

Concrete Beam Analysis 3/15

HW – Concrete Beam Analysis

Lab – Flexural Strain

Structure II
Section 004

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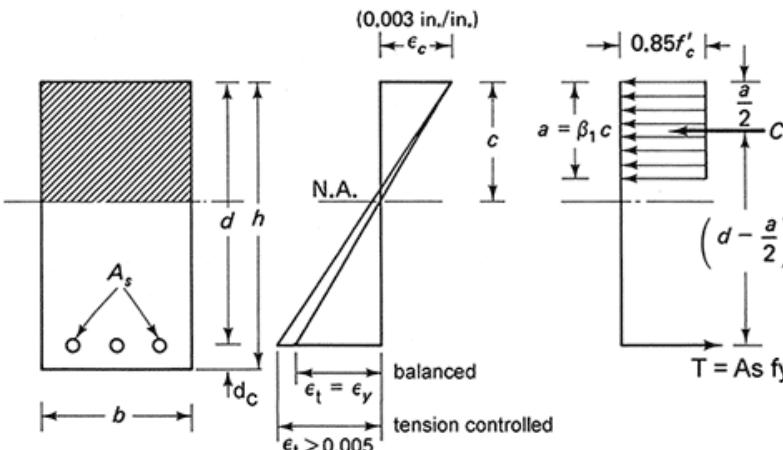
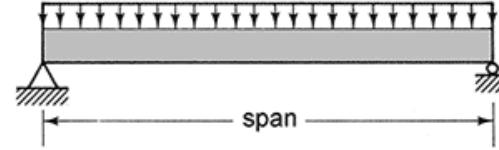


8. Concrete Beam Analysis

Analyze the given composite floor system. Using a transformed section, determine peak stress values in both concrete and steel.

DATASET: 1 -2- -3-

simple span	17 FT
section width, b	14 IN
section height, h	25 IN
max. aggregate size	0.75 IN
bar size number	5
the number of bars	6
stirrup bar size number	3
concrete cover	1.5 IN
concrete ultimate strength, f'_c	6500 PSI
steel yield strength, f_y	60000 PSI



HW - Concrete Beam Analysis

Data:

Section dimensions – b, h, d, (span)

Steel area - A_s

Material properties – f'_c , f_y

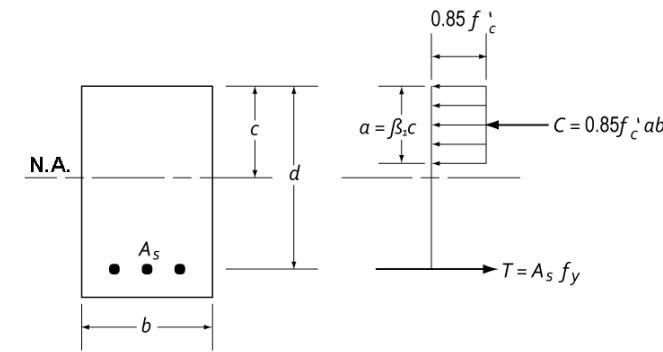
Required:

Nominal Strength (of beam) Moment - M_n

Required (by load) Design Moment – M_u

Load Capacity

1. Calculate d
2. Check A_s min
3. Calculate a
4. Determine c
5. Check that $\epsilon_t \geq 0.005$ (tension controlled)
6. Find nominal moment, M_n
7. Calculate required moment, $\phi M_n \geq M_u$
(if $\epsilon_t \geq 0.005$ then $\phi = 0.9$)
5. Determine max. loading



A_s min: greater of a and b

$$(a) \frac{3\sqrt{f'_c}}{f_y} b_w d$$

$$(b) \frac{200}{f_y} b_w d$$

$$a = \frac{A_s f_y}{0.85 f'_c b} \quad c = \frac{a}{\beta_1}$$

$$\epsilon_t = \frac{d - c}{c} 0.003 \geq 0.005$$

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

$$M_u = \frac{(1.2w_{DL} + 1.6w_{LL})l^2}{8}$$

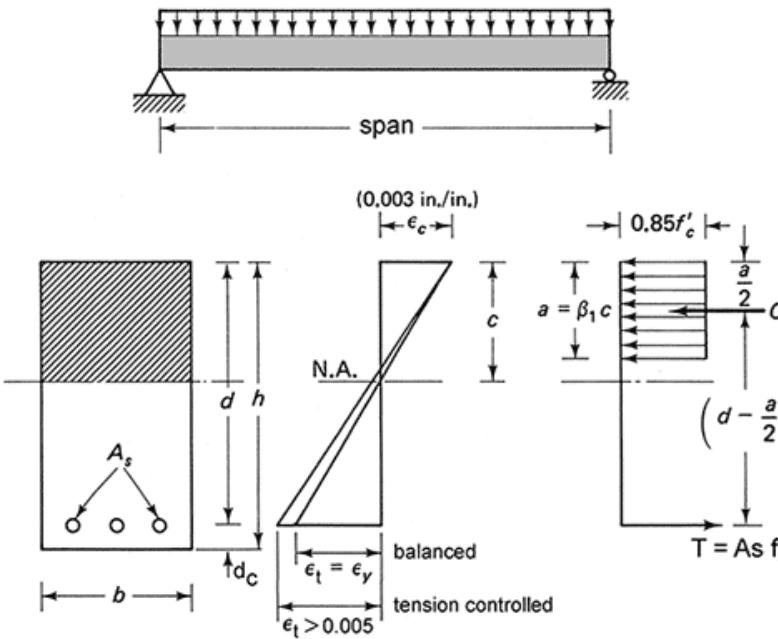
$$1.6w_{LL} = \frac{M_u 8}{l^2} - 1.2w_{DL}$$

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1. flexural steel bar diameter, db

$$dbf = 0.625 \text{ in}$$

Bar size designation	Nominal cross section area, sq. in.	Weight, lb per ft	Nominal diameter, in.
#3	0.11	0.376	0.375
#4	0.20	0.668	0.500
#5	0.31	1.043	0.625
#6	0.44	1.502	0.750
#7	0.60	2.044	0.875
#8	0.79	2.670	1.000
#9	1.00	3.400	1.128
#10	1.27	4.303	1.270
#11	1.56	5.313	1.410
#14	2.25	7.650	1.693
#18	4.00	13.600	2.257

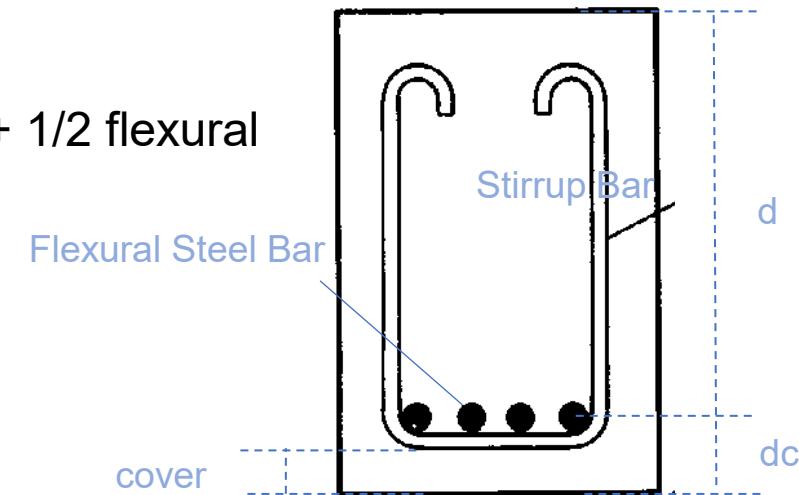
2. stirrup bar diameter

$$dbs = 0.375 \text{ in}$$

3. distance from lower beam edge to center of flexural steel, dc

$$dc = \text{cover} + \text{stirrup bar diameter} + \frac{1}{2} \text{flexural steel bar diameter}$$

$$dc = 1.5 + 0.375 + \frac{1}{2} * 0.625 \\ = 2.1875 \text{ in}$$



4. distance from top beam edge to center of flexualsteel, d

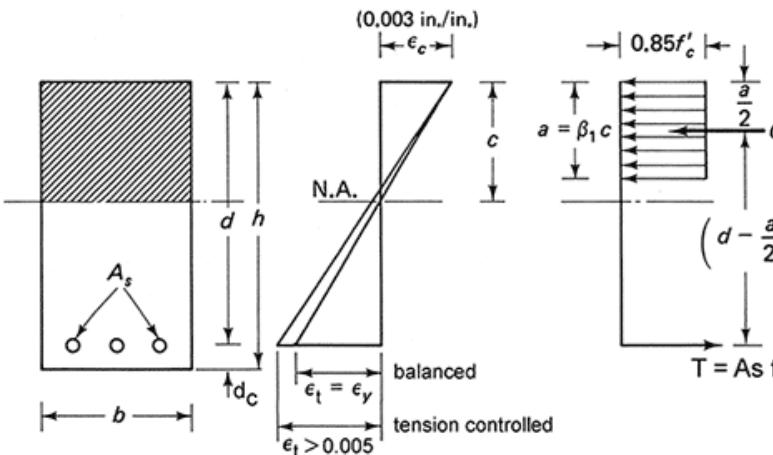
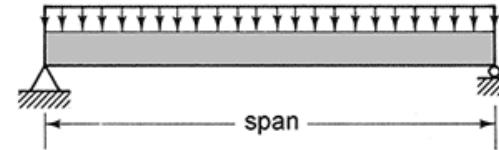
$$d = h - dc = 25 - 2.1875 = 22.8125 \text{ in}$$

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5. minimum required area of steel, A_s, min (greater of the 2 criteria)

As,min: greater of a and b

$$(a) \frac{3\sqrt{f'_c}}{f_y} b_w d = 3 * \frac{\sqrt{6500}}{60000} * 14 * 22.8125 = 1.287 \text{ in}$$

$$(b) \frac{200}{f_y} b_w d = \frac{200}{60000} * 14 * 22.8125 = 1.065 \text{ in}$$

6. actual area of flexural steel, A_s

$$A_s = \text{number of bars} * \text{bar area} = 6 * 0.31 = 1.86 \text{ in}^2$$

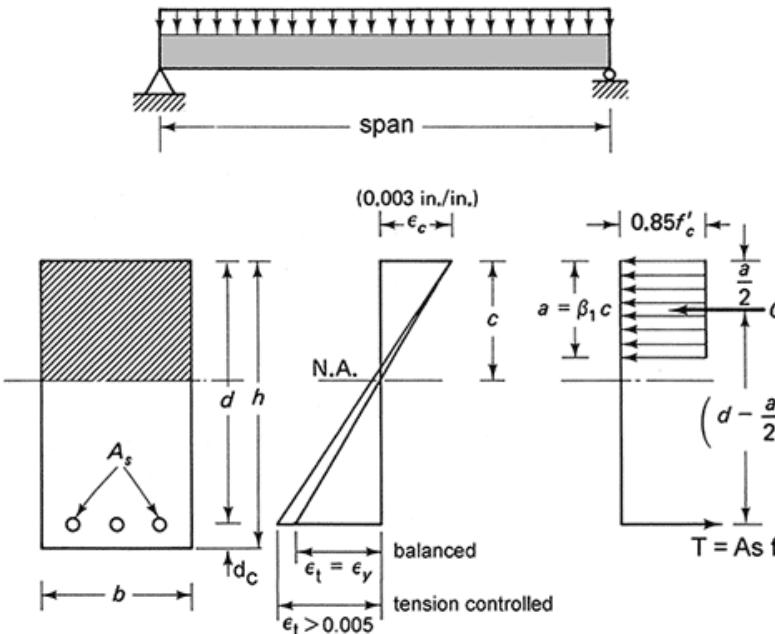
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8. Concrete Beam Analysis

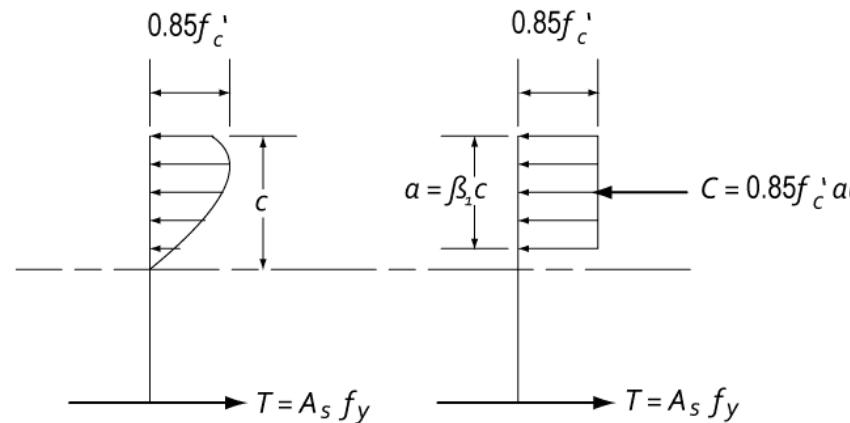
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7. depth of concrete stress block, a



$$C = T$$

$$0.85f'_c ab = A_s f_y$$

solving for a ,

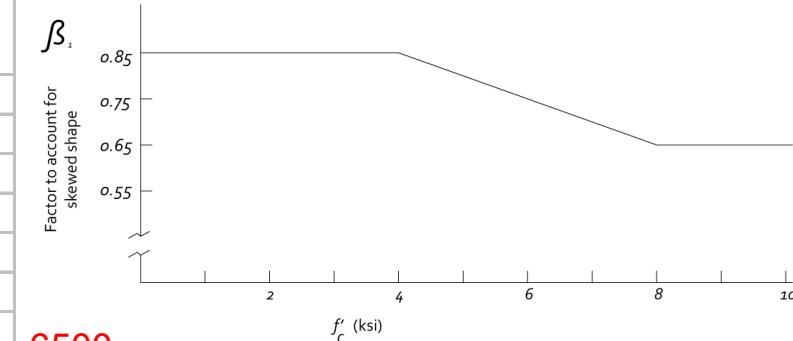
$$a = \frac{A_s f_y}{0.85f'_c b} = \frac{\rho f_y d}{0.85f'_c}$$

$$a = A_s * f_y / (0.85 * f'_c * b) = 1.86 * 60000 / (0.85 * 6500 * 14) = 1.44 \text{ in}$$

8. factor beta_1

β_1 is a factor to account for the non-linear shape of the compression stress block.

f'_c	β_1
0	0.85
1000	0.85
2000	0.85
3000	0.85
4000	0.85
5000	0.8
6000	0.75
7000	0.7
8000	0.65
9000	0.65
10000	0.65



6500

$$0.85 \geq 0.85 - 0.05 \left(\frac{f'_c - 4000}{1000} \right) \geq 0.65$$

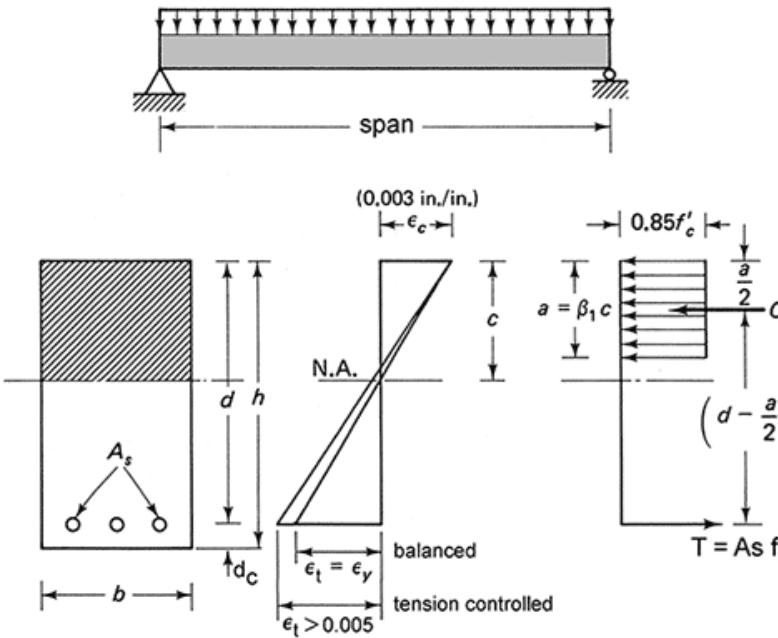
$$\beta_1 = 0.85 - 0.05 * (f'_c - 4000) / 1000 = 0.85 - 0.05 * (6500 - 4000) / 1000 = 0.725$$

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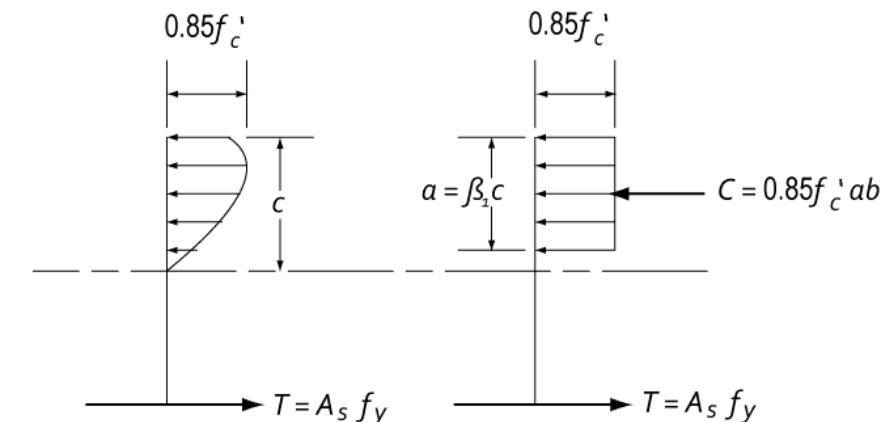
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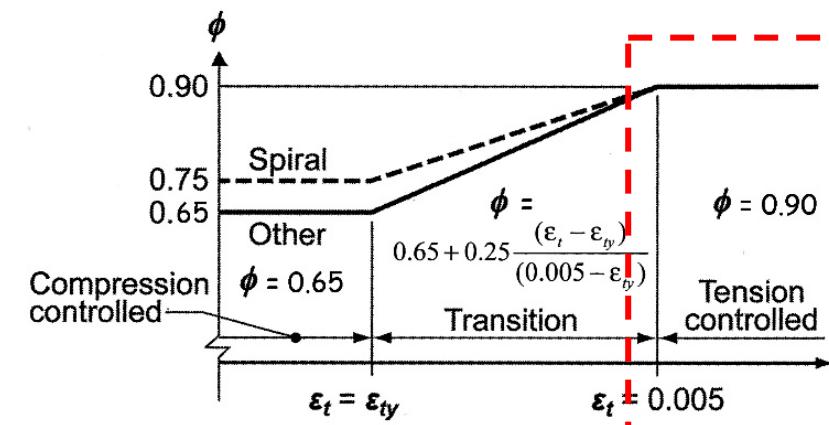
9. distance to Neutral Axis from top of beam, c

$$c = a / \beta_1 = 1.44 / 0.725 = 1.99 \text{ in}$$



10. strain in flexural steel, epsilon_t

Check that $\epsilon_t \geq 0.005$ (tension controlled)



$$\epsilon_t = \frac{d - c}{c} 0.003 \geq 0.005$$

$$= (22.8125 - 1.99) * 0.003 / 1.99$$

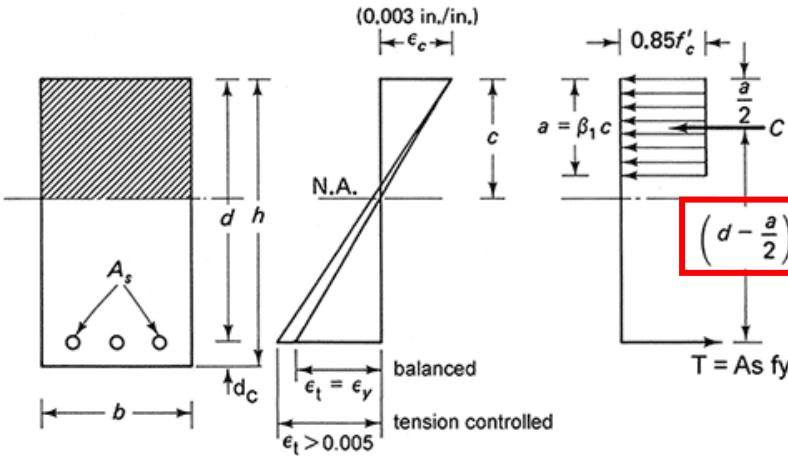
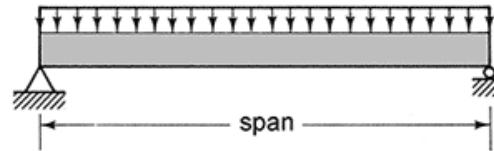
$$= 0.031$$

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11. strength reduction factor, phi

$$\epsilon_t = \frac{d - c}{c} 0.003 \geq 0.005 \quad \phi = 0.9$$

12. tensile force in the flexural steel, T

$$T = f_y * A_s = 60000 * 1.86 = 111600 \text{ lbs} = 111.6 \text{ k}$$

13. the nominal bending moment, M_n

$$T = C$$

$$M_n = C * \text{Distance} = T * \text{Distance}$$

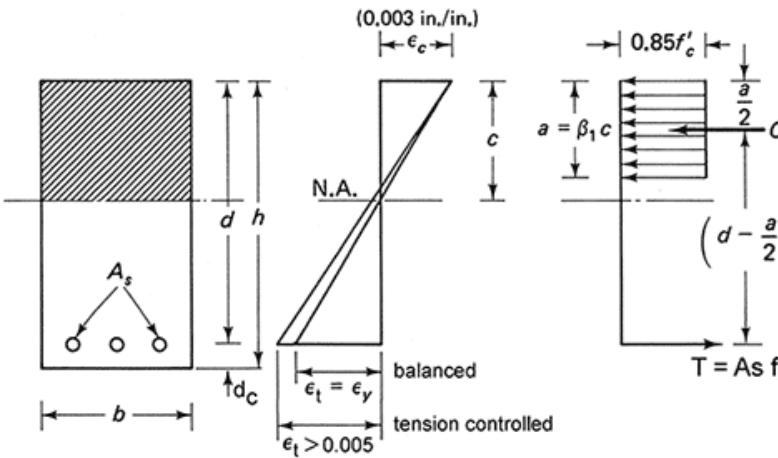
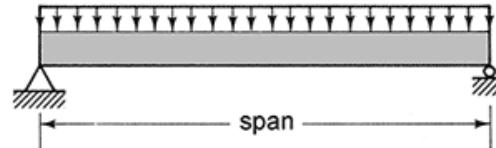
$$M_n = A_s f_y \left(d - \frac{a}{2} \right) = 111.6 * (22.8125 - 1.44/2) = 2465.52 \text{ k-in}$$

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14. the factored bending resistance, phi Mn

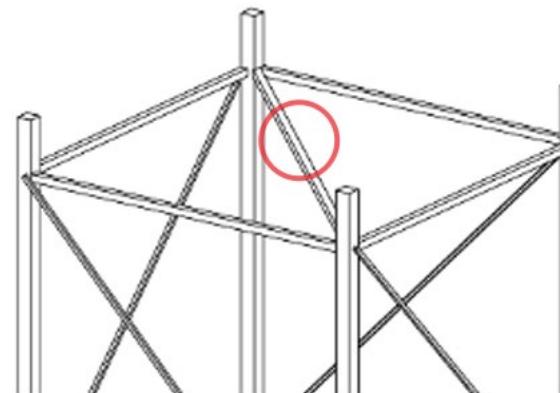
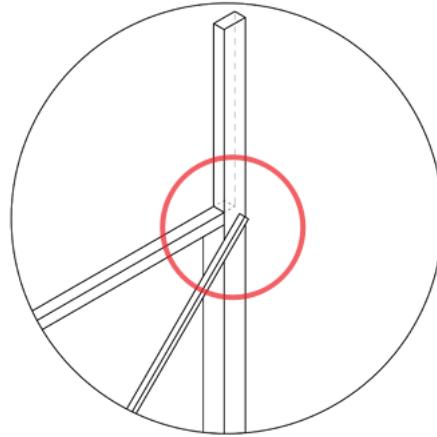
$$\phi * M_n = 0.9 * 2465.52 = 2218.97 \text{ k-in}$$

15. The factored design moment, Mu K-FT

$$M_u = \phi * M_n = 2218.97 / 12 = 184.91 \text{ k-ft}$$

Tower Tips

- 4 oz
- Dry it to save weight
- Straight Column
- The way you put the weight
- Space Connection (Torsion)



Office Hour Sign-Up

LAB - Flexural Strain

Description

This project produces a [graphic representation of the strain diagram](#) for a tension controlled concrete beam.

Goals

To plot the compression and tension strain levels in a concrete beam

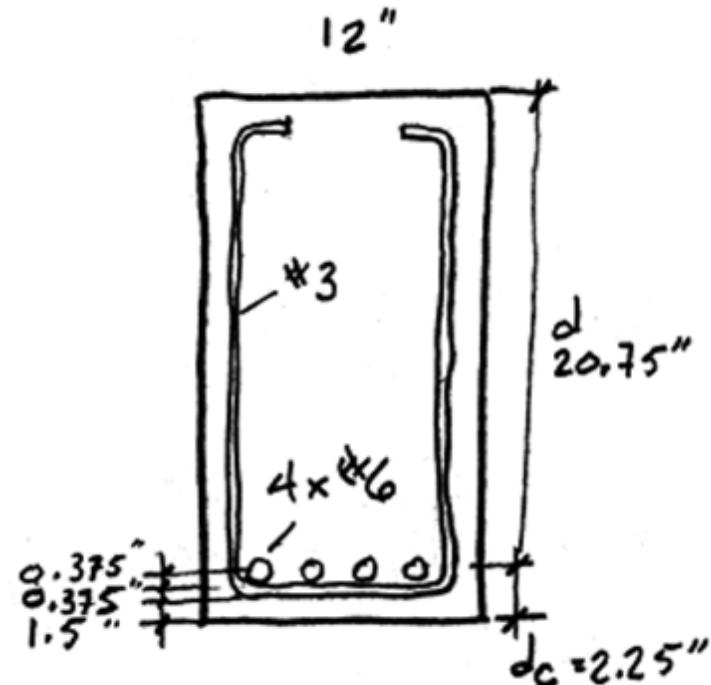
To graphically determine the [neutral axis](#).

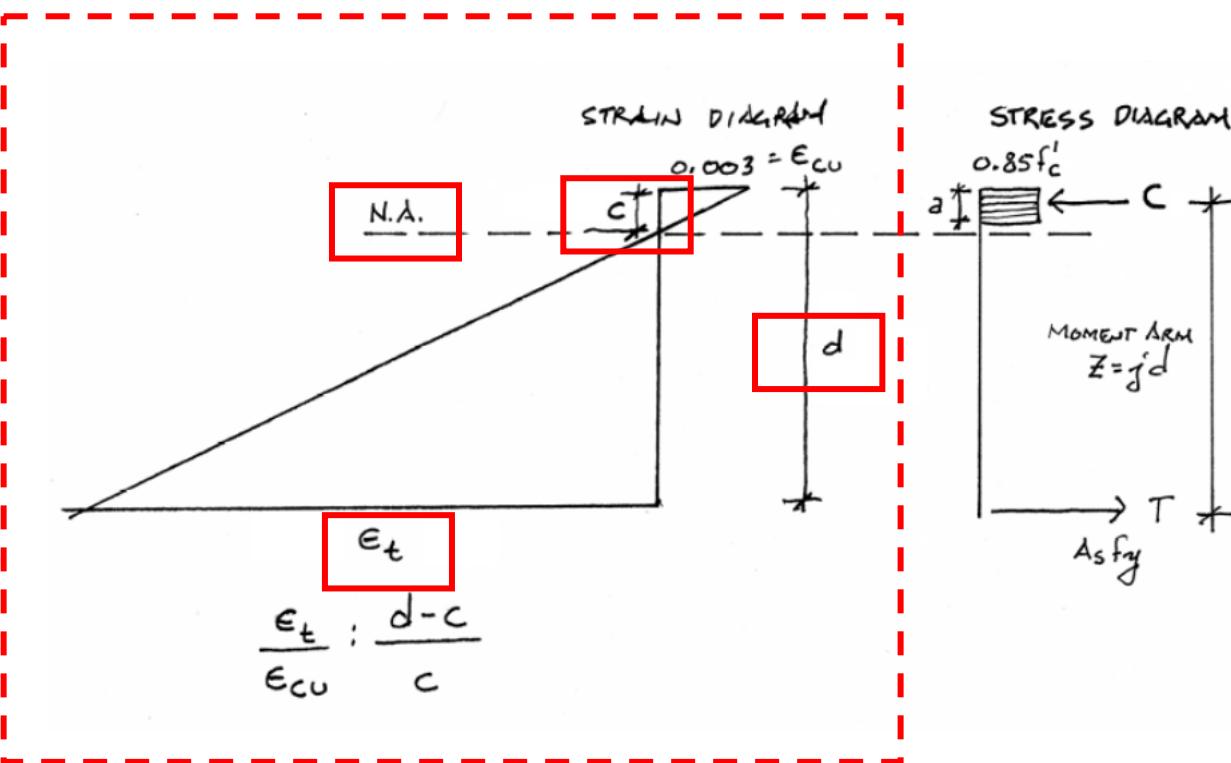
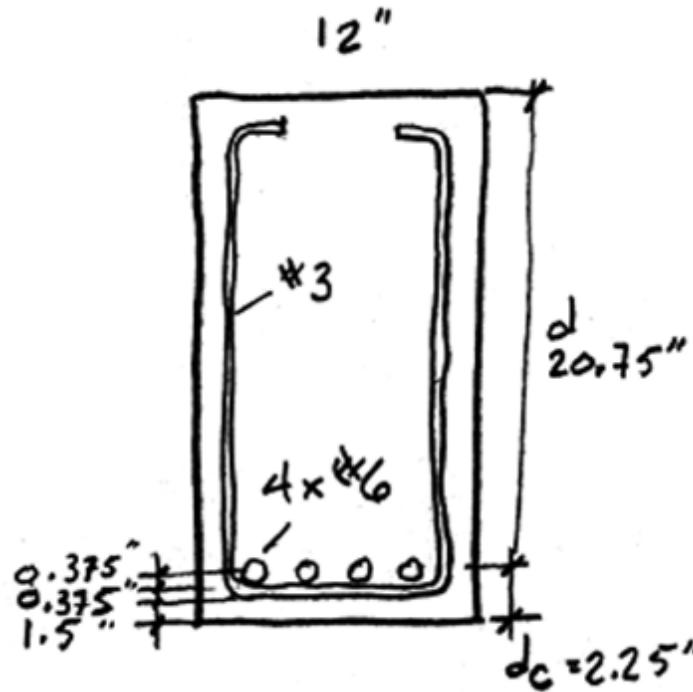
To draw the ACI "Whitney" [stress block](#) showing C and T forces.

To compare plotted and calculated results.

Procedure

1. For the tension controlled beam analysis discussed in lecture, construct the strain diagram with $\epsilon_{cu} = 0.003$ and ϵ_t as calculated.
2. Use $f_c = 6000$ psi and $f_y = 60000$ psi
3. Graphically determine the c distance from the top to the N.A on your diagram.
4. Make a second diagram to show the relationship of C & T forces to the strains.
5. Draw the ACI – Whitney stress block at "a" distance from the top.
6. Show the moment arm and calculate j using $j_d = z$.





Procedure

- For the tension controlled beam analysis discussed in lecture, construct the strain diagram with $E_{cu} = 0.003$ and ϵ_t as calculated.
- Use $f'_c = 6000$ psi and $f_y = 60000$ psi
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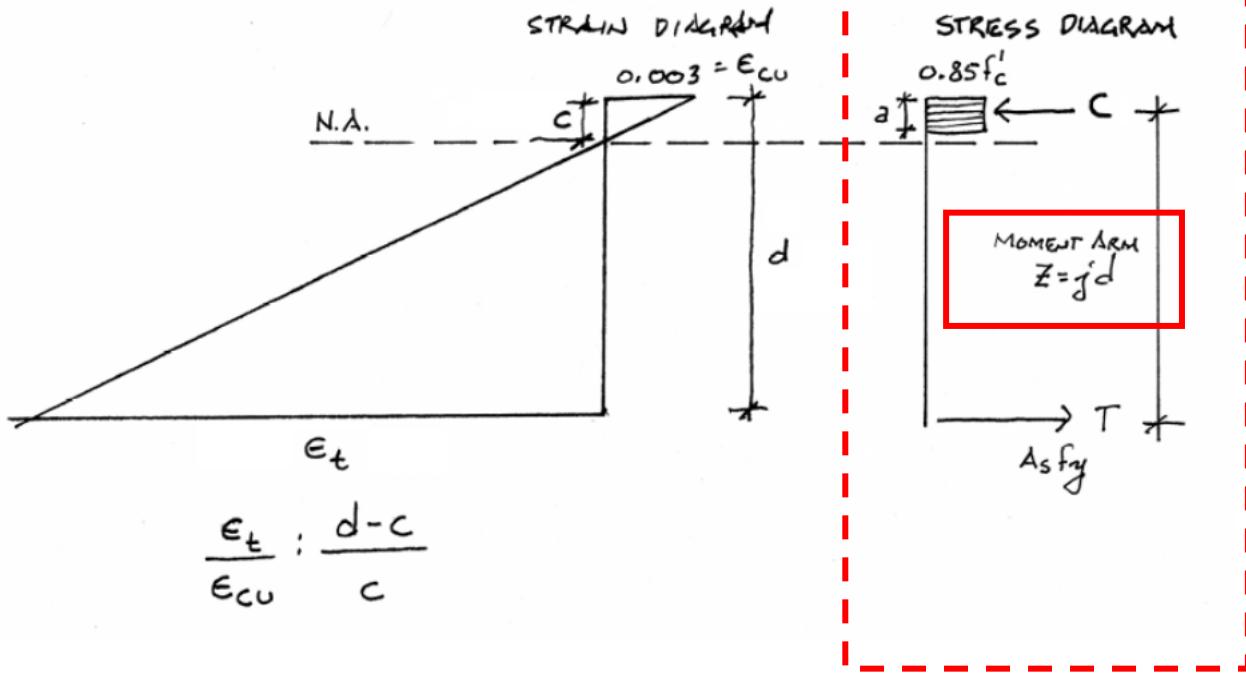
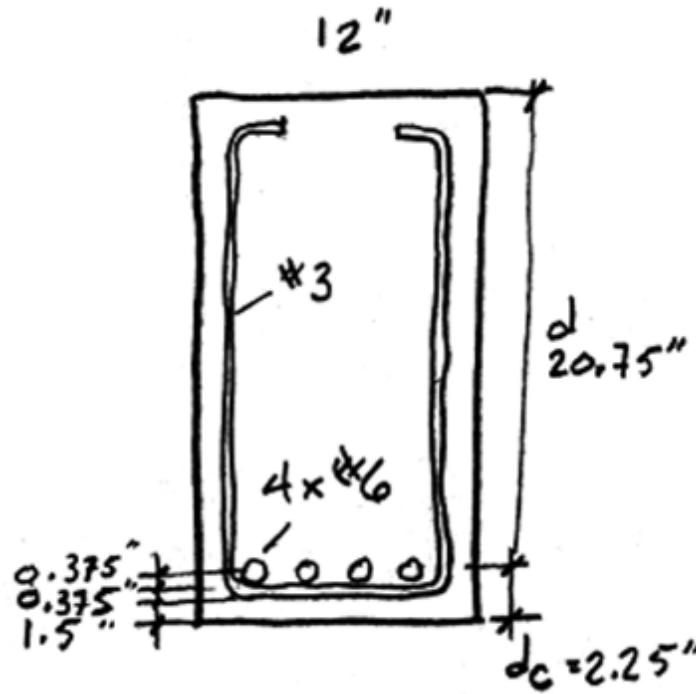
$$d_c = \text{COVER} + *3 + \frac{1}{2}(4 \times 6) \\ = 1.5 + 0.375 + \frac{0.75}{2} = 2.25" \quad \rightarrow \quad \epsilon_t = \frac{d_c - c}{c} \cdot 0.003 = \frac{20.75 - 2.3}{2.3} \cdot 0.003 \\ = 0.02406 > 0.004 \therefore \text{OK} \checkmark$$

$$d = h - d_c = 23" - 2.25 = 20.75" \quad = 0.02406 > 0.005 \therefore \text{tension controlled}$$

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{(1.76)(60)}{0.85(6)(12)} = 1.725"$$

$$\beta_1 = 0.85 - 0.05 \frac{f'_c - 4000}{10000} = 0.85 - 0.1 = 0.75$$

$$c = \frac{a}{\beta_1} = \frac{1.725}{0.75} = 2.300"$$



$$Z = d - a/2$$

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Any Questions?

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Thank You!

