Structure II Recitation 3/15

Concrete Beam Analysis

Before we start ...

Today's Tasks:

Homework Example (Concrete Beam Analysis) (15 Questions)

Lab Session (Flexural Strain)

Reminder:

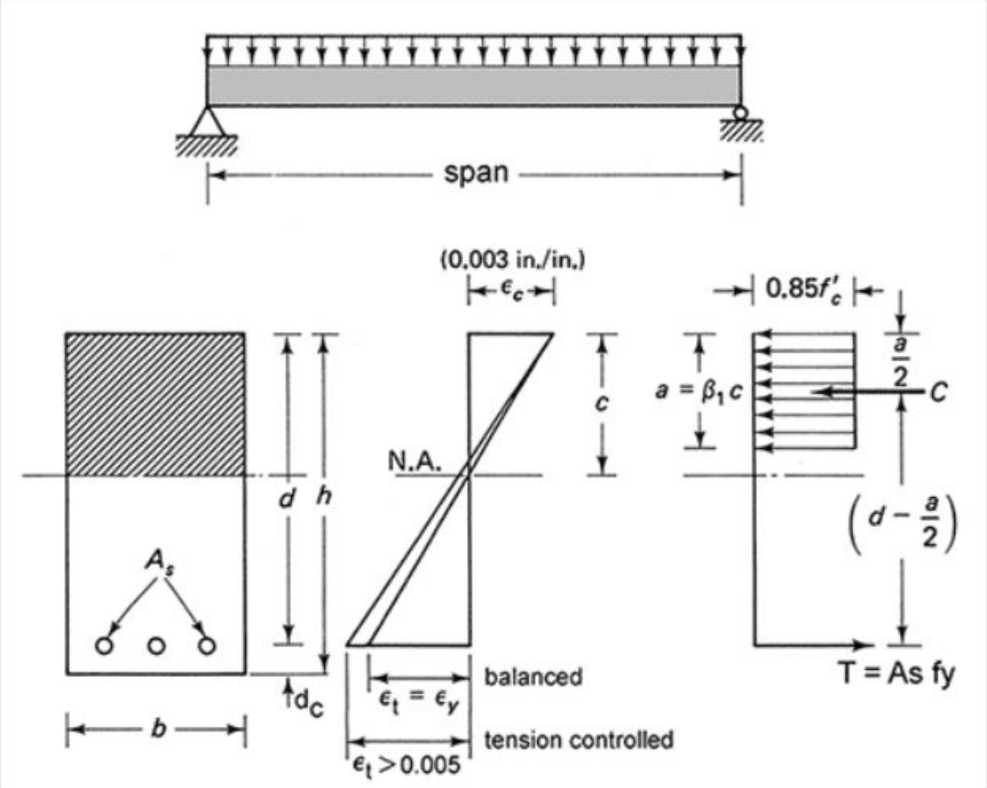
Tower Testing: 3/20, Wednesday!!!!!(Remember to sign up for your testing order)

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	20 IN
max. aggrigate size	0.75 IN
bar size number	7
the number of bars	5
stirrup bar size number	3
concrete cover	1.5 IN
concrete ultimate strength, f'c	8000 PSI
steel yield strength, fy	60000 PSI



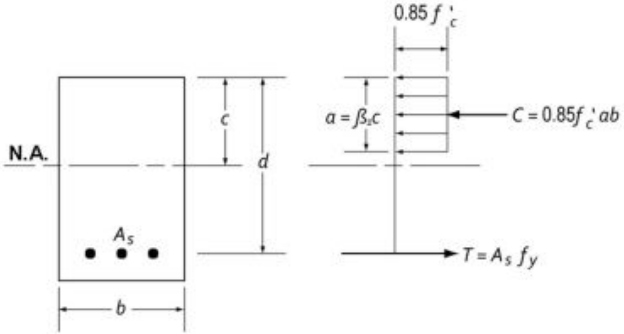
Rectangular Beam Analysis

Data:

- Section dimensions – b, h, (span)
- Steel area - As
- Material properties – f'c, fy

Required:

- Nominal Strength (of beam) Moment - Mn
- Required (by load) Design Moment – Mu
- Load capacity



As_{min}:
greater of (a) and (b)

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

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

1. Calculate d
2. Check As min
3. Calculate a
4. Determine c
5. Check that $\varepsilon_t \geq 0.005$ (tension controlled)
6. Find nominal moment, Mn
7. Calculate required moment, ϕ Mn ≥ Mu

   (if $\varepsilon_t \geq 0.005$ then $\phi = 0.9$)
8. Determine max. loading (or span)

$$\boxed{c = \frac{a}{\beta_1}}$$

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

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

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

$$\boxed{\varphi M_n \geq M_u}$$

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

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

Q1: Flexural Steel Bar Diameter (db)
Look at Table A.2, for my situation:
Bar Size Number = #7, **db = 0.875 in**

Q2: Stirrup Bar Diameter
Look at Table A.2, for my situation:
Stirrup Bar Size Number = #3, **Answer = 0.375 in**

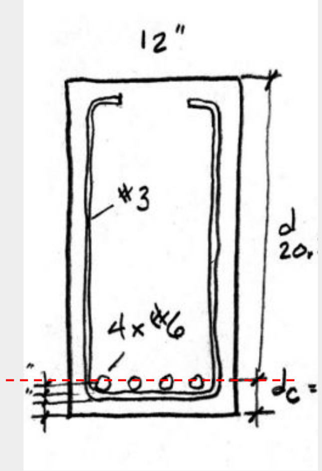
Q3: Distance from the Lower Beam Edge to Center of Flexural Steel (dc)

Q2 Q1

dc
= Concrete Cover + Stirrup Bar Diameter + db/2
= 1.5 + 0.375 + 0.875/2
= **2.3125 in**

Q4: Distance from the Top Beam Edge to Center of Flexural Steel (d)

d = Section Height - dc = 20 - 2.3125 = **17.6875 in**



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steel yield strength, fy	60000 PSI

Course Slides 3/13 p5. (PDF)

Table A.2 Designations, Areas, Perimeters, and Weights of Standard Bars

	Customary Units			SI Units		
Bar No.	Diameter (in.)	Cross-sectional Area (in.^{2})	Unit Weight (lb/ft)	Diameter (mm)	Cross-sectional Area (mm^2)	Unit Weight (kg/m)
3	0.375	0.11	0.376	9.52	71	0.560
4	0.500	0.20	0.668	12.70	129	0.994
5	0.625	0.31	1.043	15.88	200	1.552
6	0.750	0.44	1.502	19.05	284	2.235
7	0.875	0.60	2.044	22.22	387	3.042
8	1.000	0.79	2.670	25.40	510	3.973
9	1.128	1.00	3.400	28.65	645	5.060
10	1.270	1.27	4.303	32.26	819	6.404
11	1.410	1.56	5.313	35.81	1006	7.907
14	1.693	2.25	7.650	43.00	1452	11.384
18	2.257	4.00	13.600	57.33	2581	20.238

Q5: Minimum Required Area of Steel (As min)

Calculate the two formulas and choose the bigger one:

$(3 \times (f_c')^{0.5} / f_y) \times b \times d = 3 \times 8000^{0.5} / 60000 \times 14 \times 17.6875 = 1.107412$

$200 / f_y \times b \times d = 200 / 60000 \times 14 \times 17.6875 = 0.825$

Since 1.107412 > 0.825, **<u>As min = 1.107412 in²</u>**

Q6: Actual Area of Flexural Stress (As)

<u>As = cross sectional area x the number of bars</u>

As = (0.6) x 5 = **<u>3 in²</u>**

Get area from Table A-2

Check if As > As min,

For my situation, It's a Pass!

(fc', fy, b, number of bars given from question, d from Q4)

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As_{min}:

greater of (a) and (b)

(a) $\dfrac{3\sqrt{f_c'}}{f_y} b_w d$

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

Q7: Depth of Concrete Stress Block (a)

Q6

$a = (As \times fy) / (0.85 \times fc' \times b)$

$= (3 \times 60000) / (0.85 \times 8000 \times 14)$

$= \mathbf{1.89\ in}$

Q8: Factor Beta 1 (β1)

$\beta 1 = 0.85 - 0.05 \times ((fc' - 4000) / 1000)$ (or look at the table)

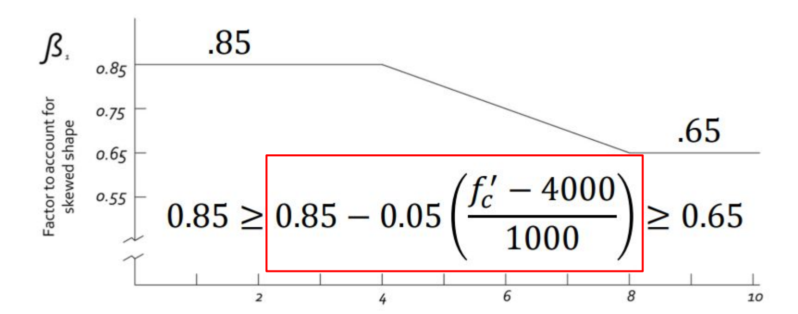
$= 0.85 - 0.05 \times ((8000 - 4000) / 1000) = \mathbf{0.65}$

Q9: Distance to Neutral Axis from Top of the Beam (c)

$c = a / \beta 1 = 1.89 / 0.65 = \mathbf{2.9\ in}$

Course Slides 3/13 p4. (PDF)

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



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

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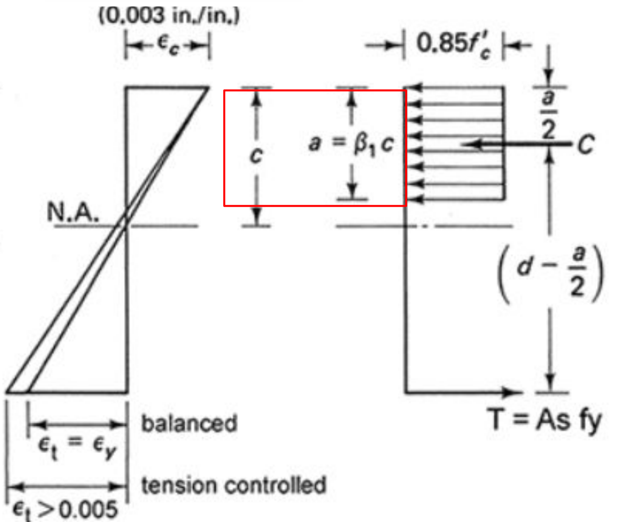
$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$a = \beta_1 c$$



Q10: Strain in Flexural Steel (εt)

$\varepsilon_t = (d - c) / c \times (0.003) = (17.6875 - 2.9) / 2.9 \times 0.003 =$ **0.0152**

Q4 Q9

Q11: Strength Reduction Factor (Φ)

Check if εt is bigger than 0.005,

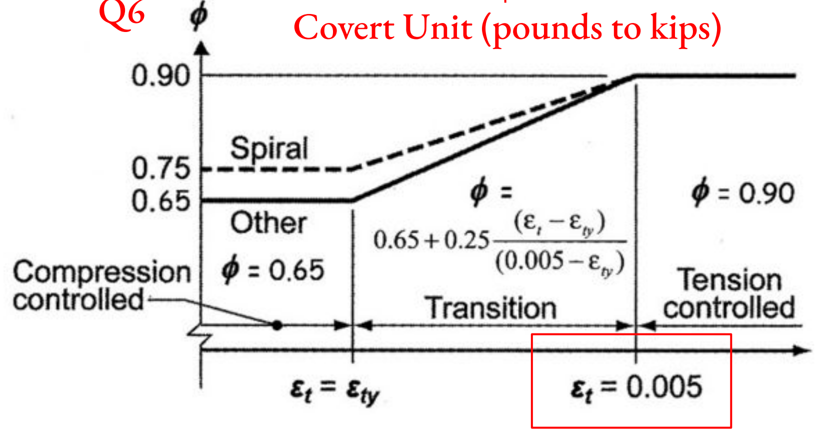
Since my εt is bigger, its tension - controlled, **Φ = 0.9**

Q12: Tensile Force in the Flexural Steel (T)

T = As x fy = 3 x 60000 / 1000 = **180 k**

Q6

Covert Unit (pounds to kips)



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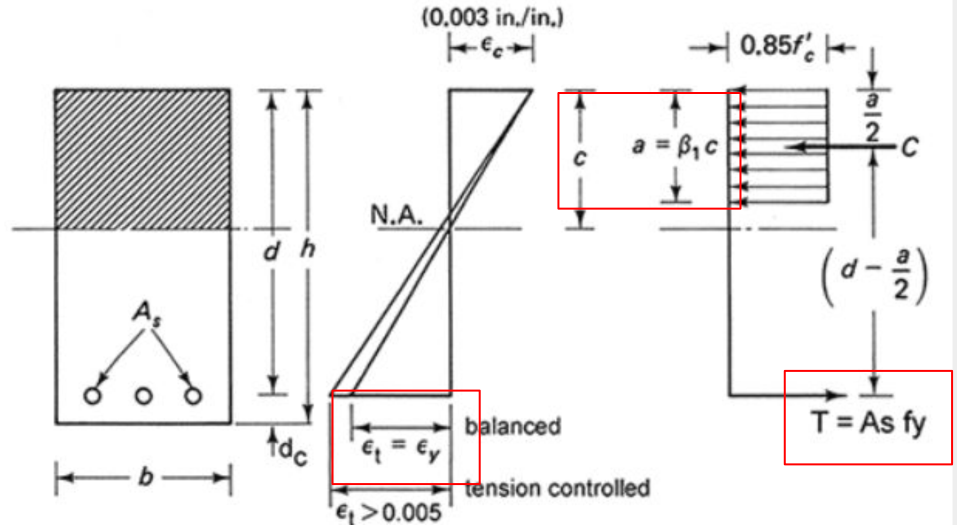
$$\varepsilon_t = \frac{d - c}{c}(0.003)$$



Q13: The Nominal Bending Moment (Mn)

Mn = T x (d - (a / 2)) = 180 x (17.6875 - 1.89 / 2) = **3013.6 k-in**

Q12 Q4 Q7

Q14: The Factored Bending Resistance (ΦMn)

ΦMn = 0.9 x 3013.6 = **2712.2 k-in**

Q10 Q13

Q15: The Factored Design Moment (Mu)

Mu = ΦMn = 2712.2 / 12 = **226 k-ft**

Covert Unit (in to ft)

simple span	17 FT
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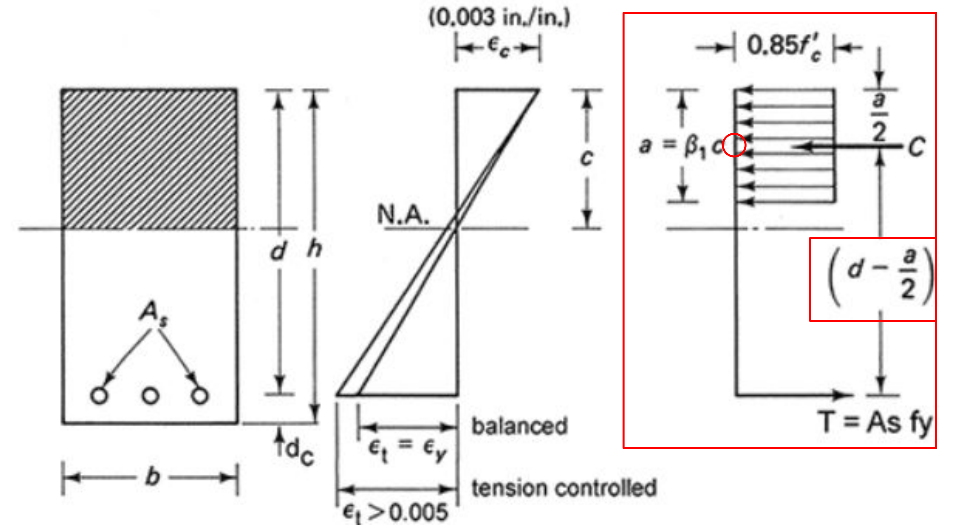
$$M_n = T\left(d - \frac{a}{2}\right) = A_s f_y\left(d - \frac{a}{2}\right)$$




We good?

Flexural Strain

Description

This project produces a graphic representation of the strain diagram for a tension controlled concrete beam.

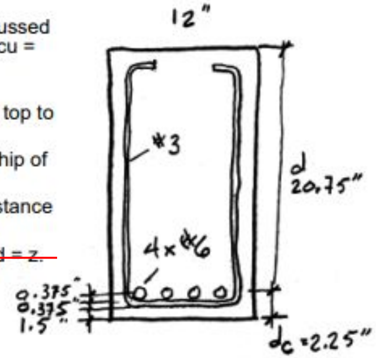
Goals

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

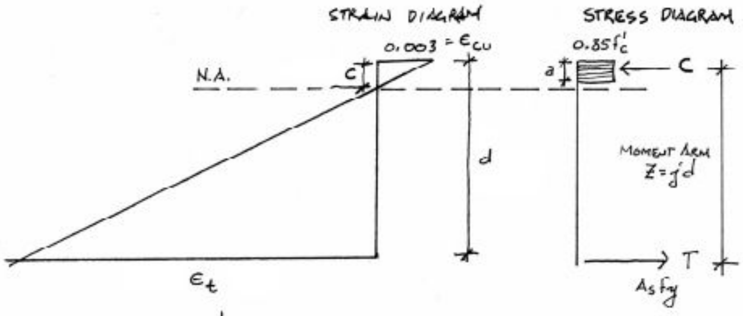
1. For the tension controlled beam analysis discussed in lecture, construct the strain diagram with ϵ_{cu} = 0.003 and ϵ_t as calculated.
2. Use f'c = 6000 psi and fy = 60000 psi
3. Graphically determine the c distance from the top to the N.A on your diagram.
4. Make a second diagram to show the relationship 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 jd = z.~~

Calculate Moment



Due

Sunday, March 28



$$\frac{\epsilon_t}{\epsilon_{cu}} : \frac{d-c}{c}$$

Lab Session:

Calculate **β1, a, c, εt, Bending Moment**

Moment:

T x Moment Arm = (As x Fy) x (d - a/2)

As = cross sectional area (#6) x number of bars

f'c	β1
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

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

$$\boxed{a = \beta_1 c}$$

$$\boxed{\varepsilon_t = \frac{d-c}{c}(0.003)}$$

Table A.2 Designations, Areas, Perimeters

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