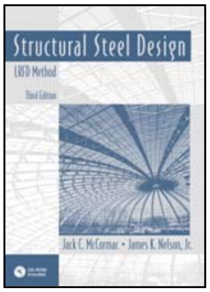
Name: **SAMPLE**

University of Maryland, College Park

Department of Civil & Environmental Engineering

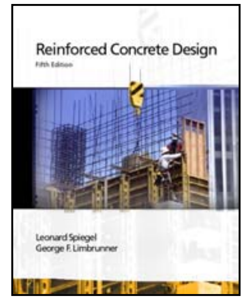
ENCE 355 – Introduction to Structural Design



Honor Pledge Code

"I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/examination."

Signature: ______________________________



Grading:

Problem 1:	40	/ 40
Problem 2:	20	/ 20
Problem 3:	20	/ 20
Problem 4:	20	/ 20
Total:	100	/ 100 ☺

Solution to EXAM I

Monday, October 28, 2002
9:00 AM – 9:50 AM, EGR 2112

Instructor: Dr. I. Assakkaf

Policies:

1. Write your name on all sheets.
2. Use only the paper provided. Ask for additional sheets, if required.
3. Place only one problem on each sheet (front and back).
4. Draw a box around answers for numerical problems.
5. Give all answers to 3 or 4 significant figures.
6. Include free body diagrams (FBD's) for all equilibrium problems.
7. Closed book / closed notes; Manual and formula sheet permitted.
8. **SHOW ALL WORK USED TO ARRIVE AT YOUR ANSWER.**

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Problem #1 (40 points)

I. True or False (8 points)
If each of the following statements is true, circle T, otherwise circle F:

(1) Structural analysis is the art of utilizing principles of statics, dynamics, and mechanics of materials to determine the size and arrangement of structural elements under prescribed loads and/or other effects. T **(F)**

(2) The various codes themselves have no legal status. However, when they are incorporated into the building codes, they have official sanctions, become legal documents, and considered part of the law controlling design and construction in a particular area. **(T)** F

(3) Concrete is very weak in compression. T **(F)**

(4) Concrete is a mixture of cement, fine and coarse aggregates, and water. **(T)** F

(5) Aggregates occupy approximately 30% to 35% of the volume of the hardened mass of concrete. T **(F)**

(6) Creep occurs at an increasing rate over a period of time and may not cease after several years. T **(F)**

(7) Generally, concrete attains approximately 70% of its 28-day strength in 7 days, and approximately 85% to 90% in 14 days. **(T)** F

(8) In the stress-strain diagram, the slope of the straight line for steel is the modulus of elasticity, *E*. **(T)** F

II. Fill in the blanks (12 points)
Complete the following five statements. Note that you are allowed to ONLY use terms from the list below; other terms WILL NOT be accepted.

(a) The _____ **modulus of elasticity** ___of carbon reinforcing steel has been adopted by the ACI Code as 29×10^6 psi.

(b) For complete ______**hydration**___of cement in a mix, a water/cement ratio of 0.35 to 0.40, or 4 to 4 ½ gal/bag is required.

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(c) The property by which concrete continues to __**deform (or strain)**_ over long periods of time while under constant load is called creep.

(d) The ______**modulus of rupture**__ is the maximum tensile bending stress in a plain concrete test beam at failure.

(e) For rectangular reinforced concrete beams, the ACI Code stipulates that the amount of tensile steel must not exceed 0.75 times the amount of steel that would produce balanced conditions.

This is an attempt to ensure a ___**ductile**_____ failure that is produced by yielding

of steel as compared with the sudden and __**brittle**__ type of failure in the concrete.

List of possible terms:

brittle	yield stress	hydration	compressive strength
ductile	Remain the same	Young's modulus	modulus of elasticity
deform	Poisson's ratio	elastic modulus	Old's modulus
strain	modulus of rupture	splitting tensile strength	shear modulus

III. **Modulus of rupture** (20 points)
A plain concrete beam has a rectangular cross section 12 in. wide and 26 in. deep. Assuming that the modulus of elasticity E_c for the concrete is 3,120,000 psi and its compressive strength f'_c=3000 psi, compute

(a) Its modulus of rupture f_r.

(b) Its unit weight in lb/ft^3, and

(c) The weight of the beam per linear foot (lb/ft)

(a) $f_r = 7.5\sqrt{3000} = \boxed{410.8\text{ psi}}$

(b) $E_c = w_c^{1.5} 33\sqrt{f'_c} \Rightarrow w_c^{1.5} = \dfrac{E_c}{33\sqrt{f'_c}} \Rightarrow w_c = \left(\dfrac{E_c}{33\sqrt{f'_c}}\right)^{\frac{1}{1.5}} = \left(\dfrac{3{,}120{,}000}{33\sqrt{3000}}\right)^{\frac{1}{1.5}} = \boxed{144\text{ lb/ft}^3}$

(c) beam weight $= \dfrac{12(26)}{144}(144) = \boxed{312\text{ lb/ft}}$

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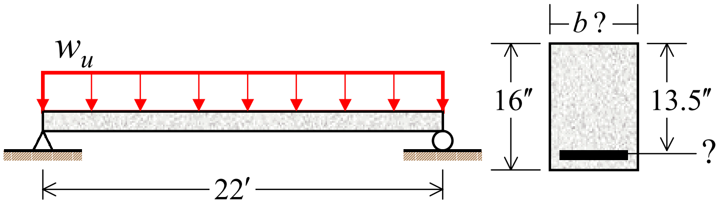
Problem #2 (20 points): A rectangular, tension-reinforced beam is to be design for dead load of 1.0 kips/ft (includes beam weight) and service live load of 1.2 kips/ft, with a 22 ft simple span as shown. The total beam depth must not exceed 16 in. Based on the ACI Specifications and using material strengths f'_c = 3000 psi for concrete and f_y = 60,000 psi for steel, and a steel ratio of 0.5ρ_b, compute:



(a) The required beam width, *b*.

(b) The tensile steel requirements (i.e., select rebars).

***** SOLUTION *****

Method I (using tables):

(a) The required beam width, *b*:

$$w_u = 1.4(1.0) + 1.7(1.2) = 3.44 \text{ kips/ft}$$

$$M_u = \frac{w_u L^2}{8} = \frac{3.44(22)^2}{8} = 208.12 \text{ ft-kips} = 2{,}497.44 \text{ in-kips}$$

For f'_c = 3000 and f_y = 60,000 psi, Table 5 gives ρ_{max} = 0.0161. Fro the same table,

$$\rho_{max} = 0.75\rho_b \Rightarrow \rho_b = \frac{\rho_{max}}{0.75} = \frac{0.0161}{0.75} = 0.0215$$

$$\text{required } \rho = 0.5\rho_b = 0.5(0.0125) = 0.0108$$

For ρ = 0.0108, Table 1 gives $\bar{k} = 0.5657$ ksi.

$$M_u = \phi b d^2 \bar{k}$$

$$b = \frac{M_u}{\phi d^2 \bar{k}} = \frac{2{,}497.44}{0.9(13.5)^2(0.5657)} = 26.92, \boxed{\text{use } b = 27 \text{ in.}}$$

(b) Tensile steel requirements:

$$\text{required } A_s = \rho b d = 0.0108(26.96)(13.5) = 3.93 \text{ in}^2$$

USE 4 #9 bars: A_s =4.0 in^2

Method II (using equations):

(a) The required beam width, *b*:

w_u = 3.44 kips/ft and M_u = 2,497.44 in-kips from Method I

$$\rho_b = \frac{0.85 f'_c \beta_1}{f_y} = \left(\frac{87}{f_y + 87}\right) = \frac{0.85(3)(0.85)}{60}\left(\frac{87}{60+87}\right) = 0.0214$$

required ρ = 0.5 ρ_b = 0.5 (0.0214) = 0.0107

$$A_s = \rho b d$$

$$0.85 f'_c b a = f_y A_s = f_y \rho b d \Rightarrow a = \frac{f_y \rho b d}{0.85 f'_c b} = \frac{f_y \rho d}{0.85 f'_c} = \frac{60(0.0107)(13.6)}{0.85(3)} = 3.399 \text{ in.}$$

$M_u = 2{,}497.44 = \phi T Z = \phi\ (f_y A_s)\ (d - a/2) = \phi f_y\ \rho\ b\ d\ (d - a/2)$

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$$2{,}497.44 = 0.90(60)(0.0107)b(13.5)\left[13.5 - \frac{3.399}{2}\right] = 102.3$$

$\therefore b = 27.13\text{ in.}$ $\boxed{\text{USE } b = 27\text{ in.}}$

(b) Tensile steel requirements:

required $A_s = \rho bd = 0.0107(27.13)(13.5) = 3.92\text{ in}^2$

USE 4 #9 bars: A_s =4.0 in^2

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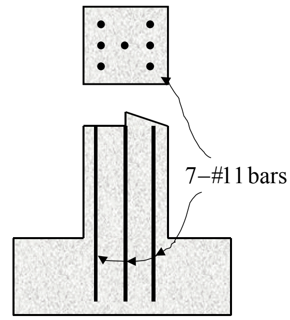
Problem #3 (20 points): Seven No. 11 vertical compression bars extend from a column into the supporting footing as shown. Use f'_c = 5000 psi and f_y = 60,000 psi. The A_s required was 10.2 in ^{2}. There is no lateral reinforcing enclosing the vertical bars in the footing. Determine:

(a) The basic compression development length, l_{db}.

(b) The required compression development length (l_{db}×MF).



***** SOLUTION *****

(a) Basic compression development length:

Using equations,

$$l_{db} = 0.02 d_b \frac{f_y}{\sqrt{f'_c}} = 0.02(1.410)\frac{60{,}000}{\sqrt{5000}} = 23.93 \text{ in.}$$

Check min:

$0.0003 f_y d_b$ = 0.0003 (60,000) (1.410) = 25.38 in. > 23.93 **NG**

Therefore, **USE l_{db} = 25.38 = 25.4 in.**

Using tables:

From Table 3, for $f'_c = 5000$ psi, l_{db} = 25.4 in., which gives the same value as above.

(b) Required compression development length:

Note: no lateral reinforcing enclosing the vertical bars in the footing, therefore, MF = 1.0 for that case. However, because the actual reinforcement, required A_s = 10.2 in^2 is given, we need to calculate MF for that case:

For 7 No. 11 bars, A_s provided = 10.92 in^2 (from Table 3)

$$\text{required length} = l_{db} \times \text{MF} = l_{db} \times \frac{A_s \text{ required}}{A_s \text{ provided}}$$

$$= 25.4 \times \frac{10.2}{10.92} = 23.72 \text{ in.} > 8 \text{ in} \qquad \text{OK}$$

Therefore,

USE 23.7 in. for required development length.

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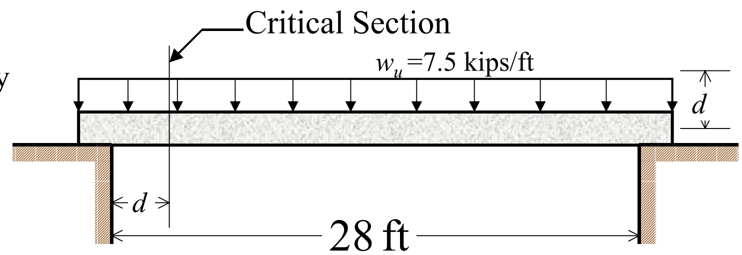
Problem #4 (20 points): A simply supported, rectangular, reinforced concrete beam having d = 24 in. and b = 15 in. supports a uniformly distributed factored load w_u = 7.5 kips/ft as shown. The given load includes the beam weight. Assume No. 3 single-loop stirrups. Use f_c' = 4000 psi and f_y = 60,000 psi.

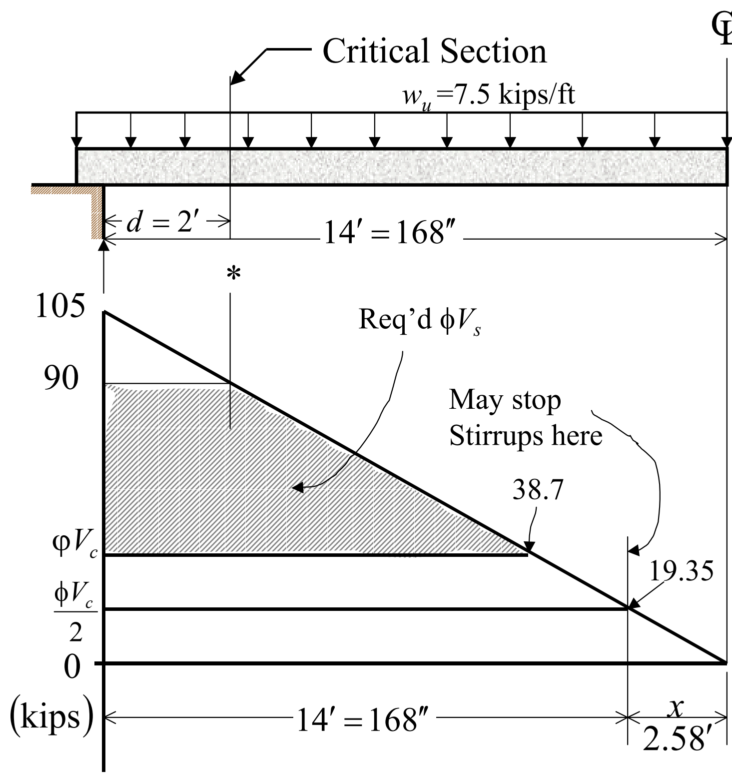
(a) Draw the complete shear (V_u) diagram showing all-important points for stirrup designs (**Hint**: make use of the symmetry of the beam about its mid span).

(b) Using the V_u diagram, select the stirrup spacing to use at the critical section (d distance from the face of the support), and the location along the beam where stirrups may be stopped



***** SOLUTION *****

(a) Complete shear diagram:



$$V_u = \frac{w_u L}{2} = \frac{7.5(28)}{2} = 105\text{ k}$$

$$\phi V_c = \phi 2\sqrt{f_c'}bd = \frac{0.85(2)\sqrt{4000}(15)24}{1000} = 38.7\text{ k}$$

$$\frac{\phi V_c}{2} = 19.35\text{ k}$$

$$V_u^* = 105 - 2(7.5) = 90\text{ k}$$

$$V_u^* > \frac{\phi V_c}{2}, \therefore \text{stirrups req'd}$$

$$x = \frac{19.35}{7.5} = 2.58\text{ ft}$$

#3 stirrups ($A_v = 0.22\text{ in}^2$)

(b) Stirrups spacing and location of not needed stirrups:

$$s = \frac{\phi A_v f_y d}{\text{req'd}\phi V_s^*} = \frac{0.85(0.22)(60)(24)}{90 - 38.7} = \boxed{5.25\text{ in.}}$$

Location along the beam where stirrups may be stopped = 14 - 2.58 = **11.42 ft from left f.o.s**