Name: SOLUTION

University of California at Berkeley
Civil and Environmental Engineering

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CEE 123 -- Design of Reinforced Concrete Structures

Midterm Examination 1 (Open Book)

Normal weight concrete with a compressive strength of **4,000 psi** may be assumed. Reinforcement is **Grade 60** deformed steel bars. Interior exposures may be assumed.

ACI recommendations should be followed, unless a question requests a solution based entirely on theory.

Please identify any assumptions you make, and clearly identify (underline) your solutions.

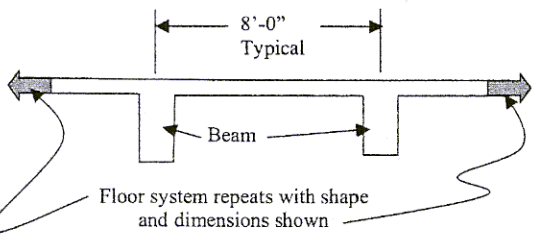
1. _____ (15)
2. _____ (40)
3. _____ (45)

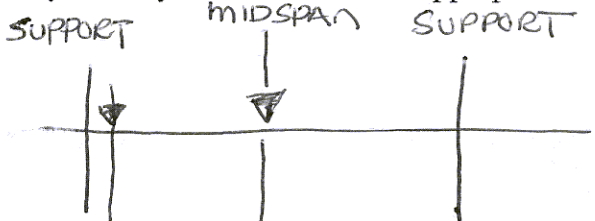
TOTAL: _____ (100)

Good Luck!

Problem 1

A monolithic floor framing system consists of a slab on beams and girders. The slab is 6 inches thick and the beam is 12 inches wide and 30 inches tall. The beam is lightly reinforced so that the neutral axis is very close to the compression face. The beams are 20 feet long and regularly spaced at 8 ft on center. In computing the moment capacity of the beam at its support AND at its midspan, what should the appropriate width of the beam should be used in the standard equation for computing M_n for a singly reinforced concrete beam having a rectangular shape? Clearly identify what value of b is appropriate at each location.

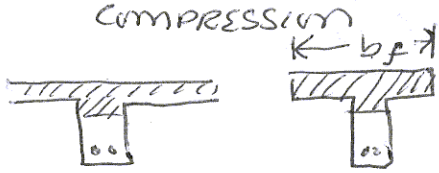




@SUPPORT TENSION IS AT TOP OF SECTION

$b = b_w = 12"$

@MIDSPAN TOP IS IN COMPRESSION



$b_f = \frac{L}{4} = 20/4 = 5' = 60"$

$= \text{SPACING}/2 = 8' = 96"$

$= b_w + 16t_s = 12 + 16(6)$

$= 9' = 108"$ CONTROLS

5 for concept
5 for support
5 for midspan

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Problem 2

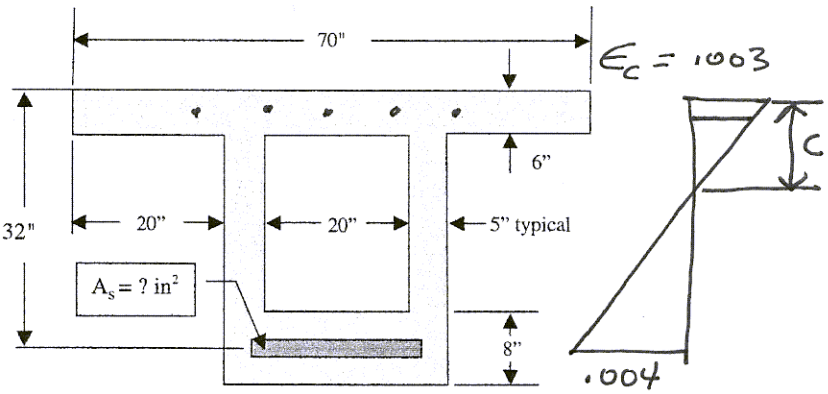
The singly reinforced beam shown below is to be provided with the maximum amount of tension steel reinforcement allowed by the ACI Code for a tension controlled or "under reinforced" design. You need not pick the specific bars. Do not check bar spacing, cracking, deflection or shear.

(15) (15) (10)

a. How much steel is allowed?

b. What is the maximum nominal moment capacity M_n that the beam can resist when this amount of steel is provided?

c. If you need to increase the moment capacity of the beam by 25%, without changing the shape or size of the section, what would you do? If you add steel reinforcement, how much would you add, and where would you place it? You need not determine the number or size of bars.



a. location of c when maximum steel is used

$$\frac{\epsilon_c}{c} = \frac{\epsilon_t + \epsilon_c}{d} \rightarrow c = \frac{\epsilon_{cu}}{\epsilon_{cu} + \epsilon_t} d = \frac{0.003}{0.007} d = \frac{3}{7} d$$

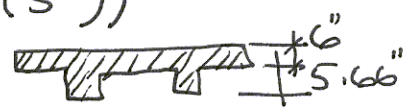
$$= \frac{3}{7} \cdot 32'' = 13.71''$$

$$\beta_1 c = 0.85(13.71) = 11.66''$$

EQUILIBRIUM TO GET AREA OF STEEL TO BALANCE C

$$A_s f_y = 0.85 f'_c \left(70'' \times 6'' + (11.66 - 6) 2(5'')\right)$$

$$= 3.4\ (420 + 56.6)$$



$$A_s = \frac{3.4(476.6)}{60} = \underline{27.0\ in^2}$$

b. $M_n = 0.85 f'_c \left(420(32-3) + 56.6(32-6-5.66/2)\right)$

$(32-3) = 29''$ → $420(29) = 12180$

$(32-6-5.66/2) = 23.17''$ → $56.6(23.17) = 1311.4$

$$= 3.4(13491.4) = \underline{45,871\ k\text{-}in} = \underline{3823\ k\text{-}ft}$$

c. Increase M by $.25 M_n = 11,468$ k-in

Increment of moment by adding A'_s to top and bottom is

$$\Delta M = A'_s f_y (d - d') \Rightarrow A'_s = \frac{11468}{60(32-3)} = \underline{6.6\ in^2}$$

$A'_s = 6.6\ in^2$

$A_s + A'_s = 27 + 6.6 = 33.6\ in^2$

does compression steel yield?

$\epsilon'_s = \frac{c - d'}{c} 0.003 = \frac{13.71 - 3}{13.71} 0.003 = 0.00234 > \epsilon_{sy}$

Extra page for calculations

3

$$\frac{c}{0.003} = \frac{c-d'}{\epsilon_s'}$$

$$\epsilon_s' = \frac{c-d'}{c}\,0.003$$

$\epsilon_s' > \epsilon_y \rightarrow$ YIELDING

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Problem 3

The beams self-weight may be assumed to be 0.8 kips/ft (i.e., this includes an allowance for the actual weight of the beam - do not recalculate the dead load based on the actual size you estimate for the beam). The beam supports a single concentrated live load at its end equal to 40 kips.

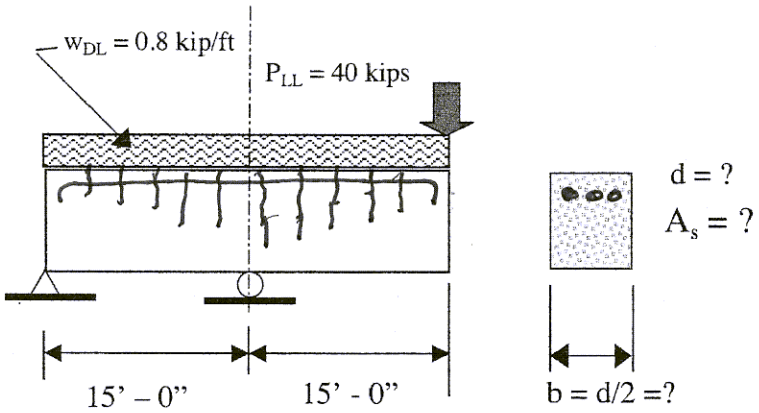
15 a. What is the maximum ultimate moment you must design this beam to resist for the loads specified?

15 b. If the beam effective depth d is set equal to twice the width b, and the longitudinal reinforcement ratio is 1.0%, what are the desired dimensions of the beam (you need not round these to integer sizes)? What area of steel is required for this beam?

5 c. Is the resulting beam deep enough according to the ACI code that you need not check deflection?

5 d. In the sketch, clearly indicate where the rebars are to be located in the section and elevation.

5 e. In the sketch, clearly indicate the basic flexural cracking pattern you would expect in the beam.



(a) $M_u = 1.6(40)15' + \frac{1.2(0.8)15^2}{2} = 960 + 108 = 1068\ k\text{-}ft$ (12816 k-in)

b. $M_n = \rho b d^2 f_y \left(1 - 0.59\rho\frac{f_y}{f_c'}\right)$

$\frac{1068(12)}{0.9} = 0.01\left(\frac{d}{2}\right)d^2(60)\left(1 - 0.59(0.01)\frac{60}{4}\right)$

$12816\ k\text{-}in = (\rho\ 0.3\ d^3)\left(\frac{1 - 0.0885}{0.9115}\right)$

$d^3 = 46867.8/0.9 = 52075.3$

$d = 37.34"$ $\quad b = 18.67"$

$A_s = 0.01(b)(d) = 0.01(18.7")(37.3") = 6.97\ in^2$

c. cantilever beam Table 9.5a GOVERNS

$\frac{L}{8} = \frac{(15)(12")}{8} = 22.5"$ { SIMPLY SUPPORTED $\frac{L}{16} = \frac{(15)(12")}{16} = 11.25"$

BEAM IS DEEP ENOUGH.

d. see above

e. see above.