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Concrete Beam Analysis

Lab Recitation #9
Group #3

March 17 2020
University of Michigan, TCAUP

What are we going to Learn today?

- Find the maximum moment capacity of a beam with the help of Ultimate Strength Method
- Check if the beam section is under Tension control
- Check if the amount of steel in the beam is enough to bear that Tension

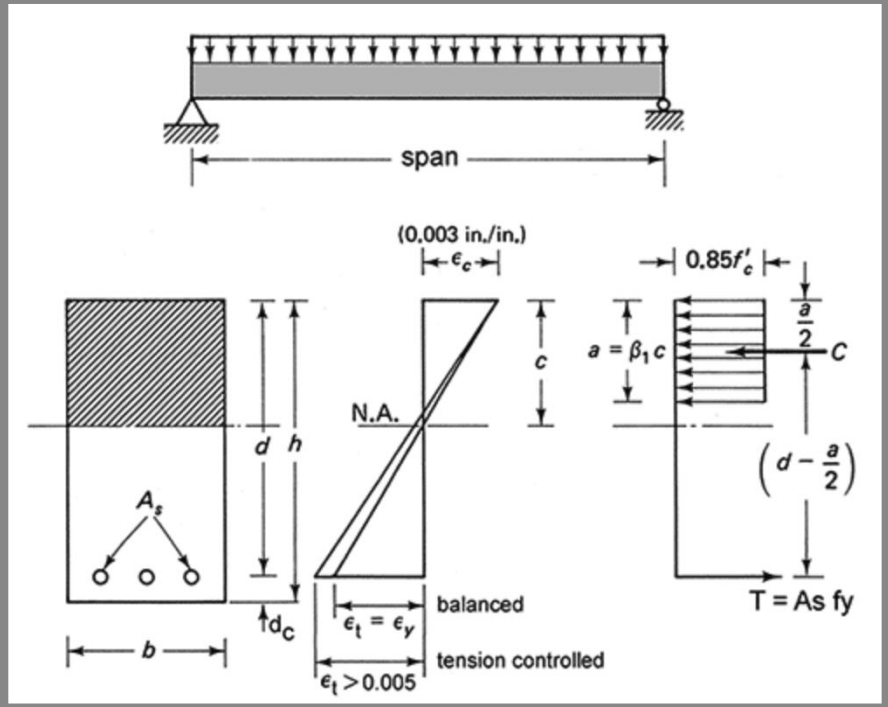
Concrete Beam Analysis

9. Concrete Beam Analysis

Using the Ultimate Strength Method, analyze the given section to determine its safe moment capacity, Mu, based on the given parameters. Check that the section is tension controlled (epsilon_t > 0.005), and that the amount of steel, As is more than the minimum, As_min.

DATASET: 1 -2- -3-

simple span	30 FT
section width, b	17 IN
section height, h	33 IN
max. aggrigate size	0.75 IN
bar size number	9
the number of bars	5
stirrup bar size number	4
concrete cover	1.5 IN
concrete ultimate strength, f'c	5500 PSI
steel yield strength, fy	60000 PSI



Q#1 Calculate flexural steel bar diameter, db

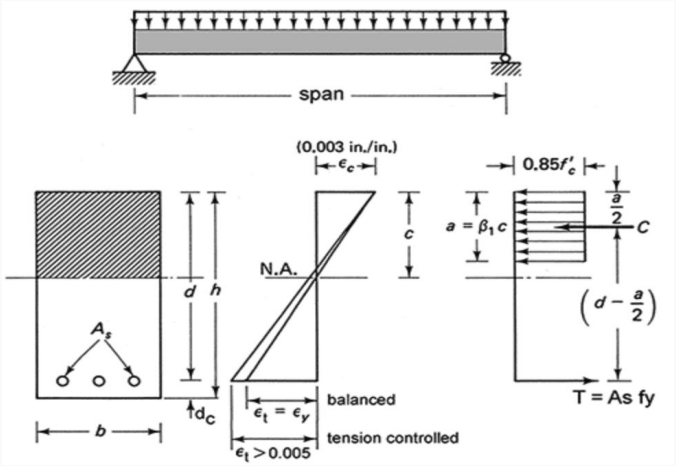
$d_{\text{steel bar}}$ = bar size number x ⅛”

(given)

$d_{\text{steel bar}}$ = 9 x ⅛”

$d_{\text{steel bar}}$ = 9/8 = **1.125”**

DATASET: 1 -2- -3-	
simple span	30 FT
section width, b	17 IN
section height, h	33 IN
max. aggrigate size	0.75 IN
bar size number	9
the number of bars	3
stirrup bar size number	4
concrete cover	1.5 IN
concrete ultimate strength, f'c	5500 PSI
steel yield strength, fy	60000 PSI



Q#2 Stirrup bar diameter

$d_{stirrup}$ = bar size number x ⅛”

(given)

$d_{stirrup}$ = 4 x ⅛”

$d_{stirrup}$ = 4/8 = **0.5”**

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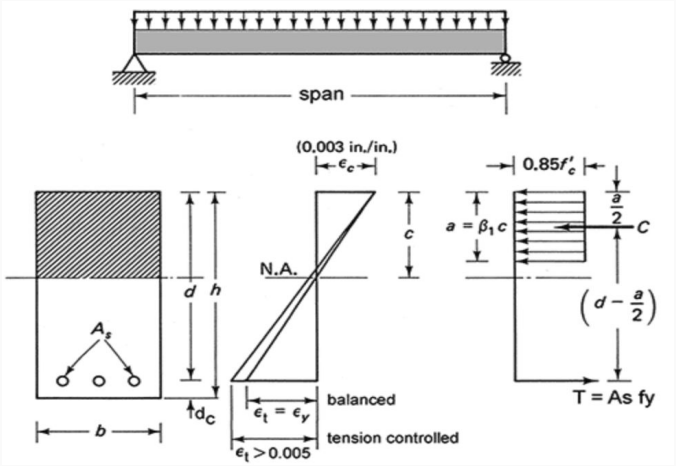

Q#3 Distance from lower beam edge to center of flexural steel, dc

$d_c = 1.5 + d_{stirrup} + (0.5 \times d_{steel\ bar})$

(concrete cover to protect steel from weather)

(Ans#2)

(Ans#1)

$d_c = 1.5" + 0.5" + (0.5 \times 1.125)"$

$d_c =$ **2.5625"**

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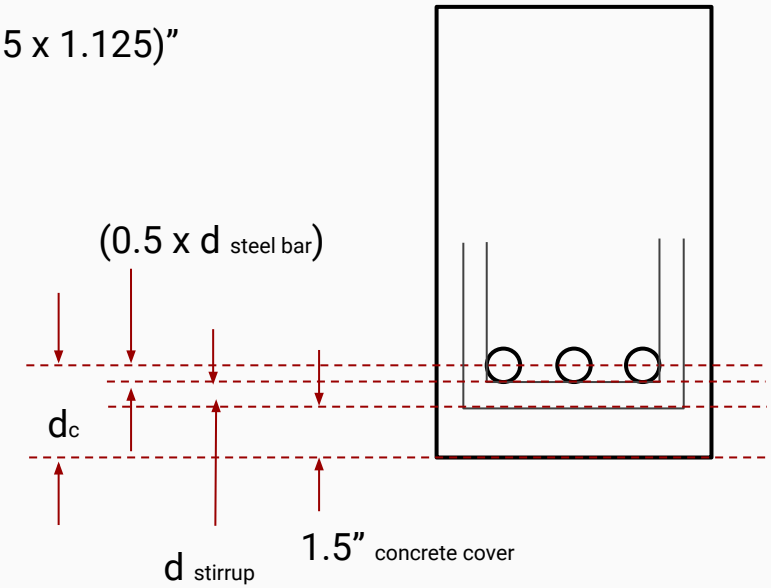
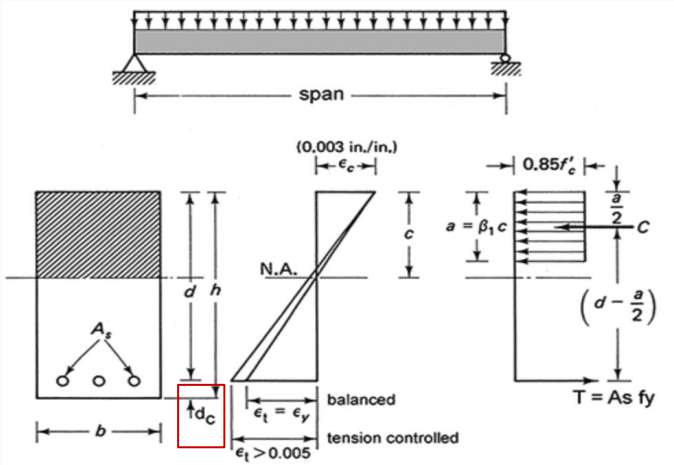




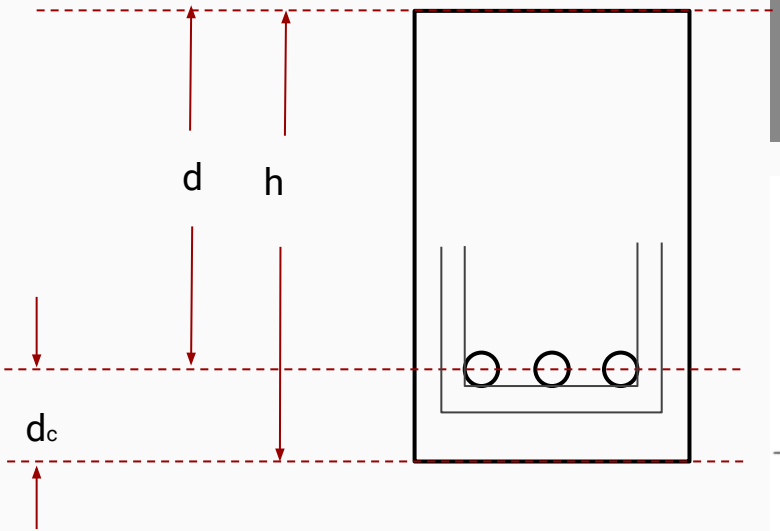
Q#4 Distance from top beam edge to center of flexural steel, d

$d = h - d_c$

(given) (Ans#3)

$d = 33" - 2.5625"$

$d = \mathbf{30.4375"}$



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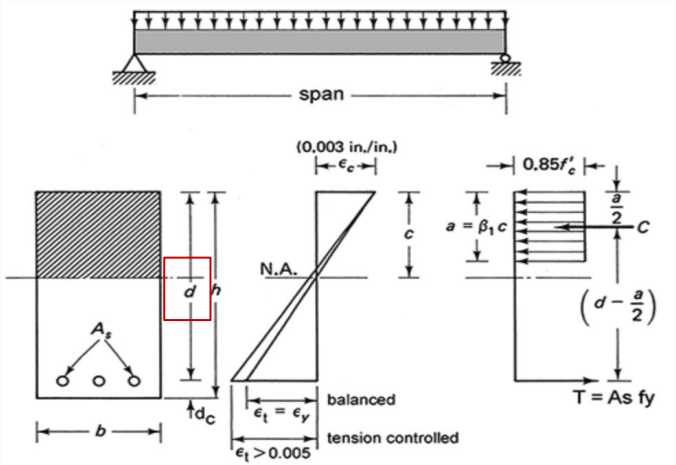

Q#5 Minimum required area of steel, $A_{s\ min}$

As min : greater of (a) and (b)

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

$3 \times (\sqrt{5500} \div 60000) \times 17 \times 30.4375$

(f'c, given) (fy, given) (b, given) (Ans#4)

= **1.918**

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

$(200 \times 17 \times 30.4375) \div 60000$

(b, given) (Ans#4) (fy, given)

= 1.724

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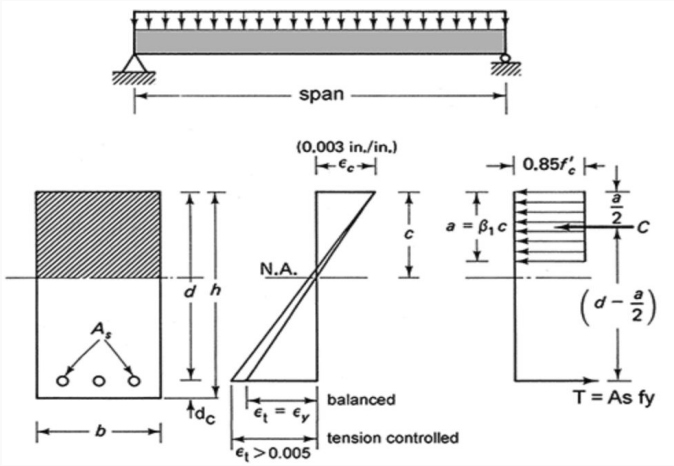

Q#6 Actual area of flexural steel, A_s

A_s = number of bars x bar area

(given) (given in the ASTM standards)

A_s = 5 x 1

A_s = **5**

ASTM STANDARD REINFORCING BARS

Bar size, no.	Nominal diameter, in.	Nominal area, in.^{2}	Nominal weight, lb/ft
3	0.375	0.11	0.376
4	0.500	0.20	0.668
5	0.625	0.31	1.043
6	0.750	0.44	1.502
7	0.875	0.60	2.044
8	1.000	0.79	2.670
9	1.128	1.00	3.400
10	1.270	1.27	4.303
11	1.410	1.56	5.313
14	1.693	2.25	7.65
18	2.257	4.00	13.60

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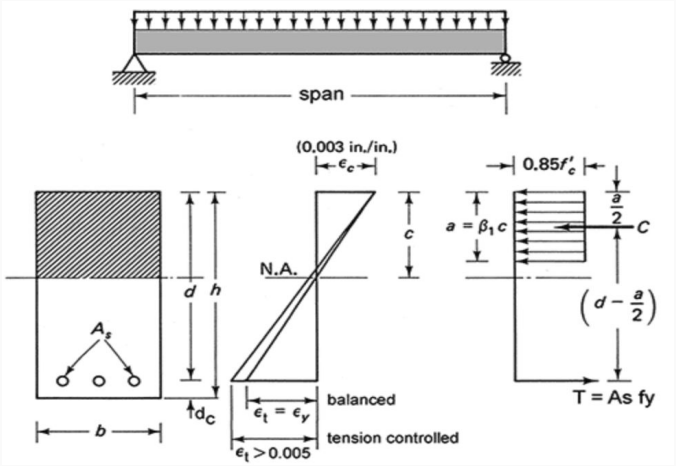

Q#7 Depth of concrete stress block, a

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

$$= \frac{(5 \times 60000)}{(0.85 \times 5500 \times 17)}$$

(Ans#6) (fy, given) (f'c, given) (b, given)

$$= 3.774$$

DATASET: 1 -2- -3-

section width, b	17 IN
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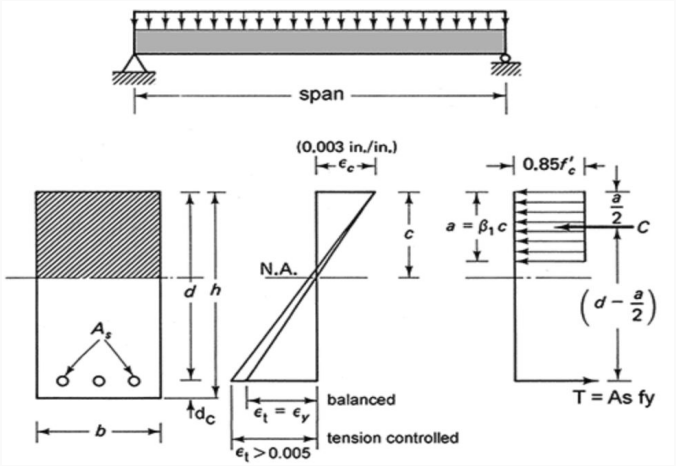

Q#8 Calculate factor beta_1

$$\beta_1 = 0.85 - 0.05\left(\frac{f_c' - 4000}{1000}\right)$$

$$= 0.85 - (0.05 \times ((5500 - 4000) \div 1000))$$

(f'c, given)

$$= \mathbf{0.775}$$

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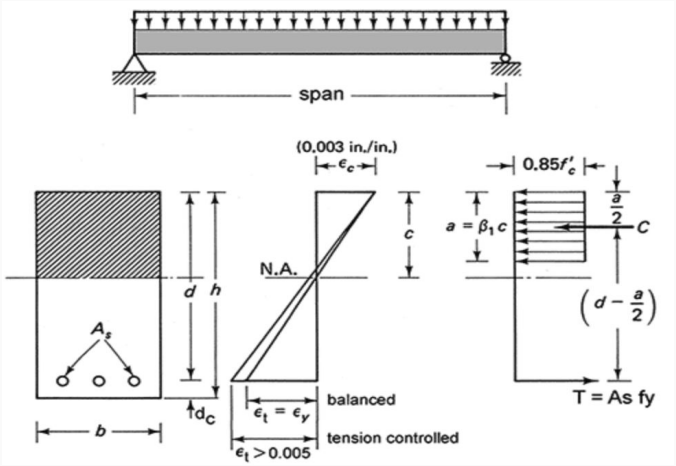

Q#9 Distance to Neutral Axis from top of beam, c

$$c = a/\beta_1$$

(Ans#7) (Ans#8)

= 3.774 / 0.775

= **4.869**

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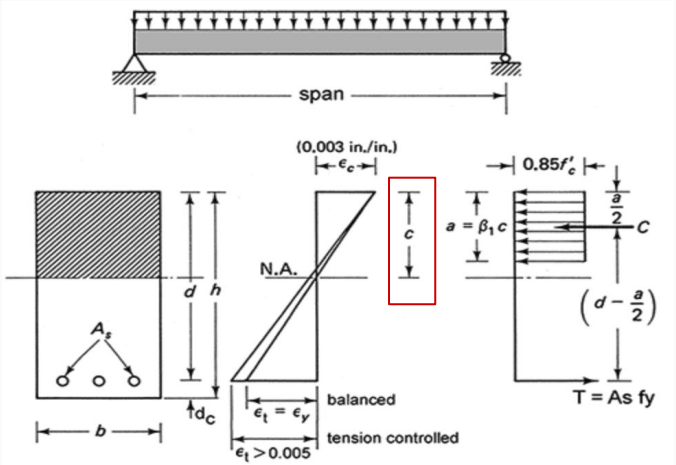

Q#10 Strain in flexural steel, epsilon_t

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

= ((30.4375 - 4.869) x (0.003)) / 4.879

(Ans#4) (Ans#9) (Ans#9)

= **0.0157** > .0005 (Hence under Tension control)

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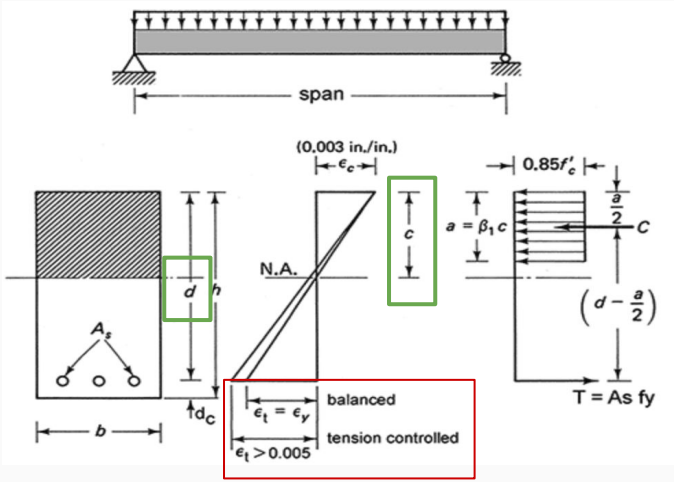

Q#11 Strength reduction factor, phi

Since the member is under Tension control, we use phi = **0.9** as our strength reduction factor

Table 21.2.1—Strength reduction factors ϕ

Action or structural element		ϕ	Exceptions
(a)	Moment, axial force, or combined moment and axial force	0.65 to 0.90 in accordance with 21.2.2	Near ends of pretensioned members where strands are not fully developed, ϕ shall be in accordance with 21.2.3.
(b)	Shear	0.75	Additional requirements are given in 21.2.4 for structures designed to resist earthquake effects.
(c)	Torsion	0.75	—
(d)	Bearing	0.65	—
(e)	Post-tensioned anchorage zones	0.85	—
(f)	Brackets and corbels	0.75	—
(g)	Struts, ties, nodal zones, and bearing areas designed in accordance with strut-and-tie method in Chapter 23	0.75	—
(h)	Components of connections of precast members controlled by yielding of steel elements in tension	0.90	—
(i)	Plain concrete elements	0.60	—
(j)	Anchors in concrete elements	0.45 to 0.75 in accordance with Chapter 17	—

Q#12 Tensile force in the flexural steel, T

$$T = A_s f_y$$

(Ans#6) (given)

= (5 x 60000) / 1000

(convert to ksi)

= **300**

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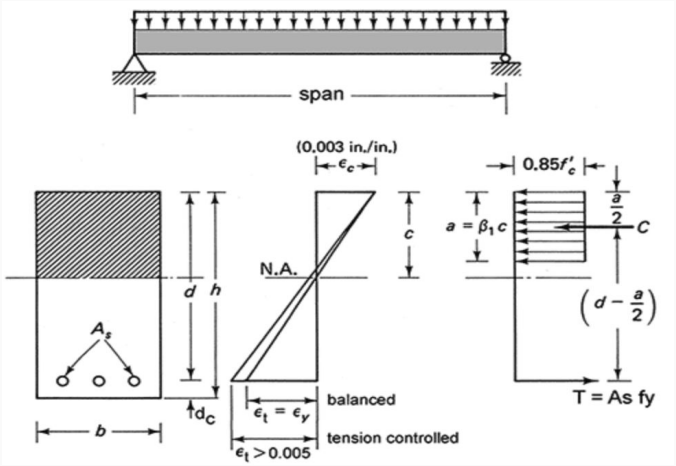

Q#13 The nominal bending moment, Mn

$$M_n = A_s f_y \left(d - \frac{a}{2} \right)$$ ← (Ans#7)

(Ans#12) (Ans#4)

= 300 (30.4375 - (3.774/2))

= **8564.7**

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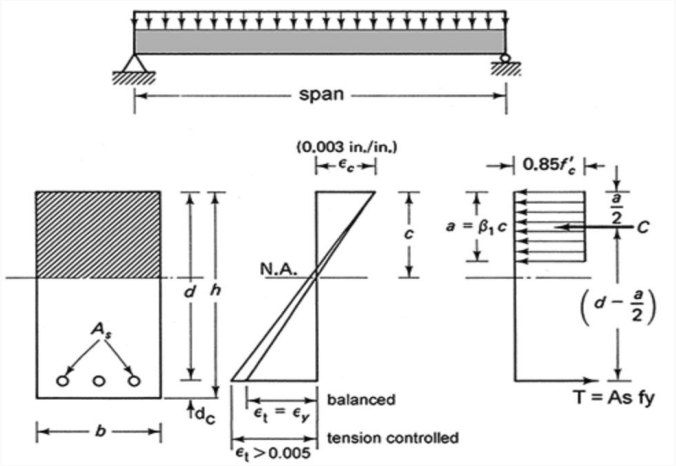

Q#14 The factored bending resistance, phi Mn

= phi x Mn

(Ans#11) (Ans#13)

= 0.9 x 8564.7

= **7708.23**

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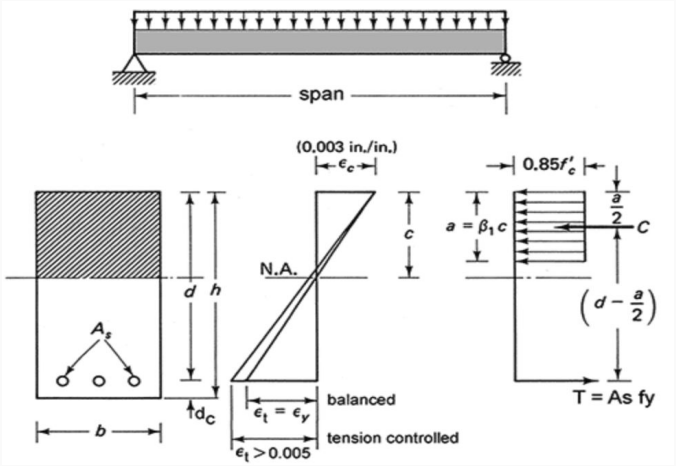

Q#15 The factored design moment, Mu

= (phixMn) / 12

(Ans#14)

= 7708.23 / 12

= **642.3525**

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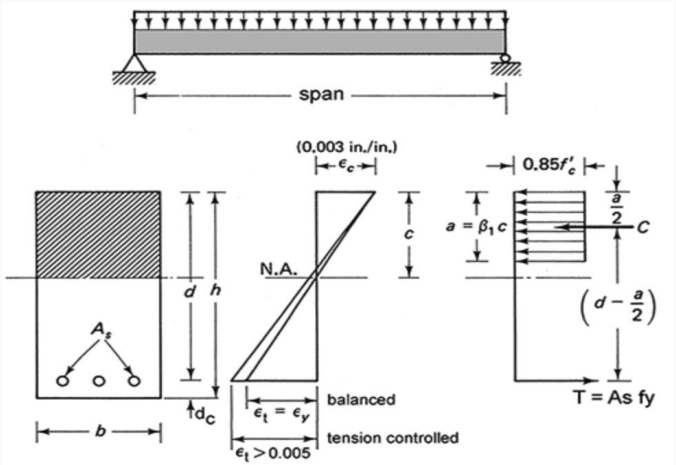

Any Questions?

Contact: gehlot@umich.edu