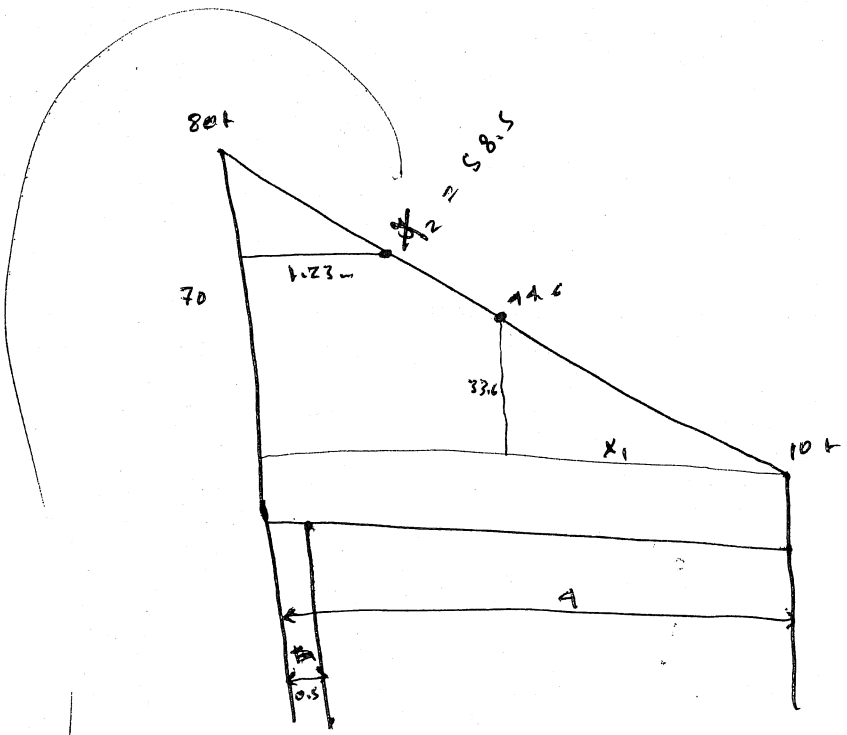

$\frac{70}{4} = \frac{33.6}{X_1}$

$X_1 = 1.92 m$

Minimum shear

$\frac{70}{4} = \frac{X}{2.77}$

$X_2 = 48.5 t$

$X_2 = 48.5 + 10$

$= 58.5 t$

Category V

$\frac{70}{4} = \frac{y}{1.23}$

$y = 21.52 t$

$X_2 = 21.52 + 10 = 31.52 t$

So Category V

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Name: محمد يوسف كفاية Number 1130190

89/100

25

Birzeit University
Faculty of Engineering
Department of Civil Engineering
ENCE 335 Reinforced Concrete Design I

Mid-Term Exam **Tuesday, August 1, 2017**

Part I

Q1. (15 points) Write the exact section in the ACI Code that specifies the following:

1. Formula for determining fr for concrete — 19.2.3.1
2. The value of Es for non-prestressed bars — 20.2.2.2
3. Concrete cover for beams not exposed to weather = 40 mm — T. 20.6.1.3.1
4. Overload factor for live load = 1.6 — T. 5.3.1
5. * Critical section for shear in beams is located at a distance equal to "d" from the face of support — 9.4.3.2
6. * The upper limit for category 5 for shear strength of beams —
7. Strength reduction factor ϕ for bending moment if ε_t is less than 0.005 — T. 21.2.2
8. As_{min} for T-sections with the flange in compression — 9.6.1.2
9. * Location of the critical section for determining Vu — 9.4.3.2
10. Maximum strain at the extreme concrete compression fiber shall be assumed equal to 0.003 — 22.2.2.1
11. Strength reduction factor ϕ for shear = 0.75 — T. 21.2.1
12. Tensile strength of concrete shall be neglected in flexural and axial strength calculations — 22.2.2.2
13. ε_t for beams shall be at least 0.004 — 9.3.3.1
14. The value of β_1 for determining "a" of the Whitney block — T. 22.2.2.4.3
15. The formula for determining the shear strength Vc of non-prestressed members without axial force — 22.5.5.1

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Q2. (15 points) Circle the appropriate letter, T for true or F for false.

1. T (F) Shear cracks usually occur near the midspan of beams.
2. (T) F Flexural cracks are usually vertical.
3. (T) F Compression steel may be added to increase the deflection of beams under ultimate conditions.
4. (T) (F) Gypsum must be added to the clinker to make portland cement.
5. T (F) Lime is a hydraulic cement.
6. (T) F Concrete and steel have similar coefficients of thermal expansion.
7. T (F) Paste is made with cement, water, and sand.
8. T (F) C_3A and C_4AF are responsible for the concrete strength gain.
9. (T) F Prestressed concrete construction allows using very high strength concrete and steel with reduced deflection and cracking problems.
10. (T) (F) If development length requirements are not satisfied, the steel bars will not reach yielding before structural failure.
11. (T) F Under-reinforced sections are those that have less reinforcement than the balanced amount.
12. T (F) Air-entraining admixtures are used to provide resistance to steel corrosion.
13. (T) (F) The shear capacity of T-sections is based on the dimensions of the web without the flanges.
14. T (F) Over-reinforced sections have more reinforcement than necessary to support the design moments and therefore are uneconomical.
15. T (F) Placing is the process of compacting concrete.

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Name: 1130490 محمد يوسف كنابة

Part II

For all questions, use f_c' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3).
You must maintain four significant-digit-accuracy, for example: 132.4, 13.24, 1.324, and so on.

Q3. (30 points) For the layout shown, a 20-cm solid one-way slab is used with drop beams. All beams have b = 60 cm and total h = 90 cm (20 cm + 70 cm drop, and assume d = dt = 81 cm in all calculations). All columns are 70 cm x 70 cm. The total factored loads are $(Wu)_{DL}$ = 1.2 t/m^2 (not including the weight of the beam drop below the slab, and $(Wu)_{LL}$ = 0.8 t/m^2. To determine the beam loads, use the tributary area. However, you **must add** the weight of the drop for the beam.

For Beam B1,

1) The total factored distributed load per meter is:
i) 3.93 t/m ii) 2.72 t/m iii) 12.00 t/m iv) 2.21 t/m v) 13.21 t/m vi) none of the given answers

2) b_E is:
i) 380 cm ii) 167.5 cm iii) 600 cm iv) 500 cm v) 192.5 cm vi) none of the given answers

For Beam B1, and assuming b_E = 230 cm,

3) Asmax $_{\varepsilon t=0.005}$ for positive moment is:
i) 321.9 cm^2 ii) 83.97 cm^2 iii) 87.78 cm^2 iv) 211.9 cm^2 v) 280.5 cm^2 vi) none of the given answers

4) Asmax $_{\varepsilon t=0.005}$ for negative moment is:
i) 321.9 cm^2 ii) 83.97 cm^2 iii) 87.78 cm^2 iv) 211.9 cm^2 v) 280.5 cm^2 vi) none of the given answers

5) As min for positive moment is:
i) 16.20 cm^2 ii) 32.40 cm^2 iii) 15.31 cm^2 iv) 30.62 cm^2 v) 162.0 cm^2 vi) none of the given answers

6) As min for negative moment is:
i) 16.20 cm^2 ii) 32.40 cm^2 iii) 15.31 cm^2 iv) 30.62 cm^2 v) 162.0 cm^2 vi) none of the given answers

7) The exact amount of reinforcement $As_{required}$ calculated for a negative moment Mu = - 200 t.m is:
i) 67.48 cm^2 ii) 75.74 cm^2 iii) 162.0 cm^2 iv) 30.62 cm^2 v) 37.87 cm^2 vi) none of the given answers

8) The exact amount of reinforcement $As_{required}$ calculated for a positive moment Mu = + 200 t.m is:
i) 67.48 cm^2 ii) 75.74 cm^2 iii) 162.0 cm^2 iv) 30.62 cm^2 v) 37.87 cm^2 vi) none of the given answers

9) If a = t, Mn = :
i) 222.2 t.m ii) 405.6 t.m iii) 777.3 t.m iv) 202.8 t.m v) 162.0 t.m vi) none of the given answers

For Beam B2,

10) b_E = :
i) 95.83 cm ii) 330.0 cm iii) 280.0 cm iv) 180.0 cm v) 104.2 cm vi) none of the given answers

0.01473

0.00362

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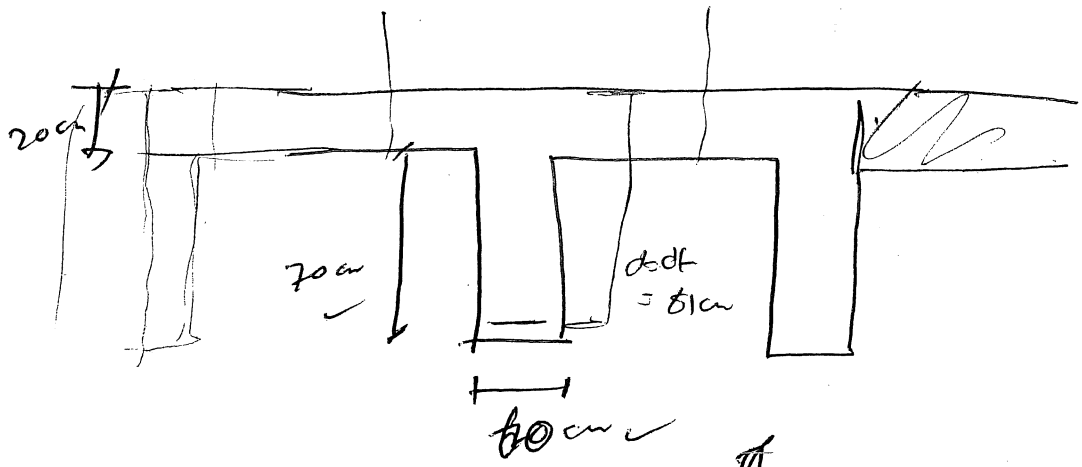

W_u D.L =

$= 1.2 \times 10 + 1.2 \times 1.2$

$= 1.008$

$= 13.21$

S.W. = 0.7×2.4

drop

$= 1.008$ t/m

$\therefore W_u = 14.01$

$b_F \leq 60 + 16 \times 20 = 340$

$\leq 60 + \frac{930}{4} = 167.5$

≤ 500

$q_{mc} = 25.82$

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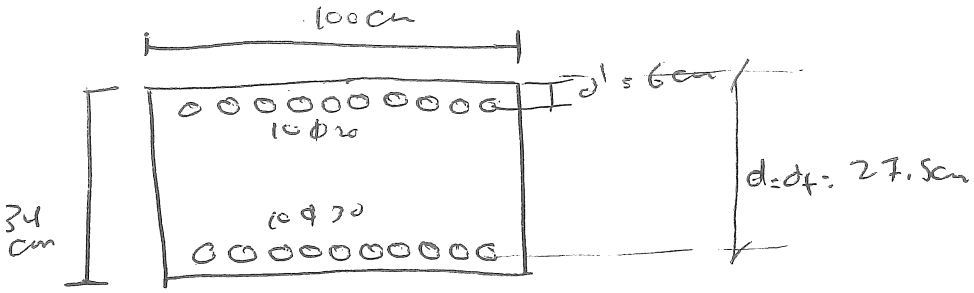
20

Q4. (20 points) A rectangular section has b = 100 cm, h = 34 cm, As' = 10 Φ 20, and As = 10 Φ 30. Determine ϕMn.



$A_s' = 10\phi 20 = 31.4\ cm^2$

$A_s = 10\phi 30 = 70.7\ cm^2$

assume compressed steel yield

$C_c = 0.85 \times 0.28 \times 100 \times 0.85x = 20.23x$

$C_s = 31.4(4.2 - 0.85(0.28)) = 124.41\ t$

$T = 70.7 \times 4.2 = 296.9\ t$

$T = C_c + C_s \Rightarrow 296.9 = 20.23x + 124.41 \rightarrow x = 8.53\ cm$

check $\epsilon_s' = \frac{x - d'}{x} 0.003$

$= 0.00089 < \epsilon_y$ (0.00

∴ not yield

$f_s' = \epsilon_s' E_s$

$= \frac{6(x-6)}{x}$

$C_c = 20.23x$

$C_s = 31.4\left(\frac{6(x-6)}{x} - 0.85 \times 0.28\right)$

$C_s = 188.4 - \frac{1130.4}{x} - 7.473$

$296.9 = 20.23x + 188.4 - 7.473 - \frac{1130.4}{x}$

$296.9 - 180.9 = \frac{20.23x^2}{x} - \frac{1130.4}{x}$

$116x = 20.23x^2 - 1130.4$

$\therefore 20.23x^2 - 116x - 1130.4 = 0$

$\therefore x = 10.87\ cm$

check:

$\epsilon_s' = 0.00134$

∴ not yield

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at $x = 10.87$ cm $\rightarrow a = 0.85 \times 10.87$

$= 9.24$ cm

$\therefore$ ~~T_2~~ $= C_c = 219.9$ t

$C_s = 76.93$ t

$\therefore M_u = 219.9\left(\frac{27.5 - \frac{9.24}{2}}{100}\right) + 76.93\left(\frac{27.5-6}{100}\right)$

$= 66.85$ t.m

for $\phi \Rightarrow \varepsilon_t = \frac{d_t - x}{x}(0.003) = 0.00459 < 0.005$

$\therefore \phi = 0.9 - \left(\left(\frac{0.005 - 0.00459}{0.005 - 0.002}\right) \times 0.25\right)$

$= 0.8658$

$\therefore \phi M_u = 57.88$ t.m

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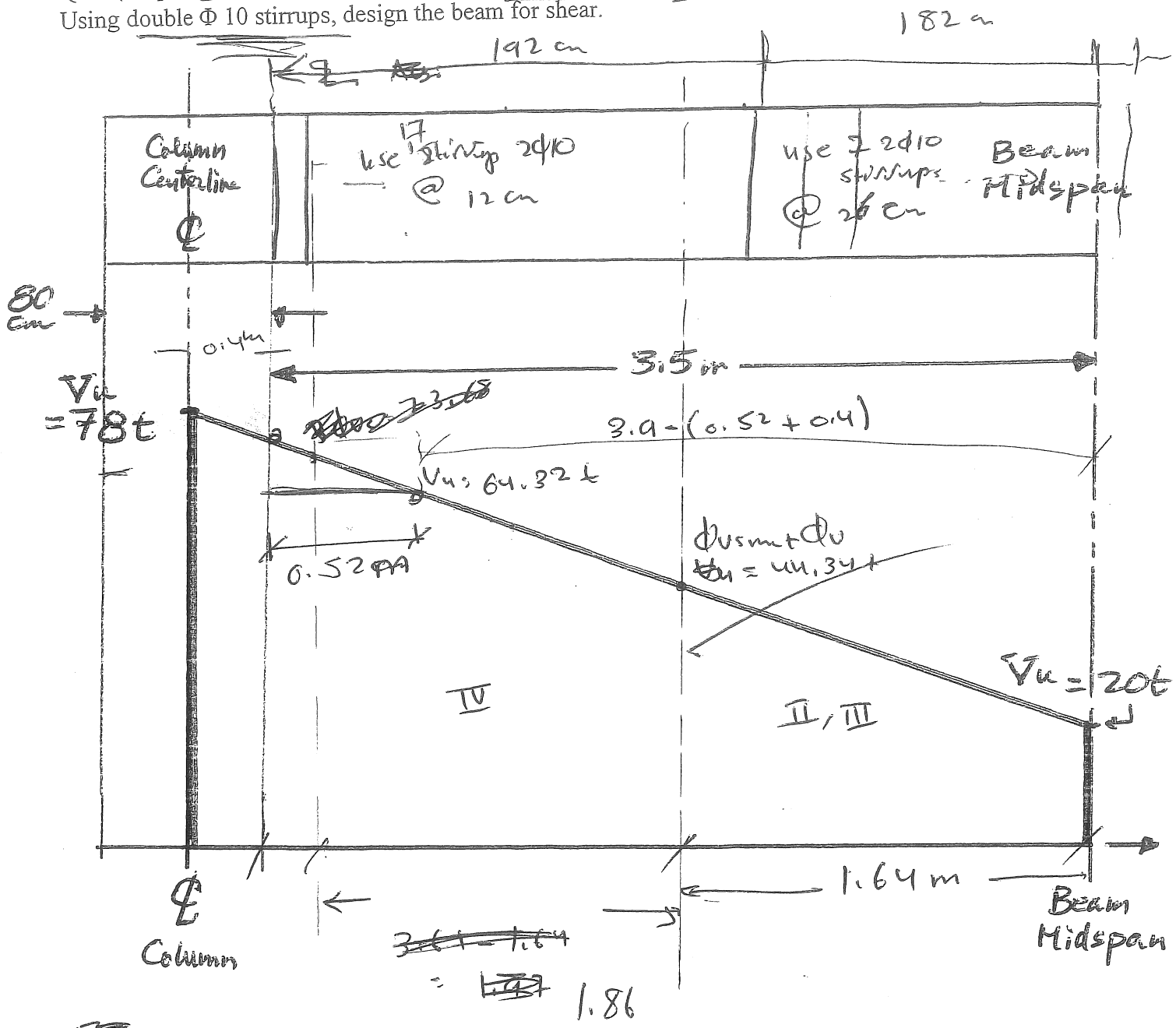
20

Q5. (20 points) A rectangular section has b = 70 cm, and d = 52 cm. The shear envelope is provided. Using double Φ 10 stirrups, design the beam for shear.



∴ For Vu at critical section

$$\Rightarrow \frac{78-20}{3.9} = \frac{V_u - 20}{2.98} \Rightarrow V_u = 64.32\ t$$

* ΦVc = 24.56 t

$\frac{\Phi V_c}{2}$ = 12.28 t

3 d Vc = 73.68 before critical sect no stirrups

② for sect II, III :-

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② for cut (II, III)

$A_v = 4 \times \frac{\pi}{4}(1)^2 = 3.14\ cm^2$

$S_{max} \leq \frac{3.14 \times 4200}{0.062 \times \sqrt{28} \times 70} = 57.43\ cm$

$\leq \frac{3.14 \times 4200}{0.35 \times 70} = 53.83\ cm$

$d/2 = \frac{52}{2} = 26\ cm$ → the smallest

60 cm

use stirrups 2ϕ10 @ 26 cm

$\phi V_{s\,min} = \frac{0.75 \times 3.14 \times 4.2 \times 52}{26} = 19.76\ t$

$\phi_c + \phi V_{s\,min} = 44.34\ t$

$\frac{28 - 20}{3.9} = \frac{44.34 - 20}{x}$ → $x = 14.64\ cm$

③ for cut IV :-

$\phi V_{s\,req} = 64.32 - 24.56 = 39.76\ t$

$S_{req} = \frac{0.75 \times 3.14 \times 4.2 \times 52}{39.76} = 12.91\ cm$

∴ use stirrups 2ϕ10 @ 12 cm

---

for IV : $\frac{28 - 20}{3.9} = \frac{73.68 - 20}{x}$ → $x = 36.1\ cm$

not need

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For IV : ~~186~~

$\frac{186}{12}$; 15.5 → use 16 spaces
17 stirrups

Distance new = 16 X 12 = 192 cm

For (II, III) : ~~158~~

$\frac{158}{26}$; 6.1 → use 7 spaces
7 stirrups

Distance new = 182 ~

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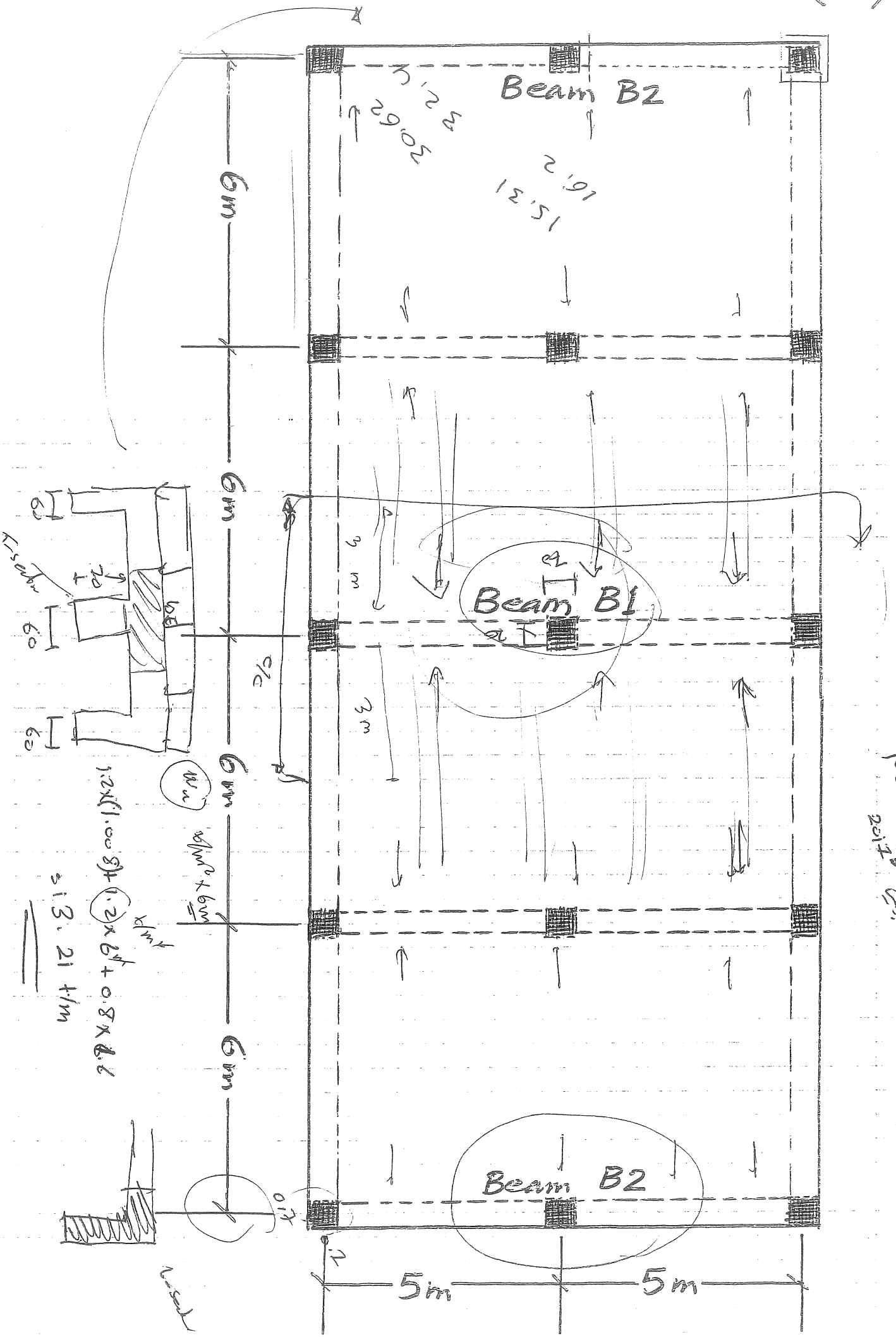
(3b)


Beam B2
Beam B1
Beam B2
5m
5m
6m
6m
6

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Total number of pages = 5

Name: Key

Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335 Reinforced Concrete Design I

Mid-Term Exam, Part I **Monday, July 18, 2016**

Q1. (4 points each) Answer very briefly. Use sketches where appropriate.

1. What would be the problem for beams if very high strength steel and concrete are used?

2. If the tension steel in a properly designed flexural member reaches the yielding point, will it be able to support any additional load? Explain.

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3. Write the chemical equations that explain the production and use of lime.

4. Why is portland cement concrete a much better construction material than lime mortars?

5. Reduction in design live loads may be permitted for members supporting large areas.

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Q3. (30 points) Circle the appropriate letter, T for true or F for false. If the answer is false, you must explain why.

1. (T) F The strength reduction factors ϕ are given different values depending on the accuracy with which various strengths can be calculated.

2. T (F) Over-reinforced sections should not be used because they contain more reinforcement than is required to carry the load.

More than the balanced condition — Compression failure

3. T (F) Reinforced concrete may not be used for spans exceeding 25 meters because of the high self-weight of concrete.

Prestressed Concrete — folded plate construction, —

4. T (F) The strain in an embedded reinforcing bar is always assumed higher than that of the surrounding concrete.

the same

5. (T) F Prestressed concrete construction allows using very high strength concrete and steel with reduced deflection and cracking problems.

6. T (F) Cross-sections that were plane prior to loading do not continue to be plane in the member under load because of the curved shape of the stress-strain diagram of concrete.

remain plane — basic mechanics assumption

7. T (F) The coefficients of thermal expansion of steel and concrete differ significantly. This is an important property of reinforced concrete that must be considered in the design process.

very similar coefficients of thermal expansion

8. (T) F In the service load design method, stresses resulting from service loads and computed by mechanics of elastic members should not exceed allowable values.

9. T (F) Excessive deflection and cracking are considered safety and strength problems.

Serviceability problems

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Q2. (10 points each) Explain how structural safety is ensured by the ACI Code. Use normal distributions and sketches as appropriate.

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10. T (F) Under-reinforced sections have less reinforcement than the amount required to carry the load.

Less than the balanced condition -

11. T (F) A tension-controlled section will exhibit excessive cracking on the compression side of the member.

on the tension side

12 (T) F Superplasticizers are used mainly to improve workability and are needed for producing high-strength concrete.

13. T (F) Air-entraining admixtures are used to provide resistance to steel corrosion.

Mainly to protect concrete against freezing and thawing cycles

14 (T) F Heavyweight concrete is used for shielding against gamma and X-radiation.

15 (T) F Concrete gains about 70% of the specified value of fc' at the end of the first week after placing.

16. (T) F Fly ash, when mixed with water, produces calcium silicate hydrate similar to that of hydrated portland cement.

17. (T) F Creep is the slow deformation of a material over a long period of time at constant stress.

18. (T) F Fatigue is an important property of a material if it is subjected to a fluctuating load.

19 (T) F Shrinkage results from the evaporation of free water not used in the hydration process.

20. T (F) The main problem of mass concrete, as is usually used for the construction of dams, is the presence of large amounts of water which will result in the corrosion and deterioration of reinforcing steel.

large amounts of heat liberated - thermal cracking

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Total number of pages = 5

Name:_____

Birzeit University
Faculty of Engineering
Department of Civil Engineering

ENCE 335 Reinforced Concrete Design I

Mid-Term Exam, Part II **Monday, July 25, 2016**

For all questions, use fc' = 28 MPa, fy = 420 MPa, and $\gamma_{concrete}$ = 24 kN/m^3 (2.4 t/m^3).

Q1. (15 points) An isolated T-beam has b_w = 80 cm, b_f = 240 cm, t_f = 40 cm, and is used over a simple span of 13 m. The columns are 40 cm x 40 cm. The total depth = 150 cm (the drop = 110 cm). Determine the reinforcement required to support an ultimate moment Mu = 600 t.m. Use Φ 35 tension bars. Select bars and provide appropriate sketches. Check ϕMn and all relevant ACI requirements including maximum and minimum limits.

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Q1 (15 points)

$t_f \geq 0.5 b_w$ $\quad 40cm \geq 0.5(80) = 40cm$ ✓

$b_E \leq 4 b_w = 4(80) = 320cm$ $\quad \therefore b_E = 240cm$

$M_u = 600$ t.m

$M_{nreq} = \frac{600}{0.9} = 666.7$ t.m (assume $a < t$)

$d_t = 150 - (4 + 1 + \frac{6.75}{2} + 3.5/2) = 143.25$ cm

$R_{n\,req} = \frac{66670}{(240)(143.25)^2} = 0.01354$ t/cm^2

$m = \frac{420}{0.85(28)} = 17.65$

$\rho_{req} = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2(17.65)(0.01354)}{4.2}}\right) = 0.003321$

$A_{sreq} = 0.003321(240)(143.25) = 114.18 cm^2$

11.9 bars $\longrightarrow$ 12 ϕ 35 bars

($A_{s\,actual} = 12 \times 9.62 = 115.44 cm^2$) (two layers : 10 + 2)

$\bar{y} = \frac{10 \times 6.75 + 2 \times 12.75}{12} = 7.75$

$\therefore d_{actual} = 150 - 7.75 = 142.25$ cm

Check Capacity :

$T = (12 \times 9.62)(4.2) = 484.8$ t

$a = \frac{484.8}{(0.85)(0.28)(240)} = 8.49 cm < t = 40cm$

($z = 9.99$ cm, $\epsilon_t = \frac{143.25 - 9.99}{9.99}(0.003) = 0.0400 > 0.005$)

which serves as a check of the maximum limit

$M_n = 484.8\left(\frac{142.25 - 8.49/2}{100}\right) = 669$ t.m

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$\phi Mn = 0.9(669) = 602.1$ t.m

$> Mu = 600$ t.m

$$As_{min} = \frac{0.25\sqrt{28}}{420}(80)(143.25) \geq \frac{1.4}{420}(80)(143.25)$$

$$= 36.10\ cm^2 \geq \underline{\underline{38.2\ cm^2}}$$

minimum limit

Alternatively:

if $a = t$, $C = 0.85(0.28)(240)(40) = 2284.8$ t

$$Mn = 2284.8\left(\frac{143.25 - 40/2}{100}\right) = 2816\ t.m > 666.7\ t.m$$

i.e. $a < t$

$$x_{max}\ (\epsilon_t = 0.005) = \frac{3}{8}(143.25) = 53.72\ cm$$

$$a_{max}\ (\epsilon_t = 0.005) = 0.85(53.72) = 45.66\ cm$$

$$C_{max} = 0.85(0.28)(240 - 80)(40) + 0.85(0.28)(80)(45.66)$$

$$= 1523.2 + 869.4 = 2392.6\ t$$

$$As_{max}\ (\epsilon_t = 0.005) = \frac{2392.6}{4.2} = 569.7\ cm^2$$

$As_{actual} = 115.4\ cm^2 < As_{max}\ (\epsilon_t = 0.005) = 569.7\ cm^2$

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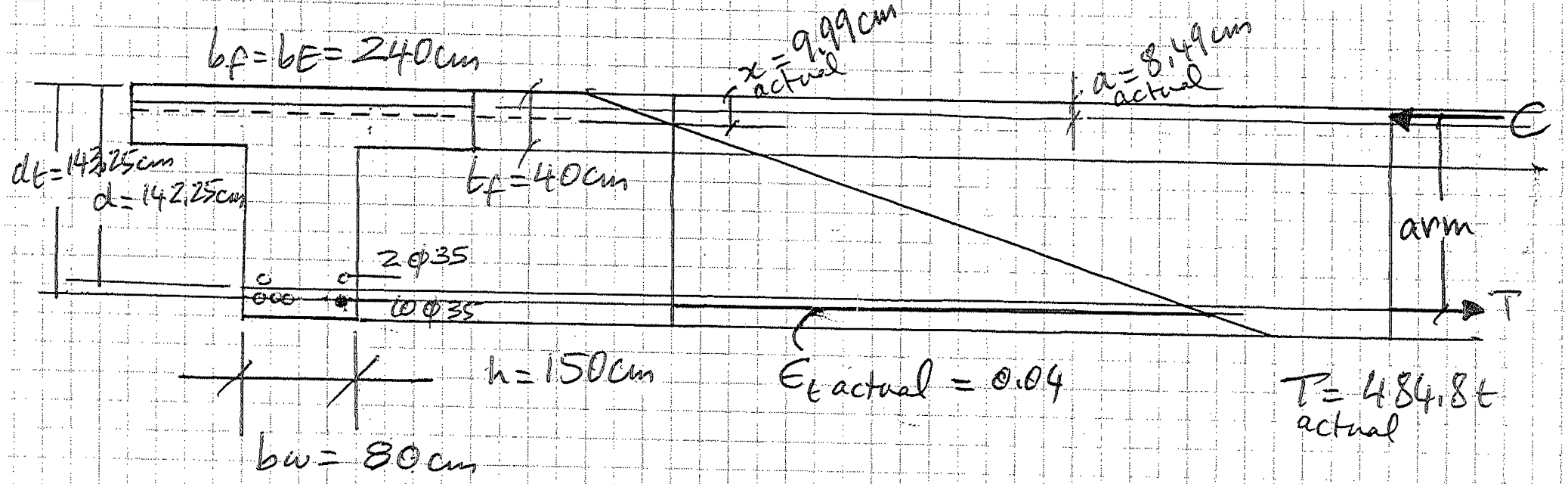

Q2. (25 points) A beam has b = 100 cm and h = 40 cm. Design the beam to support an ultimate moment Mu = 60 t.m that includes self-weight. Use Φ30 bars for tension, and for compression if needed. Excessive deflection would be a problem and must be controlled. Provide a final sketch of the section. Do not check ϕMn or the maximum and minimum limits.

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Q2 (25 points) $b = 100\,cm$, $h = 40\,cm$, ϕ 30 bars (4)

$M_u = 60\,t.m$, $d_t = 33.5\,cm$, $m = 17.65$

$$M_{n\,req} = \frac{60}{0.9} = 66.7\,t.m$$

Excessive deflection would be a problem!

$$\rho_{\substack{max \\ \epsilon_t = 0.005}} = 0.31875\left(\frac{28}{420}\right)(0.85) = 0.01806$$

$$R_{n\,req} = \frac{6670}{(100)(33.5)^2} = 0.05943\,t/cm^2$$

$$\rho_{req} = \frac{1}{17.65}\left(1 - \sqrt{1 - \frac{2(17.65)(0.05943)}{4.2}}\right) = 0.01658$$

$$\frac{\rho_{req}}{\rho_{max}} = \frac{0.01658}{0.01806} = 0.92 \text{ (too high)}$$

∴ Section must be doubly reinforced to control excessive deflection.

Using $x_{selected} = 0.75\,x_{\substack{max \\ \epsilon_t = 0.005}} = 9.42\,cm$ $\quad a_{sel} = 8.01\,cm$

where $x_{\substack{max \\ \epsilon_t = 0.005}} = \frac{3}{8}(33.5) = 12.56\,cm$

for which $\epsilon_s' = \frac{9.42 - 6.5}{9.42}(0.003) = 0.000930$

and $f_s' = 186\,MPa = 1.86\,t/cm^2$

$$C_c = 0.85(0.28)(100)(8.01) = 190.6\,t$$

$$M_{nc} = 190.6\left(\frac{33.5 - 8.01/2}{100}\right) = 56.2\,t.m$$

∴ $M_{ns\,req} = 66.7 - 56.2 = 10.5\,t.m$

$$C_{s\,req} = \frac{1050\,t.cm}{(33.5 - 6.5)\,cm} = 38.8\,t$$

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$$38.8 = A'_{s\,neg}\,(1.86 - 0.85(0.28))$$

$$A'_{s\,neg} = 23.92\ cm^2$$

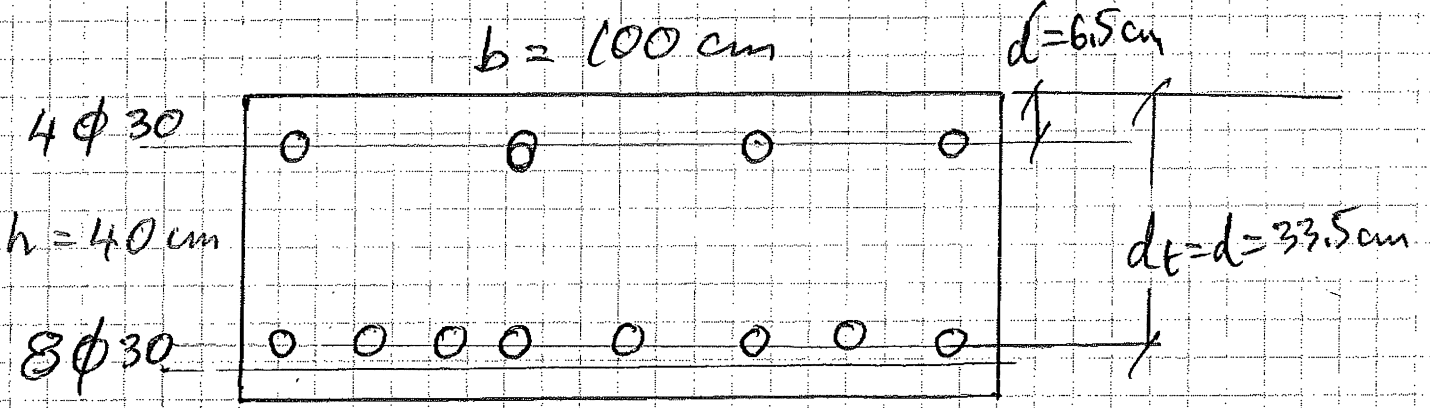
try $4\phi 30$ compression bars in one layer

$$A'_{s\,provided} = 28.27\ cm^2$$

$$A_{s\,neg} = \frac{190.6 \overset{229.46}{+} 38.8}{4.2} = 54.62\ cm^2$$

try $8\phi 30$ tension bars in one layer

$$A_{s\,provided} = 56.55\ cm^2$$



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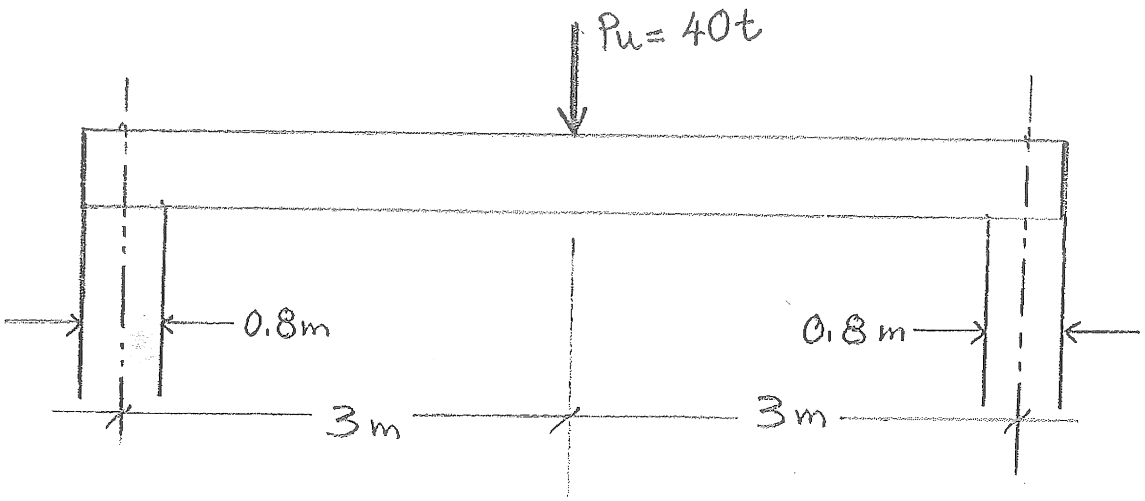
Q3. (10 points) A beam has b = 80 cm, d = 33 cm, and is used over a simple span of 6 m as shown. Ignoring the self-weight of the beam, design the beam for shear. Use double Φ10 stirrups. Determine the total number of 2 Φ10 stirrups required.



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Q3 (10 points)

$b = 80\,cm$, $d = 33\,cm$

Double $\phi 10$ stirrups, $A_v = 3.14\,cm^2$

$\underline{V_u = 20\,t \text{ (constant)}}$

$$\phi V_c = 0.75(0.17)(1.0)\frac{\sqrt{28}}{100}(80)(33)$$

$$= \underline{17.81\,t}$$

$\therefore V_u > \phi V_c$ (Category III or IV)

$< 3\phi V_c$ ($\phi V_{s\,req} = 20 - 17.81 = 2.19\,t$)

$$\underline{S_{req\,(bad)}} = \frac{0.75(3.14)(4.2)(33)}{2.19} = \underline{149.1\,cm}$$

$\underline{S_{max}}$:

$$\leq \frac{(3.14)(420)}{0.062\sqrt{28}(80)} = \underline{50.2\,cm} \qquad d/2 = \underline{16.5\,cm}$$

$$\leq \frac{(3.14)(420)}{0.35(80)} = \underline{47.1\,cm} \qquad \underline{60\,cm}$$

Of the 5 values, the smallest is 16.5 cm,

$\therefore$ use $S = 16$ cm for the entire beam.

(Note that the beam is entirely in category III.)

Total number $= \frac{600 - 80}{16} = \frac{33}{+1}$ double $\phi 10$ stirrups

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Name: Key

Total = 9 pages
(Part 1 = 6 pages, Part 2 = 3 pages)

Birzeit University
Faculty of Engineering
Department of Civil Engineering
Reinforced Concrete Design I

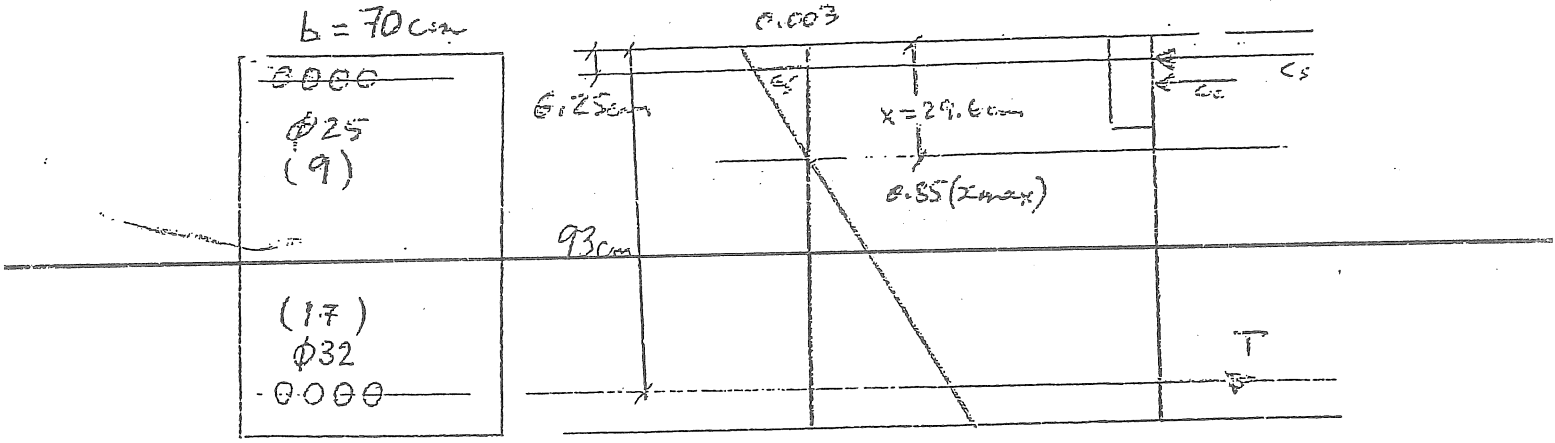
First Exam — April Tuesday, February 8, 2014

Part 1 = 6 pages

Q1.(20 points) A beam has b = 70 cm and d = 93 cm. Select the required reinforcement for the beam to support a moment Mu = 400 t.m. To control deflection, the reinforcement used must be about 85% of the maximum for εt = 0.005. Use Φ32 for the tension bars and, if needed, use Φ25 for the compression bars. Use fc' = 25 MPa, and fy = 400 MPa.

Draw appropriate stress and strain diagrams.

(To simplify your work, use d = 93 cm as the distance to the extreme layer, and if the bars are to be placed in more than one layer, h will be increased to maintain d = 93 cm.)



$M_{n req} = \frac{400}{0.9} = 444$ t.m

$\rho_{max} = 0.31875\left(\frac{25}{400}\right)(0.85) = 0.0169$

$m = \frac{400}{0.85(25)} = 18.82$

$R_{n req} = \frac{44400}{(70)(93)^2} = 0.0733$ t/cm²

$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.0733)}{4}}\right) = 0.0236 > \rho_{max}$

∴ Section must be doubly reinforced.

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x_{max} (at $\epsilon_t = 0.005$) $= \frac{3}{8}(93) = 34.9$ cm

Use $x = 0.85(34.9) = 29.6$ cm

$a = 0.85(29.6) = 25.2$ cm

$\therefore C_c = 0.85(0.25)(70)(25.2) = 375$ t

$M_{nc} = 375\left(\frac{93 - \frac{25.2}{2}}{100}\right) = 301$ t.m

$M_{ns\ req} = 444 - 301 = 143$ t.m

$\epsilon_s' = \frac{29.6 - 6.25}{29.6}(0.003) = 0.00237 > \epsilon_y$

$\therefore f_s' = f_y$

$C_{s\ req} = \frac{14300}{(93 - 6.25)} = 165$ t

$A_{s'\ req} = \frac{165\ t}{(4 - 0.85(0.25))\ t/cm^2} = 43.5\ cm^2$, $9\phi25 = 44.18 cm^2$ in one layer

$\therefore A_{s\ req} = \frac{375 + 165}{4} = 135\ cm^2$, $17\phi32 = 136.68 cm^2$ in two layers

Note: with $9\phi25$ compression bars, under maximum conditions,

$C_s = 44.18(4 - 0.85(0.25)) = 167$ t

$C_c = 0.85(0.25)(70)(0.85 \times 34.9) = 441$ t

$A_{s\ max}$ (at $\epsilon_t = 0.005$, $A_s' = 9\phi25$) $= \frac{167 + 441}{4} = 152\ cm^2$

$\frac{A_{s\ actual}}{A_{s\ max}} = \frac{136.68}{152} = 0.90$

while $\frac{A_{s\ req}}{A_{s\ max}} = \frac{135}{152} = 0.89 = 89\%$ ok

A slightly

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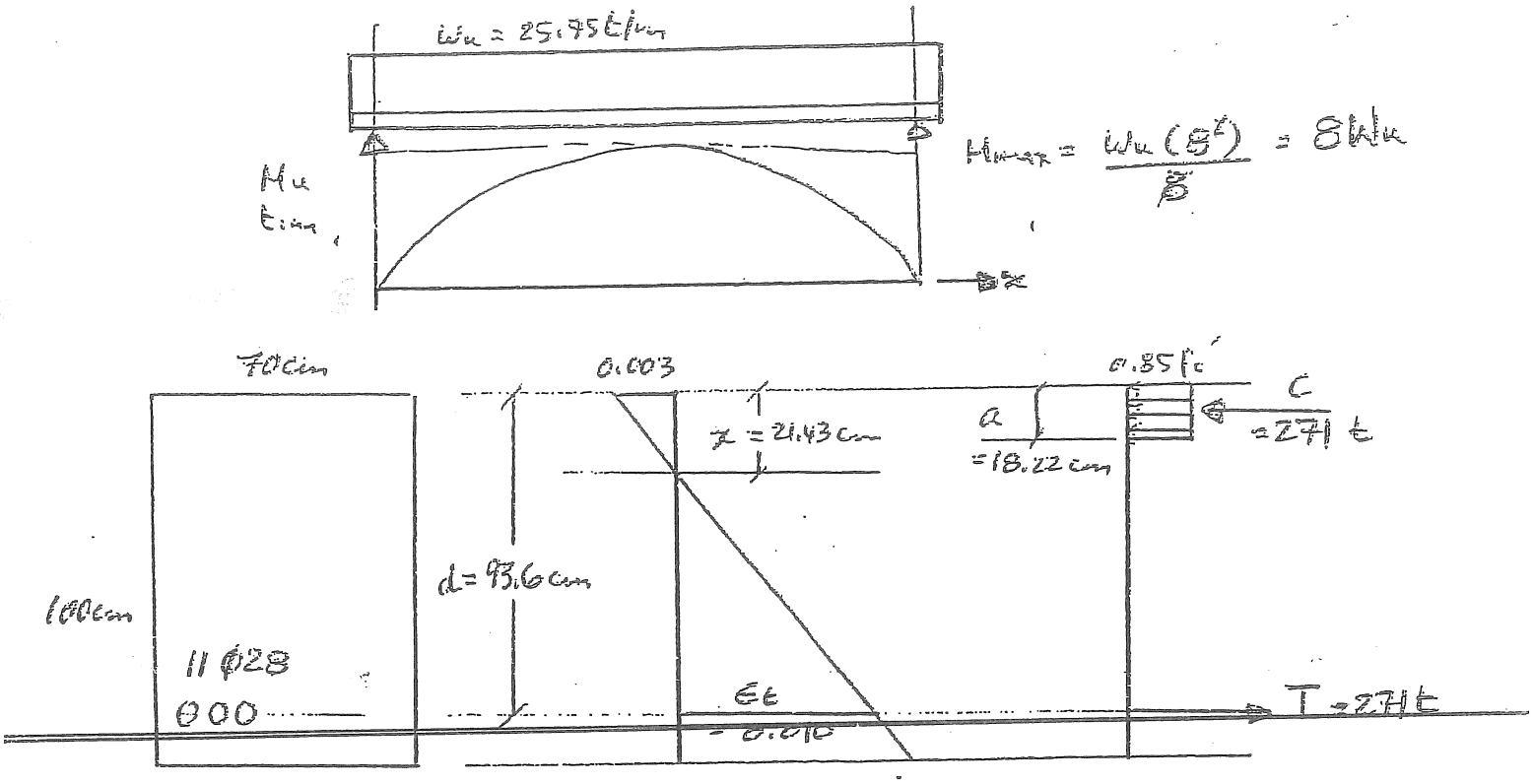
Q2.(20 points) A beam has b = 70 cm and h = 100 cm. The beam is reinforced with 11Φ28 tension bars and is used on a simple span of 8 m. Service dead load (not including self-weight) = 3 t/m. Determine the maximum service live load that can be supported by the beam. Use $\gamma_{concrete}$ = 2.4 t/m^3, fc' = 25 MPa, and fy = 400 MPa.

Draw appropriate moment, and stress and strain diagrams.



$A_s = 11\Phi 28 = 67.76\ cm^2$ in one layer

$A_{s\,max} = 110.95\ cm^2 \Rightarrow \phi = 0.9$

Self-weight = $0.70 \times 1.00 \times 2.4 = 1.68$ t/m

DL = $3 + 1.68 = 4.68$ t/m

$T = 67.76 \times 4 = 271$ t

$$a = \frac{271}{0.85(0.25)(70)} = 18.22\ cm$$ (Note: x = 21.43 cm, $\varepsilon_t = 0.010 > 0.005$ ∴ also, $\phi = 0.9$)

$$H_n = 271\left(\frac{93.6 - 18.22/2}{100}\right) = 229\ t.m$$

$$\phi H_n = 206\ t.m = 8\left(1.2\left(\frac{5.616}{4.68}\right) + 1.6(L)\right)$$

∴ Service LL = 12.59 t/m

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Q3.(20 points) Design a beam with a perfectly square x-section (i.e., b = h and in multiples of 5 cm) to support a moment Mu = 170 t.m. The reinforcement must be about 60 % of the maximum for εt = 0.005. Use Φ20 bars, fc' = 25 MPa, and fy = 400 MPa.

Draw appropriate stress and strain diagrams.

$M_{n\,req} = \frac{170}{0.9} = 188.9$ t.m $\qquad m = \frac{400}{0.85(25)} = 18.82$

$\rho_{max}\ (\varepsilon_t = 0.005) = 0.31875\left(\frac{25}{400}\right)(0.85) = 0.0169$

$\rho_{selected} = 0.6 \times 0.0169 = 0.01016$

$R_{n\,sel} = 0.01016\,(4)\left(1 - \frac{1}{2}(0.01016)(18.82)\right) = 0.03675$ t/cm²

$\frac{18890}{bd^2} = 0.03675 \Rightarrow bd^2 = 513960$ cm³

Let $d \approx b \Rightarrow b = 80.1$ cm

⇒ if h = 80 cm, d = 74 cm, $R_n = \frac{18890}{(80)(74)^2} = 0.0431$ t/cm²

$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.0431)}{4}}\right) = 0.01217 \approx 72\%\,\rho_{max}$

⇒ if h = 85 cm, d = 79 cm, $R_n = \frac{18890}{(85)(79)^2} = 0.0356$ t/cm²

$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.0356)}{4}}\right) = 0.009807 \approx 58\%\,\rho_{max}$

$A_{s\,req} = 0.009807 \times 85 \times 79 = 65.86$ cm² = 20.96 bars

Use 21 bars ⇒ $A_{provided} = 65.97$ cm²

Since the reinforcement will not fit in one layer, "d" will be reduced. Then for increase As to 22 bars, Asprov = 69.12 cm²

One layer fits 16 bars
second layer 6 bars

$\rho_{actual} = 60.9\%$ of the maximum
$= 0.609\,\rho_{max}$ (exceeds)

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Name: Key Total = 9 pages

Birzeit University
Faculty of Engineering
Department of Civil Engineering
Reinforced Concrete Design I

Mid-Term Exam **Sunday, April 14, 2013**

1. (10 points) Using diagrams as appropriate, answer or explain briefly:

a. What are hydraulic cements?

Cements that can set and harden under the water surface, i.e., in the presence of water.

b. What are the two main reasons for using admixtures?

1- Modify the properties of the concrete to make it better serve its intended use.

2- For better economy.

c. What is the difference between shrinkage and creep?

Shrinkage results from the loss of water from the concrete mix as it hardens.

Creep results from the deformation with time under sustained loads.

d. What are the serviceability factors that must be considered in a design?

1- Excessive deflection.
2- Detrimental cracking.
3- Vibrations: amplitude and frequency.
4- Noise transmission.

e. Can beams support additional (more) moment after the yielding of tension steel?

Yes because when more load is applied after the yielding of tension steel, the neutral axis continues to move upward as the concrete in the compression zone is stressed to higher levels. This results in an increase in the "moment arm".

f. The balanced strain condition is not permitted for beams.

At the balanced condition the tension steel reaches only ε_y for ε_t at failure. This must be at least $\varepsilon_t = 0.004$ according to requirements of the ACI-Code to provide sufficient warning before failure.

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g. If a beam is designed to have $As_{required}$ near As_{max}, it will probably deflect objectionably under service loads.

Because the size of the concrete x-section required under such conditions will be relatively small. This will result in higher deflections under service loads.

h. Adding a significant amount of compression reinforcement to a properly designed singly reinforced beam will not have a significant effect on its ultimate capacity.

Adding the compression reinforcement will not result in an increase in the total compressive force "C", but will reduce the load carried by the concrete in the compression zone - this load will be carried by the compression steel.

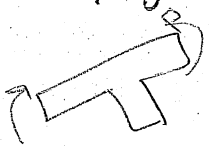
i. The two bond failure mechanisms.

1- Slip resulting from breaking the adhesion between concrete and the surface of the steel bars.

2- Progressive splitting resulting from the radial component of the force caused by the wedging action of lugs on a deformed bar.

j. The ACI Code places an upper limit on shear reinforcement.

To limit the maximum stress in the diagonal concrete "struts" which may cause a sudden and premature crushing of the web. (Refer to the truss model page 133)



2. (20 points) Circle the appropriate letter, T for true or F for false.

1. (T) F The maximum permissible reinforcement for T-sections subjected to a positive moment must be checked based on As_{max} and not ρ_{max}.

2. T (F) The maximum permissible reinforcement for T-sections subjected to (a negative) moment must be checked based on As_{max} and not ρ_{max}.

3. T (F) The minimum permissible reinforcement for T-sections subjected to a positive moment must be checked based on As_{min} and not ρ_{min}.

4. T (F) The minimum permissible reinforcement for doubly reinforced sections subjected to a negative moment must be checked based on As_{min} and not ρ_{min}.

5. (T) F Concrete ordinarily requires about (14) days to attain adequate strength so that forms can be removed and construction and dead loads carried.

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6. T (F) It is not permissible to cut bars in cantilever beams.

7. (T) F Properly designed sections fail in flexure and not in shear.

8. (T) F Stirrups help in maintaining aggregate interlock in beams.

9. T (F) Steel and concrete do not have similar rates of thermal expansion.

10. (T) F The modulus of rupture measures the strength of concrete in flexure.

11. (T) F Proper concrete mixes provide adequate impermeability of the concrete against water intrusion and bar corrosion.

12. T (F) Minimum steel reinforcement in beams is required by the ACI Code to prevent cracking of the tension side of beams.

13. T (F) The compression side of the beam will not reach a crushing strain $\varepsilon_{cu} = 0.003$ unless the actual steel reinforcement $\leq As_{max\ st} = 0.004$.

14. (T) F Welded wire fabric may be used as the main reinforcement for thin slabs.

15. T (F) Epoxy coating of reinforcing bars may be used to reduce cracking of beams.

16. T (F) In the working stress method, stresses resulting from ultimate loads and computed by mechanics of elastic members should not exceed allowable values.

17. T (F) Sections that do not have sufficient steel to resist the flexural stresses are known as under-reinforced.

18. T (F) Sections with steel reinforcement exceeding the maximum permissible limit are known as over-reinforced.

19. T (F) The strength reduction factor ϕ is intended as a safety factor against possible construction mistakes.

20. T (F) If a beam is supported on the top face of a girder, not a column, the critical section is taken at the face of support.

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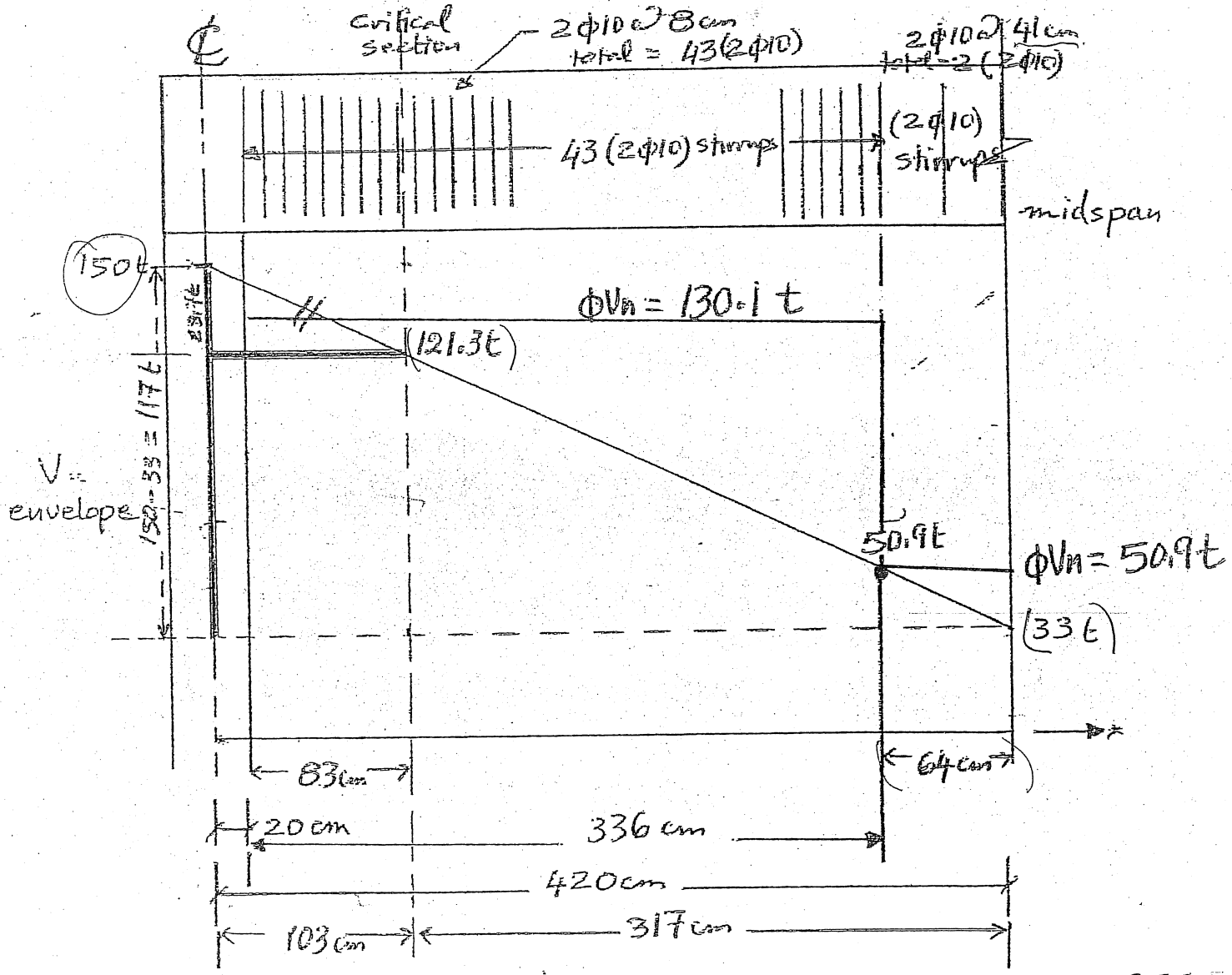
Name: Key Total = 9 pages

3. (10 points) Design the beam shown for shear. Use b = 60 cm, d = 83 cm, fc' = 25 MPa, fy = 400 MPa, and 2 Φ10 stirrups where necessary. Use two different spacings to cover the beam. On the side view of half the span, show the distribution and number of stirrups. Also, superimpose the ϕVn diagram on the Vu diagram. $A_v = 3.16\ cm^2$



$$\phi V_c = 0.75\,(0.17)(1.0)\frac{\sqrt{25}}{100} \times 60 \times 83 = 31.7\ t \qquad 3\phi V_c = 95.1\ t \qquad 5\phi V_c = 158.5\ t$$

A) Category III or IV: $S_{max} \le$

$$\frac{(3.16)(400)}{0.062\sqrt{25}\,(60)} = 68\ cm \quad , \quad \frac{d}{2} = \underline{41.5\ cm} \text{ controls}$$

$$\frac{(3.16)(400)}{0.35\,(60)} = 60\ cm \quad , \quad 60\ cm$$

$$\therefore \phi V_{s\,min} = \frac{0.75\,(3.16)(4)(83)}{41} = 19.2\ t$$

$$\phi V_n = 31.7 + 19.2 = \underline{50.9\ t}$$

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h. Adding a significant amount of compression reinforcement to a properly designed singly reinforced beam will not have a significant effect on its ultimate capacity, why?

Because it only reduces C_c and increases C_s. The moment capacity which equals C or T multiplied by the moment arm is not changed unless T is changed or the moment arm increased.

i. Can beams support additional (more) moment after the yielding of tension steel?

Yes, because the centroid of the compression zone continues to shift farther away from the tension steel and thus the moment arm and the moment capacity are increased.

j. If a beam is designed to have $As_{required}$ near As_{max}, it will probably deflect objectionably under service loads, why?

Because under these conditions the concrete X-section is minimized and this results in a reduction in the stiffness (moment of inertia) and an increase in the deflection under service loads.

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Name: Rana Nima Hamed

31

Part 2 = 3 pages

Q4. (15 points) Circle the appropriate letter, T for true or F for false.

1. (T) F — Shrinkage occurs due to the loss of water at an early age of the concrete.
2. T (F) — Steel and concrete have significantly different rates of thermal expansion.
3. (T) F — The minimum required reinforcement for doubly reinforced sections is the same as that for singly reinforced sections.
4. T (F) — Creep occurs as a result of loading concrete soon after placement.
5. (T) (F) — If a beam is designed to have $As_{required}$ near As_{max}, it will probably deflect objectionably under service loads.
6. T (F) — If a beam is designed to have $As_{required}$ near As_{max}, it will probably deflect more under service loads than under ultimate loads.
7. T (F) — Beams cannot support additional load after the yielding of tension steel.
8. T (F) — Bolsters and chairs are used to support formwork during construction.
9. T (F) — Excessive deflection under ultimate loads is not permitted because it may result in objectionable cracking.

---

10. (T) F — The Whitney block replaces the actual stress distribution with a rectangular distribution and this is permitted by the ACI Code.
11. (T) (F) — The Whitney block does not give the true location of the resultant compressive force.
12. (T) F — Admixtures may be used to modify the properties of concrete and their use is economical.
13. T (F) — Steel behaves better than concrete when exposed to fire.
14. T (F) — Cement, and concrete, are two names for the same material.
15. (T) F — The stress-strain relationship for concrete depends on its strength.

-2

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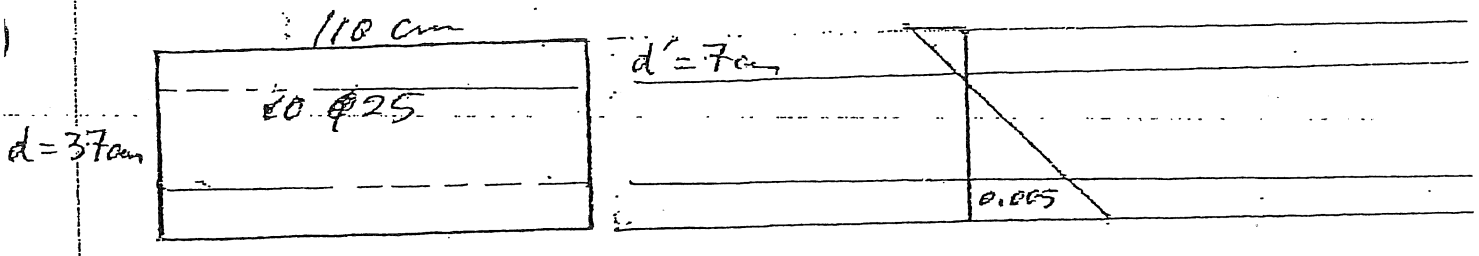
$b = 110\text{cm}$, $d = 37\text{cm}$, $d' = 7\text{cm}$, $A_s' = 10\phi 25$

$f_c' = 35\text{MPa}$, $f_y = 420\text{ MPa}$ $\quad \beta_1 = 0.80$



$$x_{max} \atop \varepsilon_t = 0.005 = \frac{3}{8}(37) = 13.875\text{cm} \qquad a = \beta_1 x = 11.1\text{cm}$$

$$\varepsilon_s' = \frac{13.875 - 7}{13.875}(0.003) = 0.001486$$

$$f_s' = 2.973\ t/cm^2$$

$$C_c = 0.85(0.35)(110)(11.1) = 363.2t$$

$$C_s = 10 \times 4.91\,(2.973 - 0.85(0.35)) = 131.4t$$

$$\therefore \underset{\substack{\varepsilon_t = 0.005 \\ A_s' = 10\phi 25}}{A_{s\,max}} = \frac{363.2 + 131.4}{4.2} = 117.8\text{cm}^2$$

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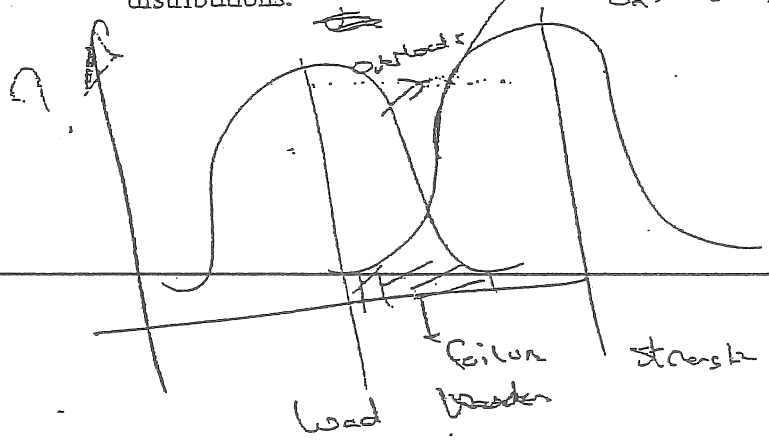
d. What is the modulus of rupture and how is it determined?

modulus of rupture: tensile strength in flexure. important when considering cracking and deflection of beams. gives higher value for tensile strength than split cylinders test, because the concrete compression stress distribution is not linear when tensile failure is imminent.

$f = Mc/I$

e. Explain the safety provisions of the ultimate strength design method using proper statistical distributions.



- overloads may arise from changing the use of which the structure was designed.
- understength: less strength than computed by acceptable calculating procedures.

NO!

3. a. (2 points) Use a simple strain versus time diagram to explain the change in strain of a loaded and drying specimen. Consider elastic, creep, and shrinkage strains.

It is about time you started to do some reading !!!

b. (2 points) What are the two requirements specified by the ACI code for adequate control of strength.

c. (1 points) Explain the difference between f_c' and f_{cr}'.

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b) $N_u = 100$ t.m

2 points $M_{u\,req} = \frac{100}{0.9} = 111.11$ t.m

$$111.11 \text{ t.cm} = \underbrace{49.1\left[\left(\frac{x-7}{x}\right)(6) - 0.85(0.35)\right](37-7)}_{C_c} + \underbrace{0.85(0.35)(110)(0.80x)\left(37 - \frac{0.80x}{2}\right)}_{C_s}$$

$$\simeq 1473\left(6 - \frac{42}{x} - 0.2975\right) + 26.18x\,(37 - 0.40x)$$

$$= 8400 - \frac{61866}{x} + 969x - 10.472x^2$$

$$10.472x^2 - 969x + 2711 + \frac{61866}{x} = 0$$

$$x^3 - 92.53x^2 + 259x + 5908 = 0$$

$x = 10$	equation $= 245$
9.8	500
10.2	−15
10.19	−2.65

$\therefore x = 10.19 < x_{max}$ $\therefore \phi = 0.9$ ✓

Check $f_s' = 1.878$ t/cm^2 $C_s = 77.62$ t

$C_c = 266.77$ t

$$A_{s\,req} = \frac{77.62 + 266.77}{4.2} = 82.0 \text{ cm}^2$$

use 12 ϕ30 bars in one layer

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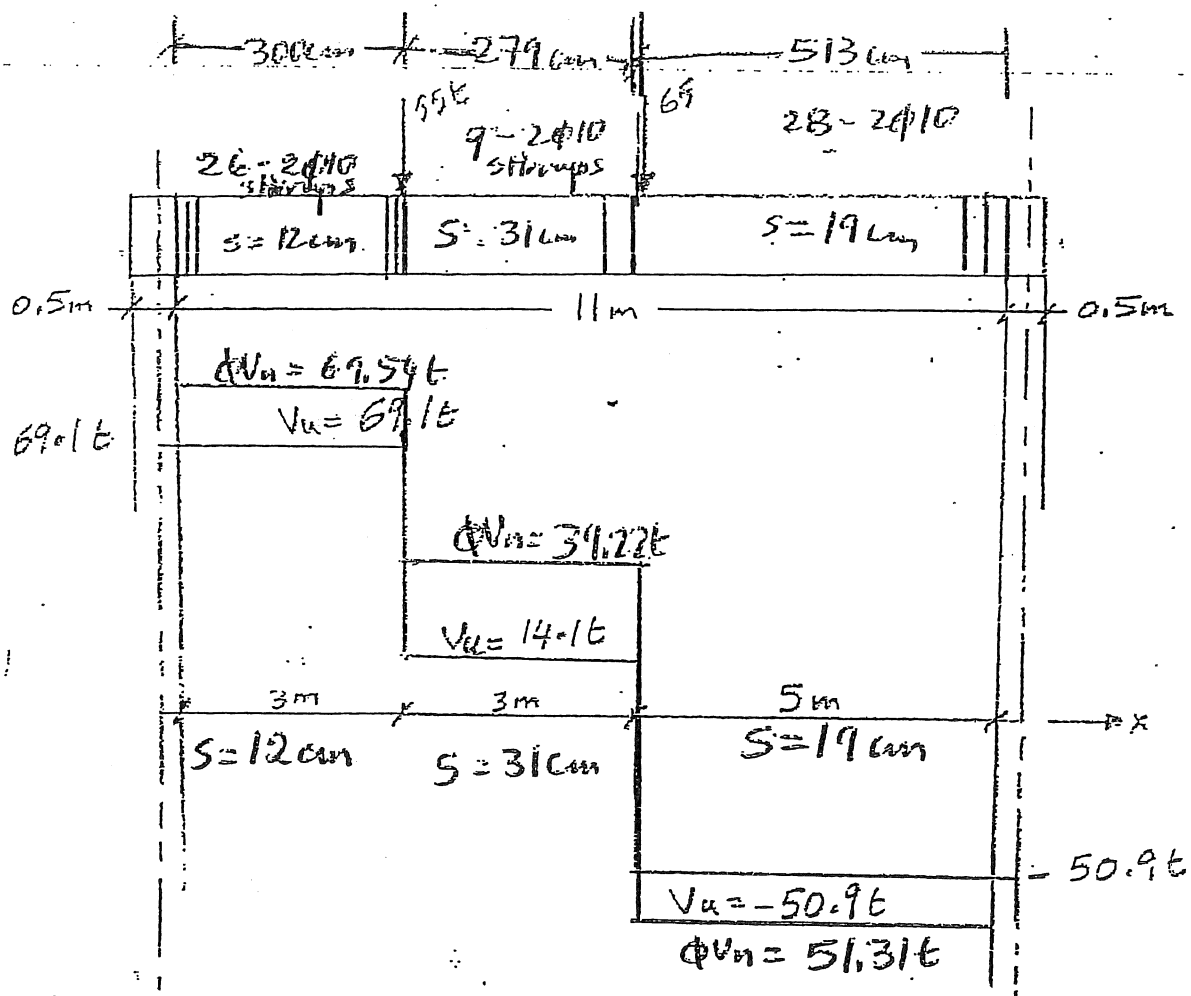
Q2. (12 points) A beam has b = 50 cm, d = 63 cm, fc' = 25 MPa, fy = 400 MPa, and Φ10 stirrups where necessary. The shear diagram is given. Draw a side view of the beam and show the distribution and number of stirrups required. Also, superimpose the ϕVn diagram on the Vu diagram.



Since b = 50cm, 2 stirrups are used, $A_v = 3.14 cm^2$

$\phi V_c = 0.75(0.17)\frac{(\sqrt{25})}{100} \times 50 \times 63 = 20.08t$

$\frac{\phi V_c}{2} = 10.04\ t$

$3\phi V_c = 60.24\ t, \quad 5\phi V_c = 100.4\ t$

Middle Part of the Beam: Category II, No Exceptions

∴ Minimum reinforcement is required.

$S_{max} = \frac{(3.14)(400)}{0.062\sqrt{25}(50)} = 81cm$

$= \frac{(3.14)(400)}{0.35(50)} = 71.8cm$

$d/2 = 31.5cm$

Smallest

60cm

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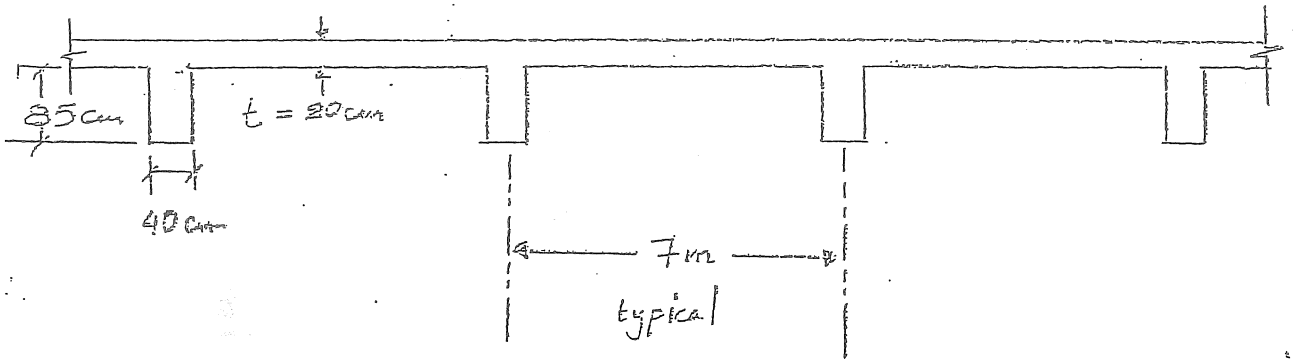
Q3. A solid slab is supported by monolithic drop beams as shown. The service dead load consists of 0.3 t/m^2 in addition to self-weight. The service LL = 0.5 t/m^2. The c/c spacing between columns (beam spans) = 9m.
Given: $\gamma_{concrete}$ = 2.4 t/m^3, d = 91 cm, bw = 40 cm, slab thickness = 20 cm, beam drop = 85 cm below slab (total h = 105 cm), fc' = 20 MPa, and fy = 420 MPa.



a. (7 points) Determine the ultimate load Wu (in tons per meter t/m) supported by the beam.

~~Slab = $\frac{20}{100} \times 7 \times 1 \times 2.4$ = 3.36 t/m~~

beam drop = $\frac{85}{100} \times 0.4 \times 1 \times 2.4 = 0.82$ t/m

DL Additional = $0.3 \times 7 = 2.1$ t/m

Total DL = 6.28 t/m

Total LL = $0.5 \times 7 = 3.50$ t/m

$W_u = 1.2(6.28) + 1.6(3.5) = 13.14$ t/m

7.536 5.6

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c. (7 points) Determine As_{max} and As_{min} for positive moment.

+ve moment

$b_E = \frac{900}{4} = 225$ cm

$= 40 + 16(20) = 360$ cm

$= 400$ cm

X_{max} ($\epsilon_t = 0.005$) $= \frac{3}{8} \times 91 = 34.125$ cm

$a_{max} = 0.85(34.125) = 29.0$ cm

$\therefore C_{max} = 0.85(0.2)(225 - 40)(20) + 0.85(0.2)(40)(29)$

$= 629 + 197.2 = 826.2$ t

A_{smax} ($\epsilon_t = 0.005$) $= \frac{826.2}{4.2} = 196.7$ cm^2

$A_{smin} = \frac{0.25\sqrt{20}}{420}(40)(91) \geq \frac{1.4}{420}(40)(91)$

$= 9.69 \geq 12.13$ cm^2

controls

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DL = 0.3
LL = 0.5

c/c

Q3. A solid slab is supported by monolithic drop beams as shown. The service dead load consists of 0.3 t/m^2 in addition to self-weight. The service LL = 0.5 t/m^2. The c/c spacing between columns (beam spans) = 9m.

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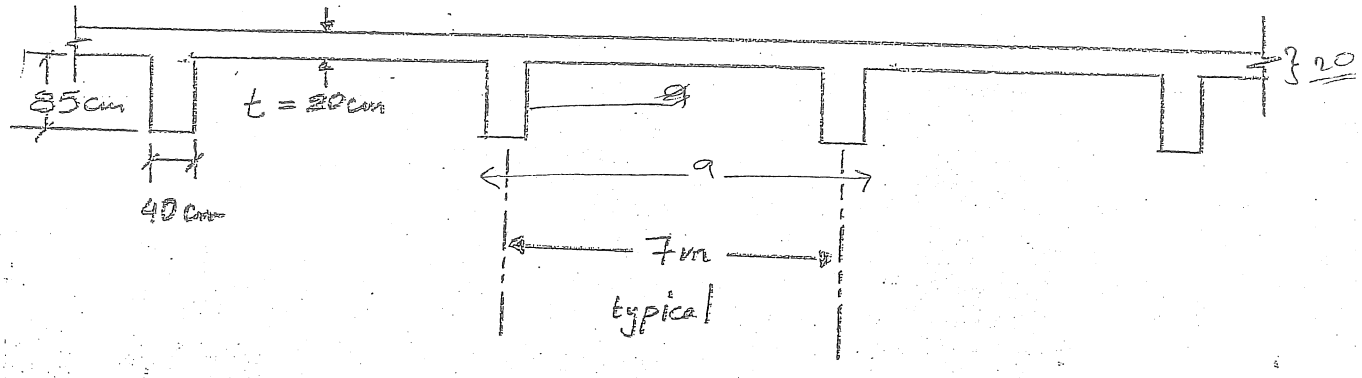

a. (7 points) Determine the ultimate load Wu (in tons per meter t/m) supported by the beam.

Slab = $\frac{20}{100} \times 7 \times 1 \times 2.4 = 3.36$ t/m

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Total DL = 6.28 t/m

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7.536 5.6

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Dr. Jamal Zalatimo (1/6)

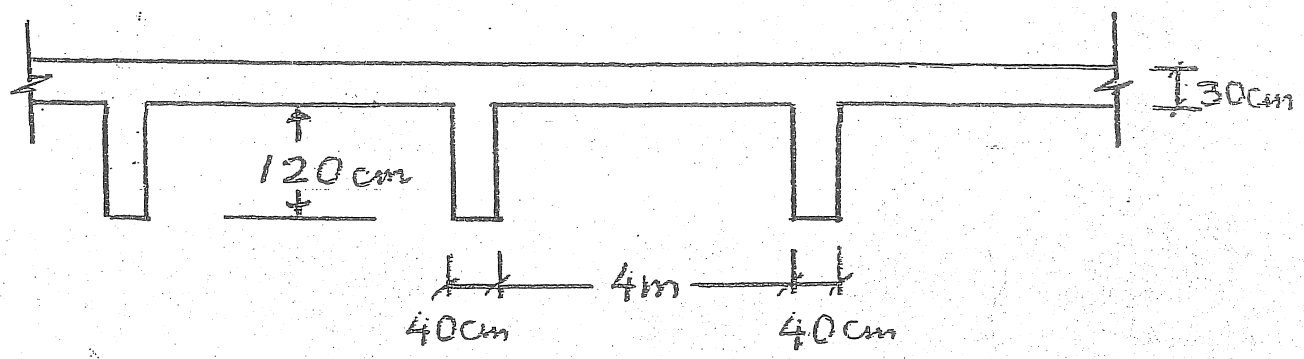
Name: Key

Birzeit University
Faculty of Engineering
Civil Engineering Department

Reinforced Concrete Design I

Second Exam **April 23, 2009**

1. The following sketch shows a solid slab supported on drop beams with 13 m simple spans. Using fc' = 25 MPa, fy = 400 MPa, 4 cm clear cover, Φ 10 stirrups, and Φ 20 longitudinal bars, determine:



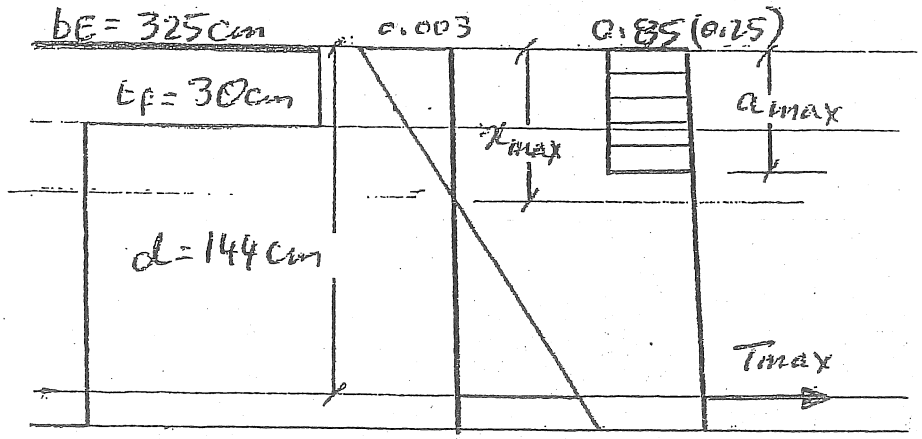
a. (3 points) Asmax – ε_t = 0.004 for positive moment.

$b_E = \frac{1300}{4} = 325\ cm$ controls

$= 40 + 16(30) = 520\ cm$

$= 440\ cm$

$d = 150 - 4 - 1 - \frac{2}{2} = 144\ cm$



$x_{max} = \frac{3}{7}(144) = 61.7\ cm$ ($\varepsilon_t = 0.004$)

$a = 0.85(61.7) = 52.4\ cm$

$C_{max} = 0.85(0.25)(325-40)(30) + 0.85(0.25)(40)(52.4)$ ($\varepsilon_t = 0.004$)

$= 1816.9 + 445.9 = 2262.8\ t$

$\therefore A_{s\,max} = \frac{2262.8}{4.00} = 565.7\ cm^2$ ($\varepsilon_t = 0.004$)

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5. (6 points) a. What is the "working stress method"?

b. What are the obstacles to its use?

c. How does it differ from the strength method in ensuring safety?

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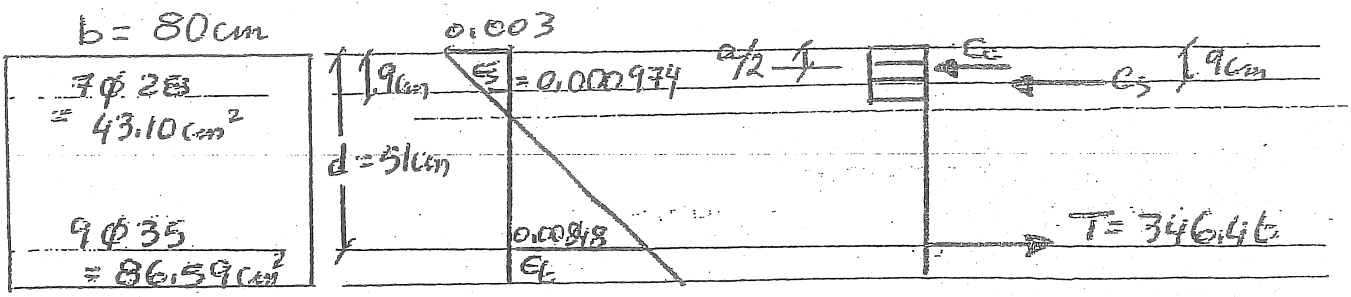
b. (5 points) If the beam is reinforced with As = 9Φ35 tension bars, determine ϕMn.



Assume compression steel yields:

$C_s = 43.10\,(4 - 0.85(0.4)) = 157.7\ t$

$C_c = (86.59 \times 4) - 157.7 = 188.6\ t \Rightarrow a = 6.93\ cm$

$x = 9.07\ cm \Rightarrow \therefore$ Compression steel does not yield

Note that this may be concluded directly from the results of part "a" since As actual < As max and ε_s' for the case of As max was < ε_y.

$$346.4 = 0.85(0.4)(80)(0.764)x + \left[6\left(\frac{x-9}{x}\right) - 0.85(0.4)\right](43.10)$$

$$346.4 = 20.78x + 258.6 - \frac{2327}{x} - 14.65$$

$$20.78x - 102.4 - \frac{2327}{x} = 0$$

$$x^2 - 4.93x - 112 = 0$$

$$x = 13.33\ cm \qquad a = 0.764x = 10.18\ cm$$

$C_c = 277.1t$, $C_s = 43.10\,(1.95 - 0.85(0.4)) = 69.3t$

$C_c + C_s = 346.4\ t = T$ ∴ (Calculations correct)

$$\varepsilon_t = \frac{51 - 13.33}{13.33}(0.003) = 0.00848 \qquad \therefore \phi = 0.9$$

$$M_n = 277.1\left(51 - \frac{10.18}{2}\right) + 69.3\left(\frac{51-9}{100}\right) = 127.2 + 29.1$$

$$= 156.3\ t\text{-m} \qquad \therefore \phi M_n = 140.7\ t\text{-m}$$

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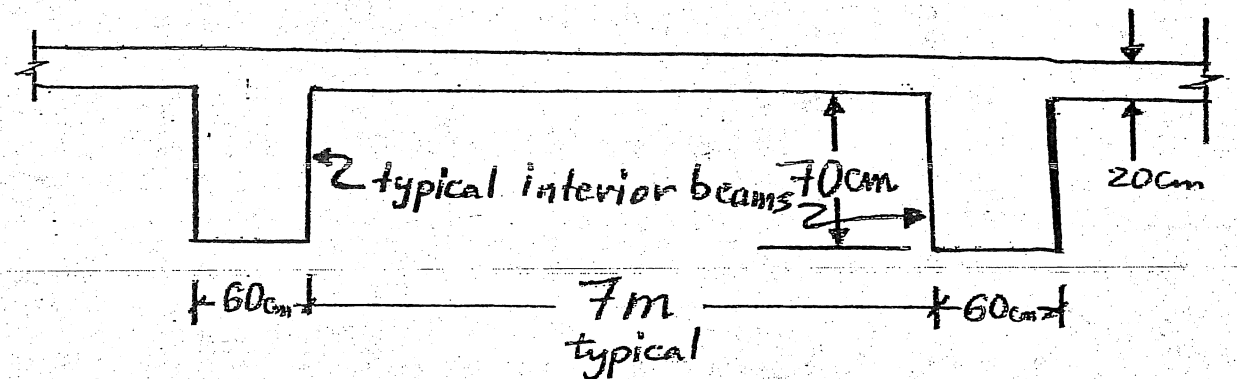
2. The following sketch shows a 20-cm thick solid slab supported on 70-cm deep drop beams. The slab carries a service live load = 0.35 t/m^2. The beams are simply supported on columns at a simple span of 12 m.
Use fc' = 25 MPa, fy = 400 MPa, concrete density $\gamma_{concrete}$ = 2.4 t/m^3, 4 cm clear cover, Φ 10 stirrups, and Φ 20 longitudinal bars.



$b_E = 60 + 16(20) = 380\ cm$

$= \frac{1200}{4} = 300\ cm$ controls

$= 760\ cm$

a. (3 points) Determine the ultimate design moment Mu for a typical interior beam.

$b_f = 7.6\ m$

L = Self weight for a 1m length = $(0.2 \times 7.6 \times 1)(2.4\ t/m^3) + (0.7 \times 0.6 \times 1)(2.4)$

$= 3.648 + 1.008 = 4.656\ t/m$

$L = 7.6 \times 0.35 = 2.66\ t/m$

$W_u = 1.2(4.656) + 1.6(2.66) = 9.84\ t/m$

$M_u = \frac{W_u l^2}{8}$

$= \frac{(9.84)(12^2)}{8}$

$\therefore M_u = 177.2\ t.m$

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b. (6 points) If the ultimate design moment for an interior beam was determined to be Mu = 150 t.m., determine the required reinforcement in accordance with the ACI-318 Code (check appropriate limits.)

$M_{n\,req} = 150/0.9 = 166.7$ t.m $d = 90-4-1-1 = 84$ cm

if $a = t$, $C = 0.85(0.25)(300)(20) = 1275$ t

$M_n = 1275\left(\frac{84 - 20/2}{100}\right) = 943.5$ t.m $\therefore a < t$

$R_{n\,req} = \frac{166.7 \times 100}{(300)(84)^2} = 0.007875$ t/cm²

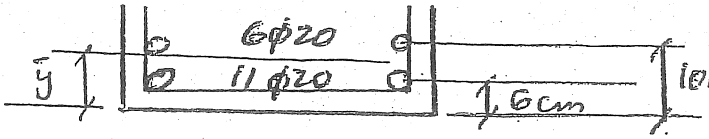
$m = \frac{400}{0.85(25)} = 18.82$

$\rho_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.007875)}{4}}\right)$

$= 0.00220066$

$\therefore A_{s\,req} = 0.00220066 \times 300 \times 84 = 50.57\,cm^2 = 16.1\ \phi 20$ bars

use 17 ϕ 20



$\bar{y} = \frac{(11 \times 6) + (6 \times 10.5)}{11 + 6} = 7.59$ cm

$\therefore d_{rev} = 82.41$ cm

$x_{max\ \varepsilon_t = 0.005} = \frac{3}{8}(84) = 31.5$ cm, $a = 26.78$ cm

$T_{max} = C_{max} = 0.85(0.25)(300-60)(20) + 0.85(0.25)(60)(26.78)$

$= 1020 + 341 = 1361$ t

$\therefore A_{s\,max\ \varepsilon_t \geq 0.005} = \frac{1361}{4} = 340\,cm^2$

$A_{s\,min} = \frac{0.25\sqrt{25}}{400}(60)(82.41) \geq \frac{4}{400}(60)(82.41)$

$= 15.175\,cm^2 \not\geq 17.64\,cm^2$ controls

$a = \frac{17(3.14)(4)}{0.85(0.25)(300)} = 3.35$ cm

$17\phi 20 = 53.38\,cm^2 = A_{s\,actual}$

$M_n = 213.5\left(\frac{82.41 - 3.35/2}{100}\right) = 172$ t.m $> M_{n\,req}$

use 17φ20 in two layers (11 lower, 6 second la

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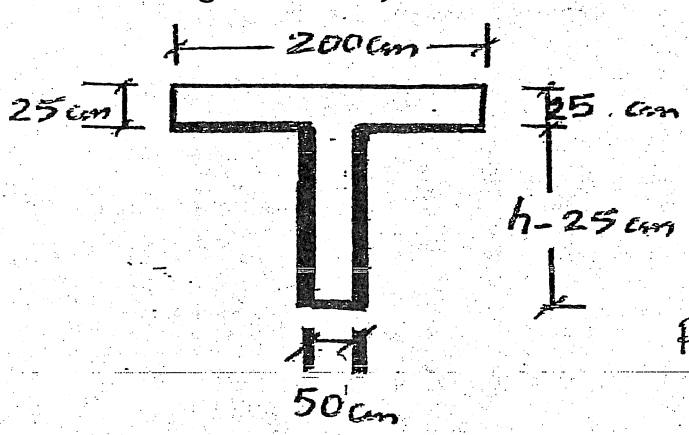
3. a. (6 points) Design the isolated T-beam shown to support a negative ultimate moment Mu = 110 t.m. Use fc' = 25 MPa, fy = 400 MPa, d = 73 cm, and Φ 20 longitudinal bars, in accordance with the ACI-318 Code.



$m = \frac{400}{0.85(25)} = 18.82$

$M_u = -110$ t.m

$M_{n\,req} = -\frac{110}{0.9} = 122.2$ t.m

$R_{n\,req} = \frac{122.2 \times 100}{(50)(73)^2} = 0.0459$ t/cm^2

$$\rho_{req} = \frac{1}{18.82}\left(1-\sqrt{1-\frac{2(18.82)(0.0459)}{4}}\right) = 0.01308$$

$A_{s\,req} = (0.01308)(50)(73) = 47.74$ cm^2

ρ_{max} ($\varepsilon_t = 0.005$) $= (0.31875)(0.85)\left(\frac{25}{400}\right) = 0.01693$

$\therefore A_{s\,max}$ ($\varepsilon_t = 0.005$) $= (0.01693)(50)(73) = 61.81$ cm^2

$$A_{s\,min} = \frac{0.5\sqrt{25}}{400}(50)(73) \leq \frac{0.25\sqrt{25}}{400}(200)(73)$$

$\therefore A_{s\,min}$ = controls 22.81 cm$^2 \leq 45.62$ cm^2

N^o of bars $= \frac{47.74}{3.14} = 15.2 \Rightarrow$ use 16 ϕ20 bars

$A_{s\,min} = 22.81$ cm$^2 < A_{s\,provided} = 50.24$ cm$^2 < A_{s\,max} = 61.81$ cm^2

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b. (3 points) The most appropriate stirrup spacing "s" at the critical section.

$0.30 + 0.73 = 1.03\,m$

$3\phi V_c = 69.8\,t$

$5\phi V_c = 116.4\,t$

$$\frac{(5.80-1.03)}{(5.80)}(85) + (15) = \frac{4.77}{5.80}(85) + 15$$

$\therefore$ Vu at the critical section $= 69.9 + 15 = 84.9\,t \Rightarrow$ Category 5

$\phi V_{s\,req} = 84.9 - 23.27 = 61.6\,t$

$$S_{req} = \frac{(0.75)(1.57)(4)(73)}{61.6} = 5.58\,cm \; (= 11.16\,cm \text{ for double } \phi 10)$$

$S_{max} \leq 40.5\,cm$
$\leq 35.9\,cm$ } as before ; $S_{max} \leq 73/4 = 18.25\,cm$
$\leq 30\,cm$ controls minimum

$\therefore$ use $2\phi 10$ @ 11 cm c/c

c. (2 points) Explain why the ACI-Code places lower and upper limits on Vs (shear reinforcement).

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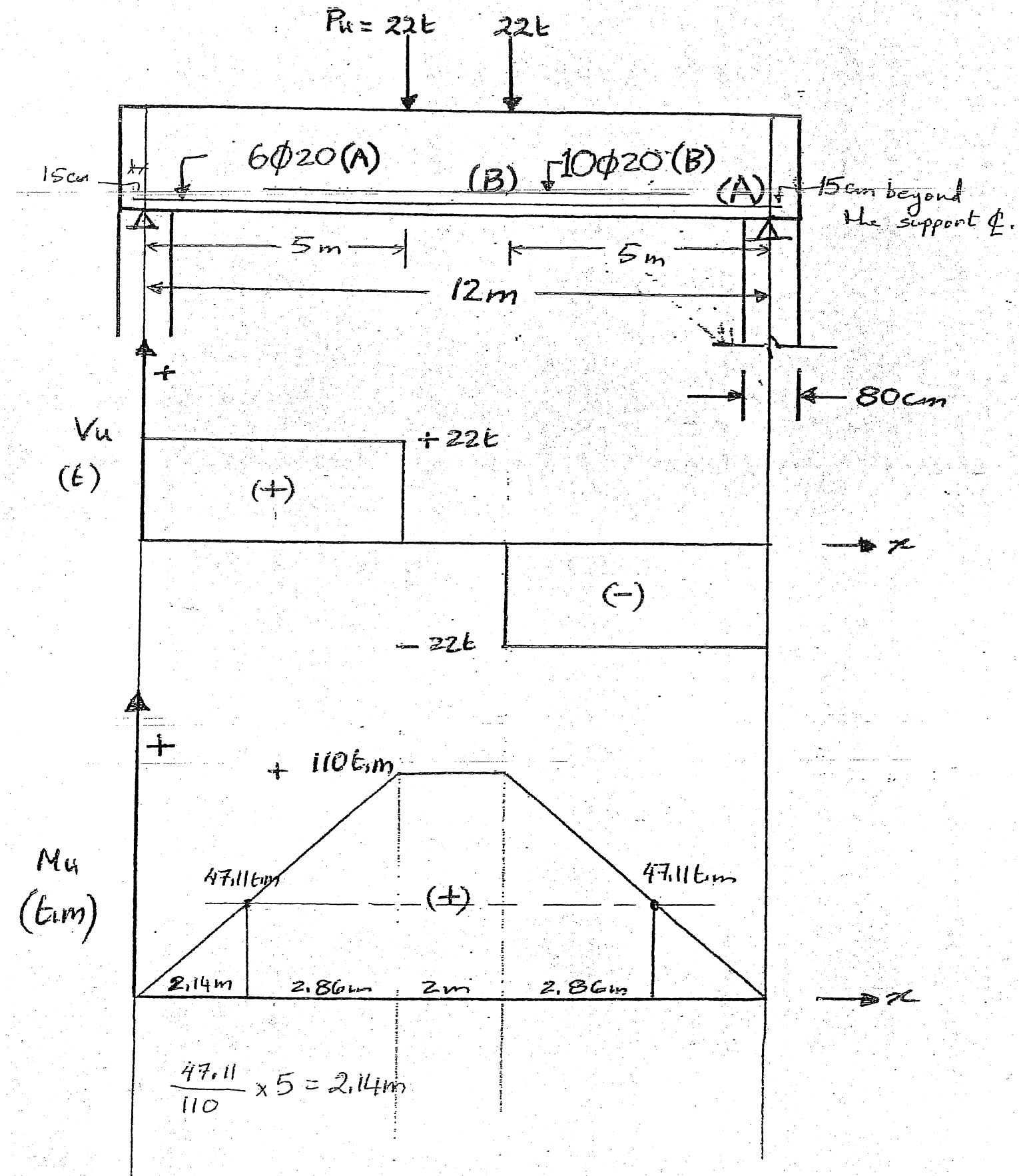
3. A beam has b = 50 cm, d = 73 cm, fc' = 25 MPa, fy = 400 MPa, and Φ 10 stirrups. The shear and bending moment diagrams for the beam are provided.

(use d = 73cm in all calculations)



$\frac{47.11}{110} \times 5 = 2.14m$

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b. (2 points) Asmin for positive moment.

$$A_{s\,min} = \frac{0.25\sqrt{25}(40)(144)}{400} \geq \frac{1.4(40)(144)}{400}$$

$$= 18\ cm^2 \geq 20.16\ cm^2$$

controls

c. (5 points) Bars required for a positive moment of Mu = 160 t.m.

$Mn_{req} = 177.8$ t.m

if $a = t$, $Mn = 0.85(0.25)(325)(30)\left(\frac{144 - 30/2}{100}\right) = 2672.7$ t.m

$\therefore a < t$

$$Rn_{req} = \frac{177.8 \times 100}{(325)(144^2)} = 0.002644\ t/cm^2$$

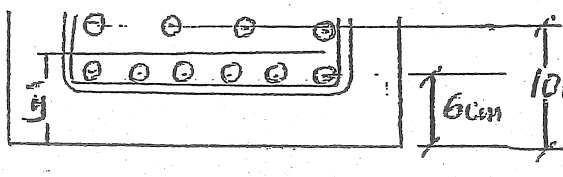
$$m = \frac{400}{0.85(25)} = 18.82$$

$$P_{req} = \frac{1}{18.82}\left(1 - \sqrt{1 - \frac{2(18.82)(0.002644)}{4}}\right)$$

$\therefore P_{req} = 0.0006643$

$As_{req} = 0.0006643 \times 325 \times 144 = 31.09\ cm^2$

$\frac{31.09}{3.14} = 9.9 \Rightarrow 10\ \phi 20 \Rightarrow$ two layers



$\bar{y} = \frac{6 \times 6 + 4 \times 10.5}{10} = 7.8$ cm

$d_{revised} = 150 - 7.8 = 142.2$ cm

$Rn_{rev} = 0.002714\ t/cm^2$, $P_{rev} = 0.000681$, $As_{rev} = 31.5\ cm^2$

$10\ \phi 20 = 31.42\ cm^2$ ~

$\Rightarrow a = \frac{31.42 \times 4}{0.85(0.25)(325)} = 1.82$ cm

$$Mn = 31.42 \times 4\left(\frac{142.2 - 1.82/2}{100}\right)$$

$Mn = 177.6$ t.m

$\phi Mn = 0.9 \times 177.6 = 159.8$ t.m $\approx$ Mu (obvious)

$\therefore$ OK

use 10 ϕ20 bars, $As_{provided} = 31.42\ cm^2$

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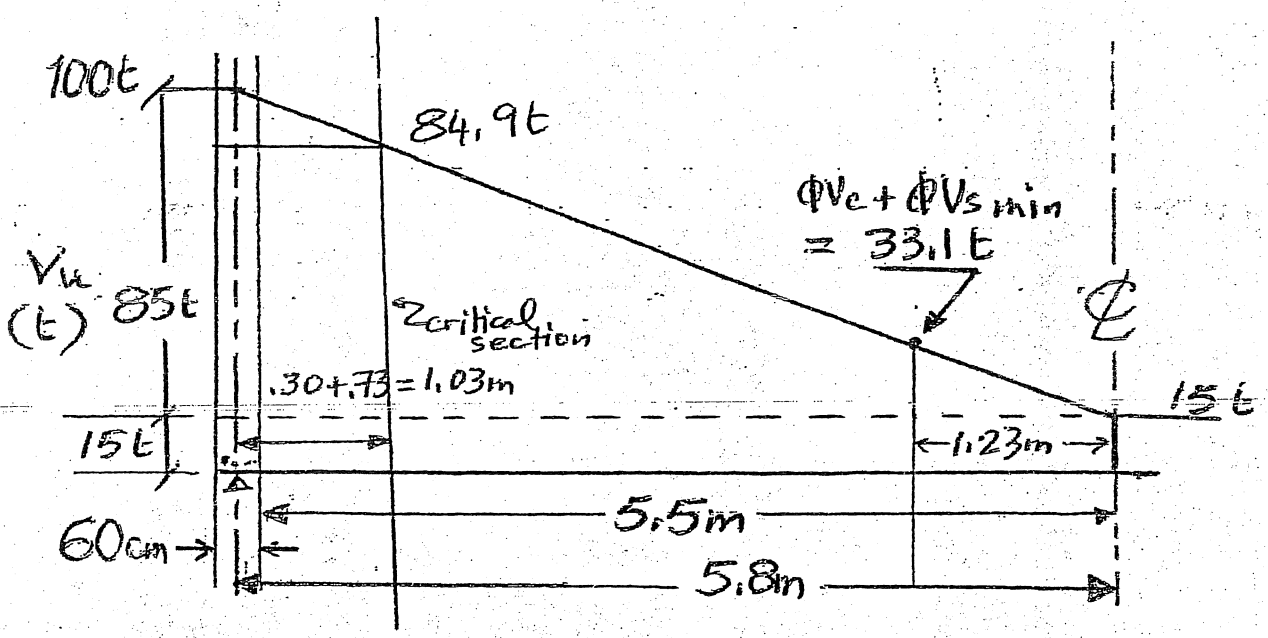
2. A beam has b = 50 cm, d = 73 cm, f_c' = 25 MPa, f_y = 400 MPa, and Φ 10 stirrups. The shear envelope for half of the span is provided. Determine:



a. (4 points) The distance "A" for which no or only minimum stirrup reinforcement is required.

$\phi V_{s\,min}$: $s_{max} = \dfrac{(1.57)(400)}{(0.062)\sqrt{25}(50)} = 40.5$ cm

$\leq \dfrac{(1.57)(400)}{0.35(50)} = 35.9$ cm controls

$\leq 73/2 = 36.5$ cm

≤ 60 cm

for $s = 35$ cm,

$\phi V_{s\,min} = \dfrac{(0.75)(1.57)(4)(73)}{35} = 9.82$ t

$\phi V_c = (0.75)(0.17)\dfrac{\sqrt{25}}{100}(50)(73) = 23.27$t

$\phi V_c + \phi V_{s\,min} = 9.82 + 23.27 = 33.1$ t

$\dfrac{(33.1-15)}{85}(5.8) = 1.23$ m

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Name: Key

Part 2 = 4 pages

Q4. (15 points) Circle the appropriate letter, T for true or F for false.

1. T (F) Under-reinforced sections do not have sufficient reinforcement to support the design moments.

2. (T) F Over-reinforced sections have more reinforcement than $A_{s,balanced}$.

3. (T) F Steel and concrete have similar rates of thermal expansion.

4. (T) F The minimum permissible reinforcement for doubly reinforced sections is the same as that for singly reinforced sections.

5. T (F) Concrete ordinarily requires about 7 days to attain adequate strength so that forms can be removed and construction and dead loads carried.

6. (T) F A tension-controlled section will exhibit a ductile failure mode with visible flexural cracks and deflection.

7. T (F) Minimum steel reinforcement in beams is required by the ACI Code to prevent cracking of the tension side of beams.

8. (T) F The nominal maximum size of coarse aggregate may not exceed 3/4 the minimum clear spacing between reinforcing bars.

9. T (F) If the actual steel reinforcement exceeds $A_{s,max\ at\ \varepsilon_{cu}=0.004}$ the compression side of the beam will not reach a crushing strain $\varepsilon_{cu} = 0.003$ at failure.

10. T (F) The modulus of rupture measures the shear strength of concrete.

11. T (F) Excessive deflection under ultimate loads is not permitted because it may result in objectionable cracking.

12. T (F) The strength reduction factor ϕ is intended as a safety factor against possible construction mistakes.

13. (T) F If a beam is supported on the side face of a girder, not a column, the critical section is taken at the face of support.

14. T (F) Welded wire fabric may be used as the main reinforcement for thin slabs and shallow beams.

15. T (F) The ACI Code does not allow using bar sizes that differ by more than 4 mm in diameter, together in the same layer, for beam reinforcement.

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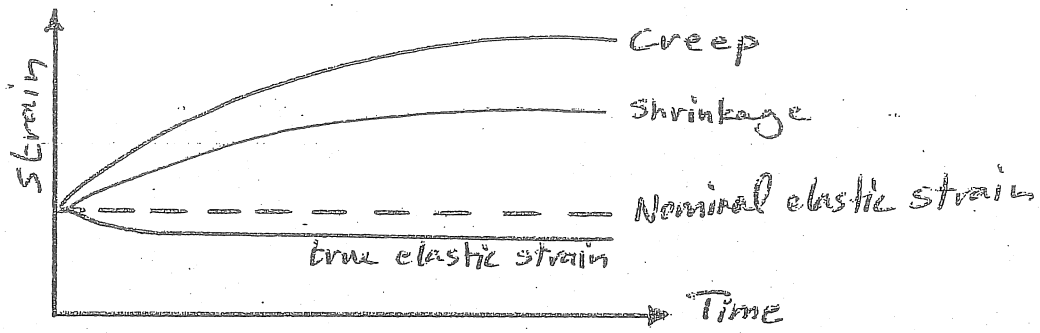
Q5. (2 points each) Answer briefly. Use sketches where appropriate.

a. Use a simple strain versus time diagram to explain the change in strain of a loaded and drying specimen. Consider elastic, creep, and shrinkage strains.



b. What is the working stress method?

The elastic stress computed under service load does not exceed a predesignated allowable value $f_{actual} \leq f_{allowable}$

c. What are the two requirements specified by the ACI code for adequate control of strength?

1- Every average of 3 consecutive strength tests (each test is the average of the strengths of two cylinders) equals or exceeds f_c'.

2- No individual strength test falls below f_c' by more than 3.5 MPa. (Average of 2 cylinders)

d. Explain the difference between fc' and fcr'.

f_{cr}' is the required average compressive strength used for proportioning the mix and must exceed the design strength f_c' by increasing amounts for increasing values of the standard deviation.

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e. What are over-reinforced sections?

Over reinforced sections have an amount of reinforcement in excess of $A_{s\,balanced}$ and exhibit a compression failure as the concrete crushes in compression before yielding of the tension steel.

f. What is the balanced strain condition and why is it not permitted for beams?

In this condition the concrete in compression crushes just as the tension steel reaches yielding.
It is not permitted for beams because the failure would be sudden without enough warning.

g. What is the purpose of using bolsters and chairs (bar supports) in construction?

To maintain proper bar spacing and concrete cover for reinforcement. Hold the bars in place properly during construction.

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