FINAL EXAMINATION

Open books, notes and any other material.
Time of Examination: 3 Hours

READ following notes:

1. **The total number of points exceeds 100 points**. However, your score may not exceed 100.

2. There will be **no credits** for correct "answers" which are not relevant to the question. There might be even deductions for such attempts.

3. **Budget your time according to your strength**. The questions are not in order of their difficulty. Start and solve in order of their difficulty for you, starting from the easiest.

4. Each problem should be solved **starting a new odd page** in the exam book.

5. **Optional:** At the end of the examination, please answer a few questions on the enclosed form (on the back of this page). **Do not sign it** and submit the page **separately** from your examination, if you wish to do so. Add additional pages if you think you need it. Your feedback is very important to us.

SUCCESS TO YOU IN YOUR EXAMINATION

and

SUCCESS IN YOUR ENGINEERING LIFE.

Andrei M Reinhorn, PE PhD
Professor
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Graduate Assistant

Have a nice holiday and winter vacation!!

Problem #1 TWO WAY SLAB (30 pts.)

Using load distribution method (based on equal deflections in mid spans), **determine the load distribution in each direction, determine the maximum moments and design the reinforcement** for all directions of <u>**ONE** panel</u> of the slab supported by beams (along all axes lines) shown in Fig 1 below. Assume a 4" thick slab and a service live load of 150 psf. The concrete is 3500-psi strength and the steel is GR50. [You may approximate the maximum moments using the suggested envelopes – see below - and you may assume k=0.2 for all cases to reduce computations] Indicate all your approximations!

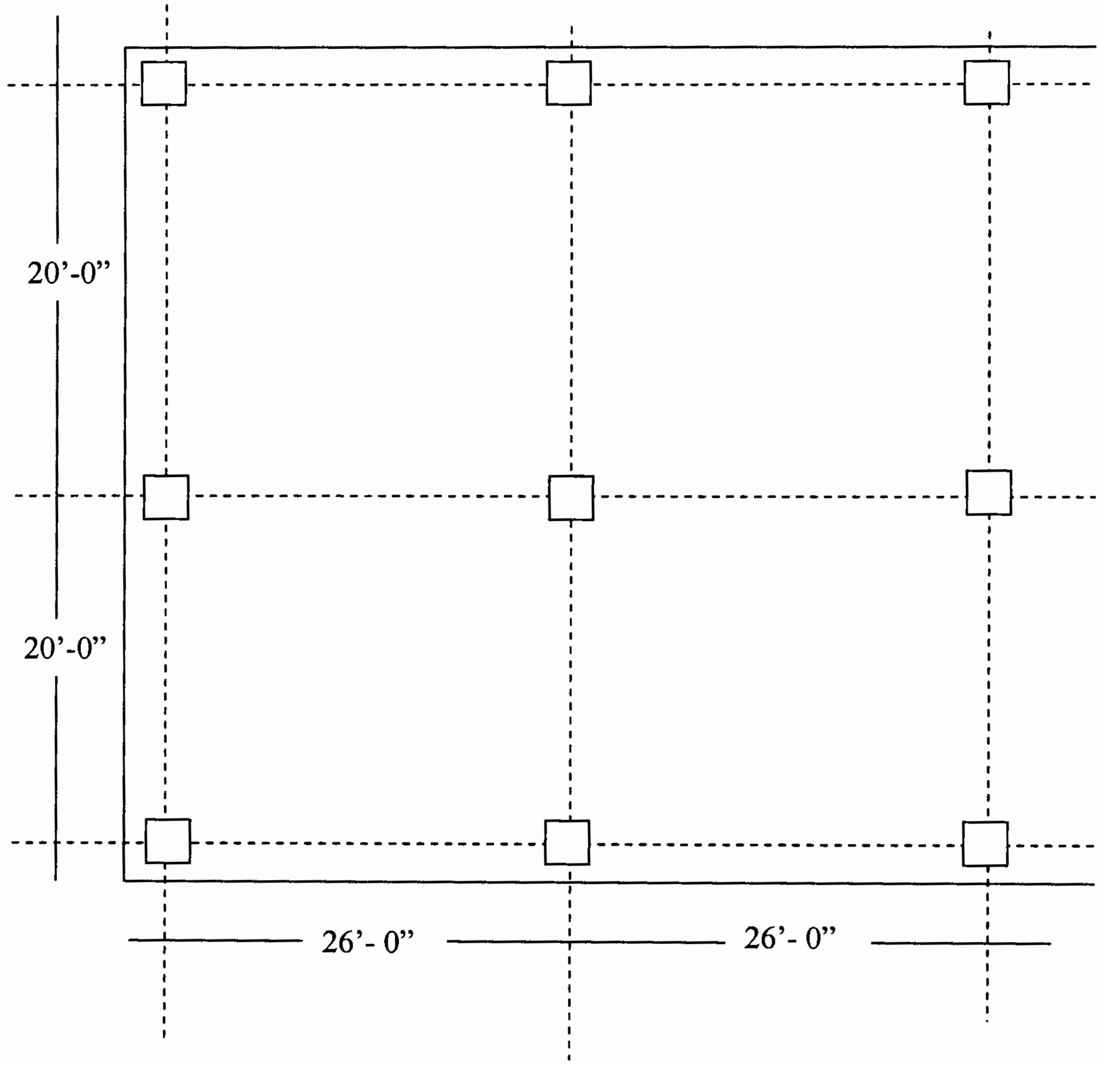
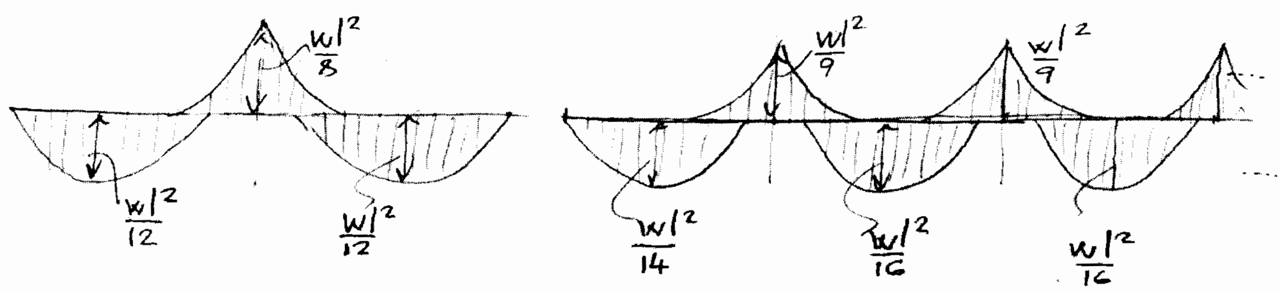


Fig 1 – Floor layout for Problem 1 (not in scale)



SUGGESTED APPROXIMATIONS FOR MOMENT ENVELOPES

Problem #2 EVALUATION OF BEAMS (40 pts.)

For the 15" x 28" rectangular beam, reinforced with 4#8 at both supports, and 3#8 in midspan as shown below, determine:

a) Determine the moment capacity in each of the critical sections (10 pts).

b) Determine how much total ultimate uniformly distributed load can be supported on this beam.(5 pts)

c) Assuming that the dead load is 35% of the total, determine the service live and dead load which can be supported by the beam. (5 pts)

d) Determine the amount of camber that you need in the forms during the casting of the beam such that the beam will be perfectly flat under half of the live load Use equivalent moment of inertia determined using midspan moment of inertia only (c_1=c_2=0, c_m=1) -(20 points).

Data: Concrete: 3000 psi, Steel: GR60; Cover: 3", E_s/E_c=9

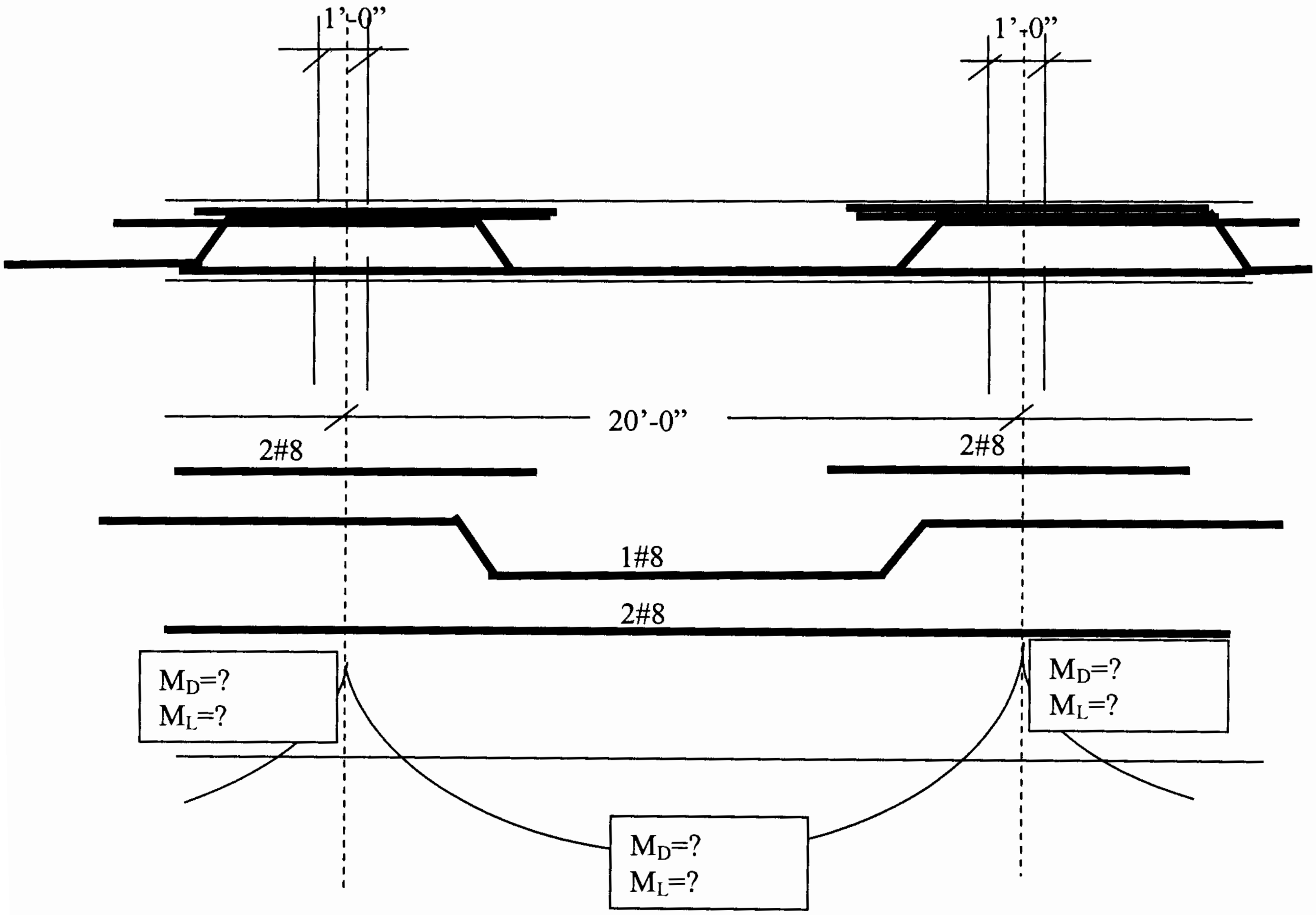


Fig 2 –Beam and moment diagram for Problem 2

Problem #3 Columns (30 pts).

1) Determine the ultimate capacity interaction diagram for the column below defined by two (optional three) points:
   a) Axial capacity without any moments (5 pts)
   b) Balanced failure of the column (18 pts)
   c) (Optional for 5 more points) Failure of the column with tension strain at extreme tensioned fiber equal to the double the yield strain of steel. (= 2 ϵ_y) – extreme tension fiber is at the edge of the column
2) Determine the design space derived from the capacity diagram developed in (1) above. (7 pts)

Notes:

Moments should be calculated about the symmetry axis of the section. Assume a tied column (no spiral reinforcement)

Data for the column:

Concrete: 4,000 psi, $\varepsilon_{cu} = 0.004$ *!!!!!* *Steel: 12#9 of GR60,*

Cover of reinforcing bars form the center of the bar (including the hoops): 3" – from axis of reinforcement to the outside surface in all places.

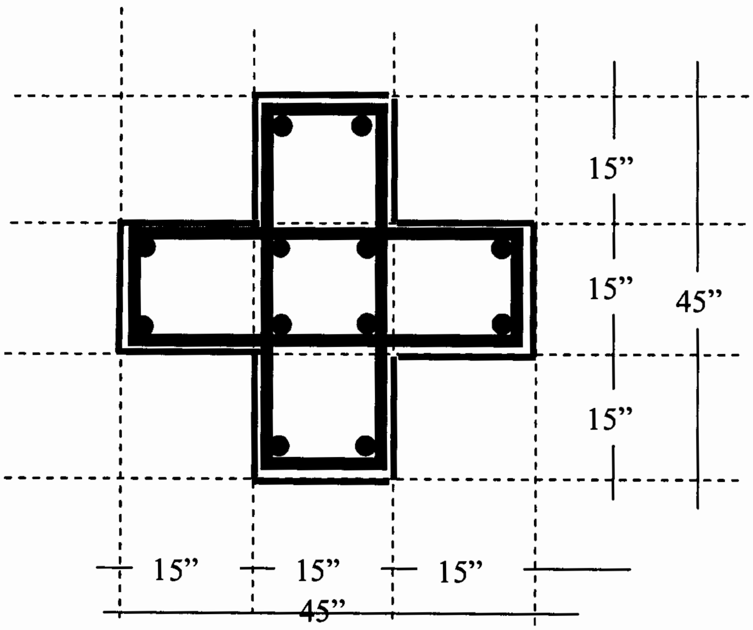


Fig 3 - Cross section of column in Problem #3

Problem #4 - CONCEPTS AND DETAILING (20 pts.)

For the retaining wall shown below indicate:

1) The expected deflected line of the retaining wall (5 pts)
2) The expected moment diagram due to lateral soil pressure. Assume in the lower level embedment is 9 times bigger than the pressure in the high level soil. (5 pts)
3) The location of the needed reinforcement (only the reinforcement required to compensate for tension in concrete) (5 pts)
4) The detailed required reinforcement and the details of the bars to be able to construct the wall. (5 pts)

ONLY APPROXIMATIONS ARE ALLOWED FOR THIS QUESTION. POINTS WILL BE DEDUCTED FOR ANY DETAILED COMPUTATIONS APPLIED HERE.

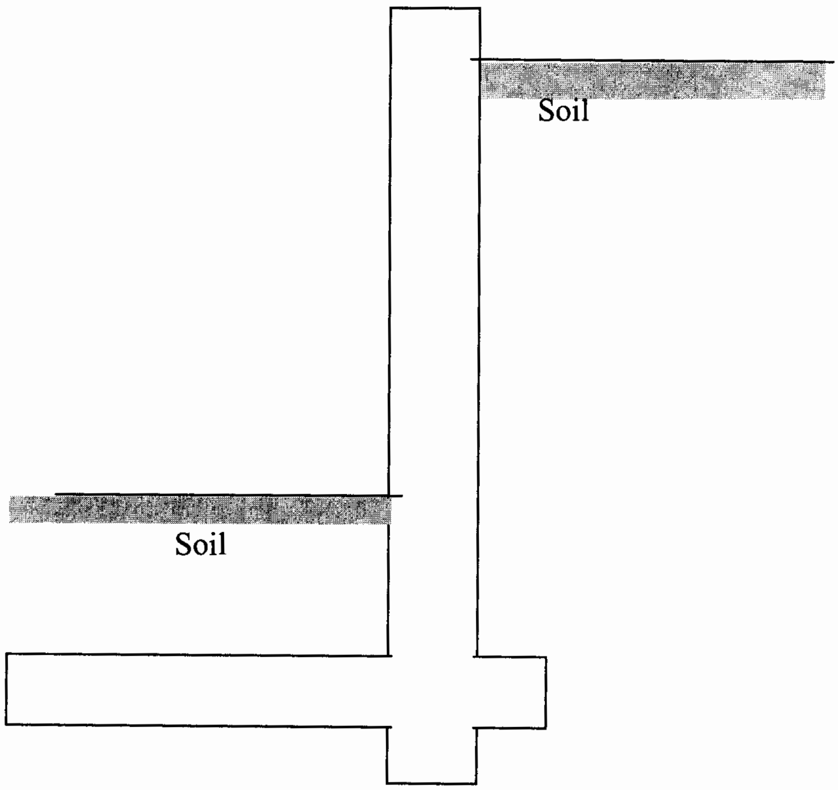
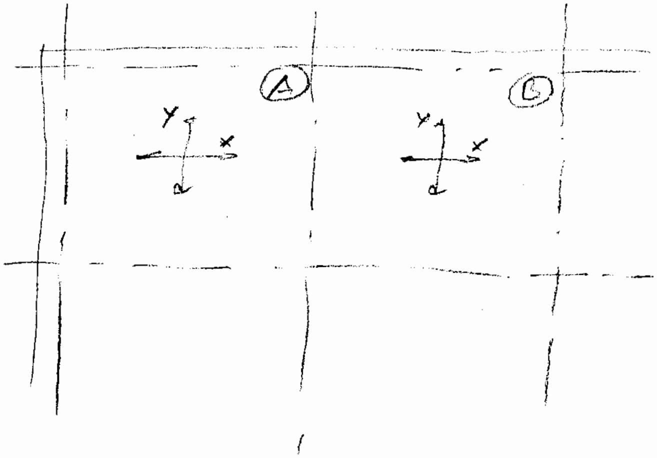


Fig 4 – Cross section for Question #4

Problem #1



The distribution will follow

$$\frac{w_x}{w_y} = \left(\frac{l_y^*}{l_x^*}\right)^4$$

Panel (A):

$l_x = 26'\text{-}0 \quad l_x^* \cong 0.8 \times 26 = 21.4\ ft.$

$l_y = 20'\text{-}0' \quad l_x^* \cong 0.8 \times 20 = 16.0\ ft$

$$\frac{l_y^*}{l_x^*} = \frac{16.00}{21.4} = \frac{1}{1.3375} \qquad \left(\frac{l_y^*}{l_x^*}\right)^4 = \frac{1}{3.20}$$

$$w_x = w_{TOT} \cdot \frac{1}{3.20+1} = \frac{w_{TOT}}{4.20} \qquad w_y = w_{TOT} \cdot \frac{3.20}{4.20} =$$

$= 0.233\ w_{TOT} \qquad = 0.662\ w_{TOT}$

Panel (B)

$l_x = 26.0 \qquad l_x^* = 0.6 \times 26 = 15.6'$

$l_y = 20'\text{-}0 \qquad l_y^* = 0.8 \times 20 = 16.00'$

$$\frac{l_y^*}{l_x^*} = \frac{16.0}{15.6} = 1.025 \qquad \left(\frac{l_y^*}{l_x^*}\right)^4 = 1.107$$

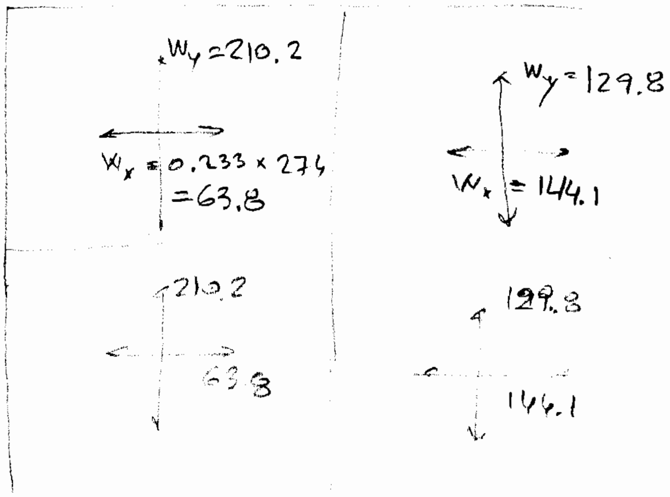
$$w_x = w_{TOT} * \frac{1.107}{2.107} = \qquad w_y = w_{TOT} \cdot \frac{1}{2.107} =$$

$= 0.526\ w_{TOT} \qquad = 0.474\ w_{TOT}$

TOTAL LOAD =

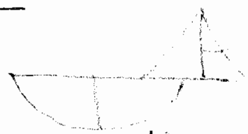
$w_D = \frac{4}{12} \times 150 = 50\ psf$ $\qquad w_L = 120\ psf$

$w_{tot} = 1.4 \times 50 + 120 \times 1.7 = 274.0$



Panel A

(X)



$\frac{wl^2}{9} = \frac{68.3 \times 26^2}{9} = 4795\ lb\text{-}ft/ft = 4.79\ k\text{-}ft/ft$

$A_s = \frac{4.79 \times 12 / 0.9}{50 \times 3.0 \times 0.9} = 0.0987 \times 4.79 = 0.47\ in^2/ft$

(#8@12) > min (0.78)

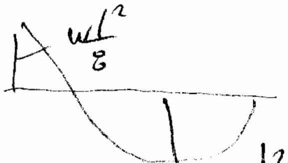
$\frac{wl^2}{14} = \frac{63.8 \times 26^2}{14} = 3082\ lb\text{-}ft/ft = 3.08\ k\text{-}ft/ft$

$A_s = 3.08 \times 0.10 = 0.30\ in^2/ft \gg min$

#6@12 (0.44)

$A_{s\,min} = 0.0018 \times 3 \times 12 = 0.065\ in^2/ft$

(Y)



$\frac{wl^2}{8} = \frac{210 \times 20^2}{8} = 10507.90$ $\qquad A_s = 0.1 \times 10.507 = 1.05\ in^2/ft$

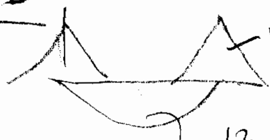
#7@7 > min

$\frac{wl^2}{12} = \frac{210.2 \times 20^2}{12} = 6004.5$ $\qquad A_s = 0.60\ in^2/ft$ > min

#7@12.

Panel B

(X)



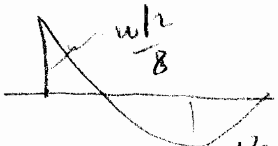
$\frac{wl^2}{9} = \frac{129.8 \times 26^2}{9} = 13.70\ k\text{-}ft$ $\qquad A_s = 0.1 \times 13.70 = 1.37\ in^2/ft$

#8@6

$\frac{wl^2}{16} = \frac{129.8 \times 26^2}{16} = 7.83\ k\text{-}ft$ $\qquad A_s = 0.78\ in^2/ft$

#8@12

(Y)



$\frac{wl^2}{8} = \frac{144 \times 20^2}{8} = 15.8\ k\text{-}ft$ $\qquad A_s = 1.58\ in^2/ft$

#7@7 + #7@14

$\frac{wl^2}{12} = \frac{144 \times 20^2}{12} = 10.14\ k\text{-}ft$ $\qquad A_s = 1.01\ in^2/ft$

#7@7

Problem #1 TWO WAY SLAB (30 pts.)

Using load distribution method (based on equal deflections in mid spans), **determine the load distribution in each direction, determine the maximum moments and design the reinforcement** for all directions of all panels of the slab supported by beams (along all axes lines) shown in Fig 1 below. Assume a 5" thick slab and a service live load of 120 psf. The concrete is 3500-psi strength and the steel is GR60. [You may approximate the maximum moments using the suggested envelopes – see below - and you may assume k=0.2 for all cases to reduce computations] Indicate all your approximations !

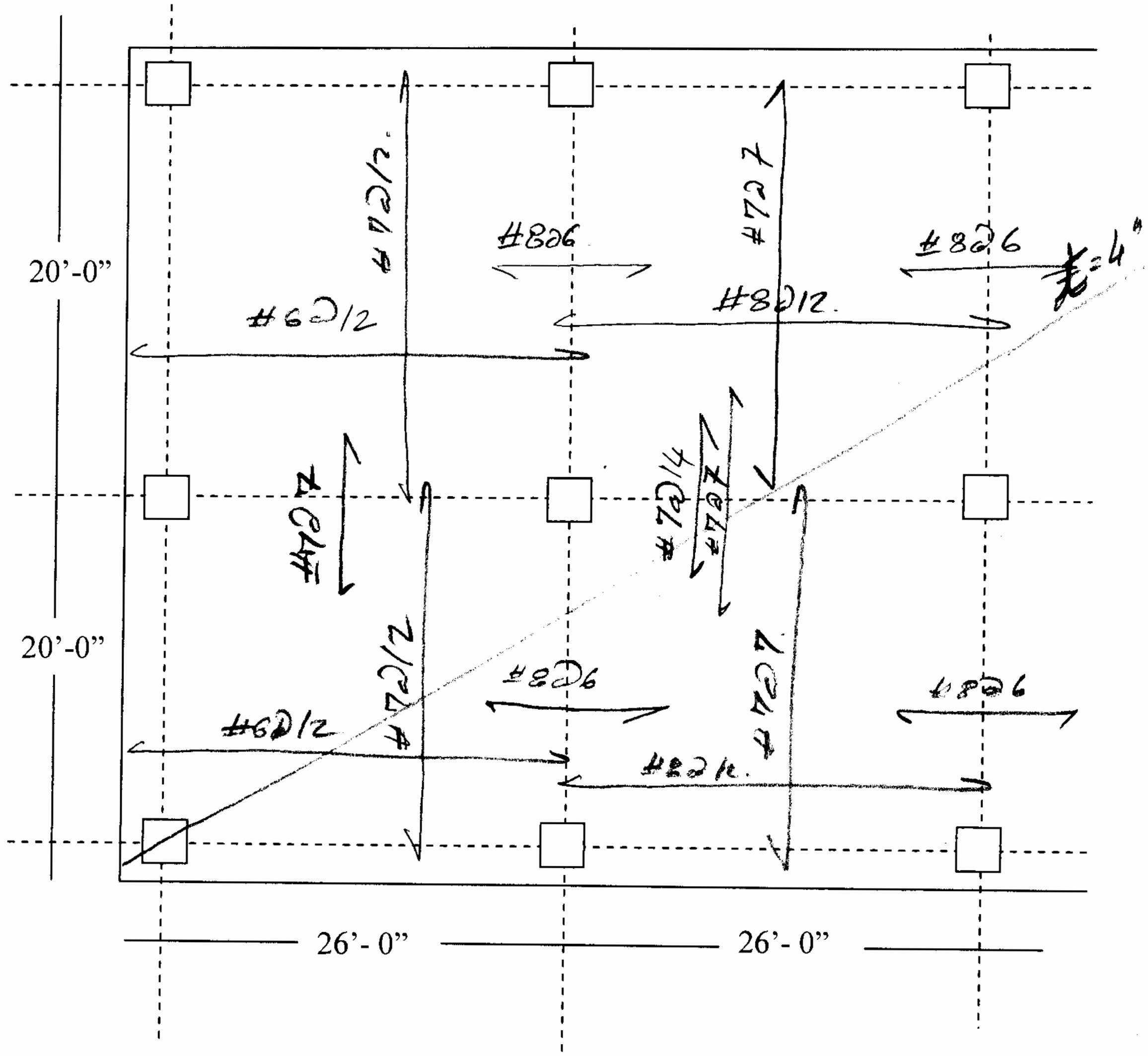
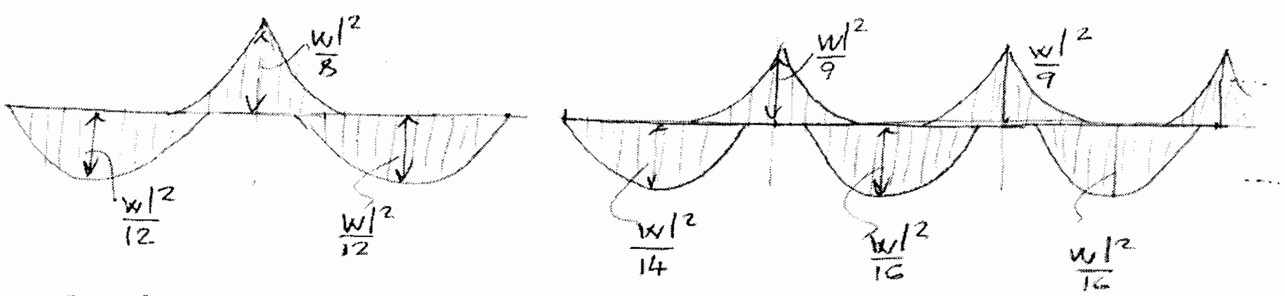
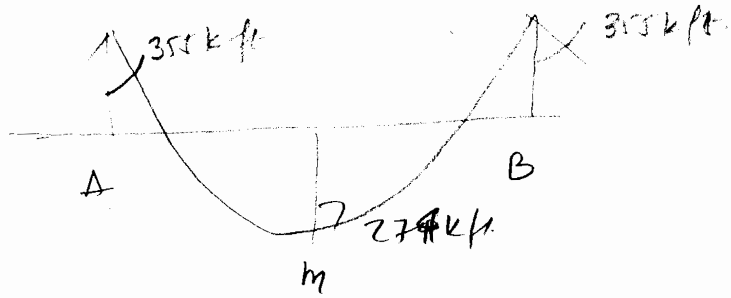


Fig 1 – Floor layout for Problem 1 (not in scale)



SUGGESTED APPROXIMATIONS FOR MOMENT ENVELOPES

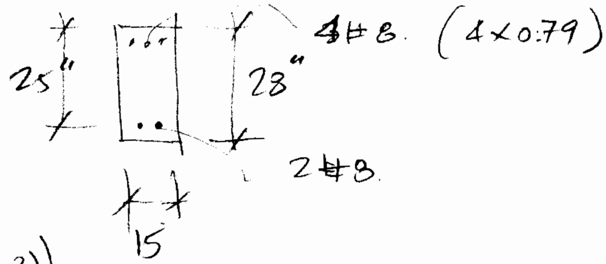
Problem #2



(a) Moment capacity:

A ≡ B = $f_c' = 3$ ksi $f_y = 60$ ksi

$d = 25''$ $\varepsilon_y = 0.002$



$A_s = 4 \times 0.79 = 3.16 \text{ in}^2$

$A_s' = 2 \times 0.79 = 1.58 \text{ in}^2$

$$k = \frac{60}{0.85 \times 3.0}\left(\frac{3.16}{25 \times 15} - \frac{1.58}{25 \times 15}\left(1 - \frac{0.85 \times 3}{60}\right)\right) = 0.103$$

$=$

$$\varepsilon_y' = 0.002 \cdot \left(\frac{0.103 - 0.85 \cdot (3/25)}{0.103}\right) = 0.00002 \cong 0.00 \text{ (no contribution)}$$

recalculate k:

$$k = \frac{60}{0.85 \times 30} \times \frac{3.16}{25 \times 15} = 0.193$$

$$M = 3.16 \times 60 \times 25\left(1 - \frac{0.193}{2}\right) =$$

$= 4266 \text{ k-in} = \underline{355 \text{ k-ft}}$

MIDSPAN

$A_s = 3 \times 0.79 = 2.37 \text{ in}^2$

$$k = \frac{60}{0.85 \cdot 3} \times \frac{2.37}{25 \times 15} = 0.150$$

$$M = 2.37 \times 60 \times 25\left(1 - \frac{0.15}{2}\right) =$$

$= 3288 \text{ K in} = \underline{274 \text{ k ft}}$

(b) Ultimate load for $l = 20$ ft span

$$\frac{wl^2}{8} = M_{TOT,0} = 355 + 274 = 629 \text{ k-ft}$$

$$W_{TOT} = \frac{8 \times 629}{20^2} = 12.58 \text{ k/ft}$$

$W_D = 0.35\,w \qquad W_L = 0.65\,w$

$W_{TOT} = 1.4 \times 0.35 w + 1.7 \times 0.65 w$

$w = W_{TOT} / (1.4 \times 0.35 + 1.7 \times 0.65) = 0.63\, W_{TOT} = 0.63 \times 12.58 = 7.89\ K/ft$

$W_D = 0.35 \times 7.89 = \underline{2.76}\ K/ft \qquad (0.35 \times 0.63)\, W_{TOT} =$

$W_L = 0.65 \times 7.89 = \underline{5.12\ K/ft}$

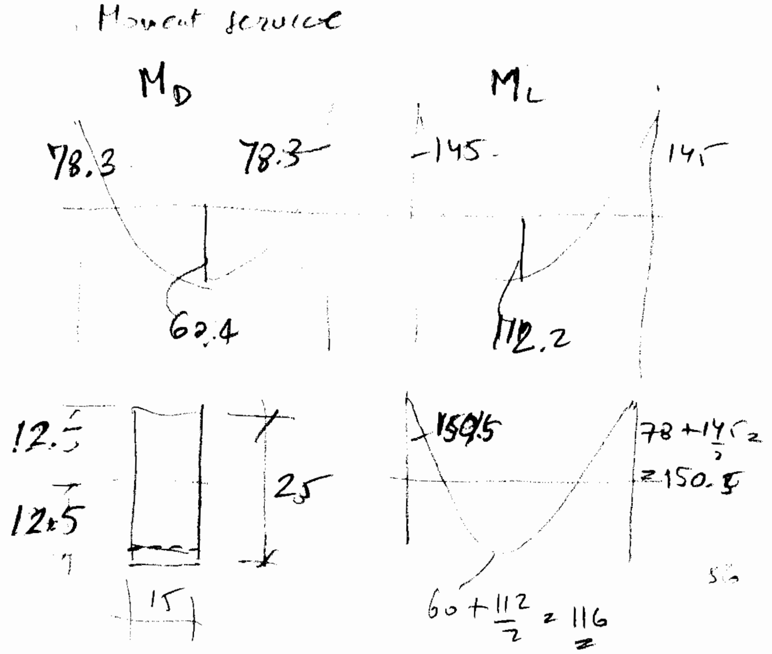
(d) Deflections due to dead load & liveload × 0.5 = require service data.

$M^{\ominus}_{D(5)} = 0.35 \times 0.63 \times 355 = 78.3$

$M^{+}_{D(1)} = 0.35 \times 0.63 \times 274 = 60.4$

$M^{-}_{DL} = 0.65 \times 0.63 \times 355 = 145.3$

$0.65 \times 0.63 \times 274 = 112.2$



$I_{gr} = \frac{15 \times 25^3}{12} = 19531\ in^4$

$M_{cr} = \frac{I}{y} \cdot I_g = \frac{7.5\sqrt{3000}}{12.5} \times 19531 =$

$= 641862\ lb\text{-}in = 641.8\ K\text{-}in = 53.48\ k\text{-}ft.$

All cases section will be cracked ⇒ check mid section only

$k_{cr} = -0.0063 \times 9 + \sqrt{0.0063 \times 9 + 2 \cdot 0.0063 \times 9} = \qquad \rho = \frac{2.37}{15 \times 25} = 0.63\% \quad n = 9$

$= 0.285$

$x_{cr} = 0.285 \times 25 = 7.14\ in.$

$I_{cr} = \frac{15 \times 25^3}{} \left[\frac{0.285^3}{3} + 0.0063 \times 9 \cdot (1 - 0.285)^2 \right] = \underline{8626\ in^4}$

$\left(I^D_{eq} = \left(\frac{53.5}{60.4}\right)^3 \times 19531 + \left[1 - \left(\frac{53.5}{60.4}\right)^3\right] \times 8626 = 16204\ in^2 \right)$ not necessary

$$I_{eq}^{D+L/2} = \left(\frac{53.5}{116}\right)^3 \times 19531 + \left[1 - \left(\frac{53.5}{116}\right)^3\right] 8626 = 9695 \text{ in}^4.$$

$$\delta_{D+L/2} = \frac{L^2}{48 E I_{eq}} * (5M_o - 3M_a - 3M_B) =$$

$$= \frac{(20 \times 12)^2}{48 \times 3.500 * 9695} \left(5 * (\underset{(k\text{-}ft)}{116} + 152.5) - 3(150.5 + 150.5) \right) =$$

$$= 0.17 \text{ in}$$

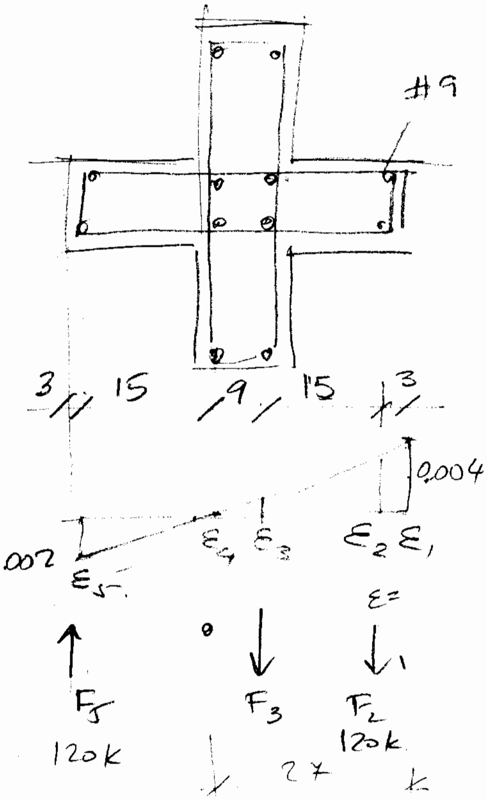
CAMBER THE FORMS BY ~0.17 in. SAY 0.2"

Problem #3

(a) Axial capacity

$$N = (45\times45 - 4\times15\times15)\,0.85\times4.0 + $$
$$+12\times1.0\,(60 - 0.85\times4.0) =$$
$$= 4504 \text{ kips}$$

$M = \emptyset$



(b) $\varepsilon_y = 60/29000 = 0.00207 \approx 0.002$

$\varepsilon_1 = 0.004$

$$\varepsilon_2 = \frac{(15+9+15)}{(15+9+15+3)} \times (0.004+0.002) - 0.002 =$$
$$= 0.0036$$

$$\varepsilon_3 = \frac{(15+9)}{42} \times (0.004+0.002) - 0.002 =$$
$$= 0.00143$$

$$\varepsilon_4 = \frac{15}{42} \times 0.006 - 0.002 =$$
$$= 0.00014 \approx 0.0.$$

$\varepsilon_5 = -0.002.$

$F_2 = \underbrace{0.0036\times29000}_{>60} \times 2\times1.0 = 60\times2\times1 = 120\text{k}.$

$F_3 = 0.0143\times29000\times4\times1 = 16.57$ kips

$F_4 = 0$

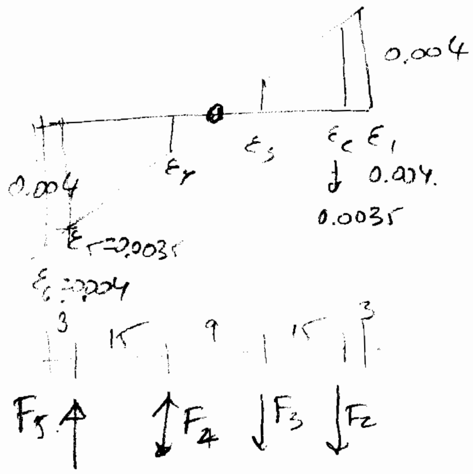
$F_5 = 0.002\times29000\times2\times1 = 60\times2\times1 = 120\text{k}$

$F_{concrete} = (27\times45 - 2\times15^2)\times0.85\times4.0 = 2601\text{ K}$ ‖ $(27\times45\times0.85\cdot4 = 4131$ | centroid 13.5; $15\times15\times0.85\times4 = 1530$ | center at 7.5.

$$N = 2601 + 120 + 16.57 - 120 = \underline{2617.6\text{ K}}.$$

$$M = 4131\times(22.5-13.5) - 1530\times(22.5-7.5) + 120\times(22.5-3) +$$
$$+ 16.57\,(22.5-18) + 120\times(22.5-3.0) = 18983 \text{ K-in} = \underline{1581} \text{ K-ft}$$

(c)



$\varepsilon_1 = 0.004$

$\varepsilon_2 = \frac{42}{45} \times 0.008 - 0.004 = 0.0035$

$\varepsilon_3 = \frac{27}{45} \times 0.008 - 0.004 = 0.0008$

$\varepsilon_4 = \varepsilon_3$

$\varepsilon_5 = \varepsilon_2$

$\varepsilon_6 = \varepsilon_1$

$F_2 = 60 \times 2 \times 1 = 120K \downarrow$

$F_3 = 0.008 \times 29000 \times 4 \times 1.0 = 92.8K \downarrow$

$F_4 = 92.8K \uparrow$

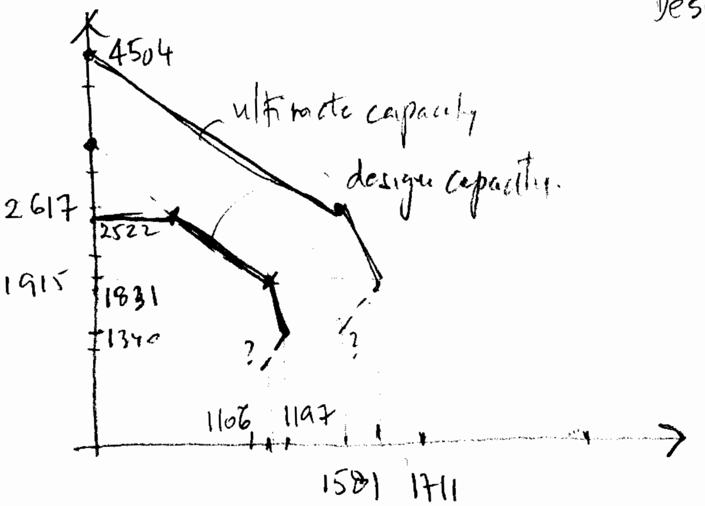
$F_5 = 120K \uparrow$

$F_c = 22.5 \times 45 \cdot 0.85 \times 4.0 - 2 \times 15^2 \times 0.85 \times 4.0 = 3442.5 - 1530 = \underline{\underline{1912.5K}}$

$N = 1912 + 120 + 92.8 - 92.8 - 120 = \underline{\underline{1912.5 \text{ Kips}}}$

$M = 3442.5\left(22.5 - \frac{22.5}{2}\right) + 120\,(22.5 - 3) \times 2 + 92.8 \times (22.5 - 18) -$
$- 1530\,(22.5 - 7.5) = = = = \underline{\underline{20532 \text{ K-in}}} = \underline{\underline{1711 \text{ K-ft}}}$

Diagram



Design values $4504 \times 0.70 = 3152$.

$2617 \times 0.7 = 1832$. $1581 \times 0.7 = 1106$

$1915 \times 0.7 = 1340$ $1711 \times 0.7 = 1197$

$1832 \times 0.80 = 2522$