CE 123 – Fall 2011
Instructor: M. Panagiotou

Name:______________________________

Mid-Term Examination No. 1 – **Duration 1 hour and 45 minutes**

Instructions:

- Read these instructions. Do not turn the exam over until instructed to do so.
- Work all problems. Pace yourself so that you have time to work on each problem. Reasonable assumptions and approximations should be made where necessary.
- Show all relevant work. Credit will not be given for key elements of the solution that are not apparent.
- Partial credit will be given if procedures are outlined clearly.
- Work the solutions for each of the problems on separate sheets, working on one side of each sheet of paper. One problem solution may span more than one sheet. However, do not show the work for more than one problem on any given sheet. Staple the solution sheets to this cover sheet, problem 1 first, then problem 2, etc.
- If you have any questions, or need any paper or other materials, walk to the front of the classroom and ask the exam proctor. Do not raise your hand to get the proctor's attention, and do not call out questions from your seat.
- Neatness counts five percent of the grade. Therefore, write neatly and organize your solutions to make checking as easy as possible.
- Unless otherwise stated, all problems use the ACI 318-11 strength design method, and all concrete is normal weight.

	Possible Points	Score
Problem 1	30	_____
Problem 2	35	_____
Problem 3	35	_____
TOTAL	100	_____

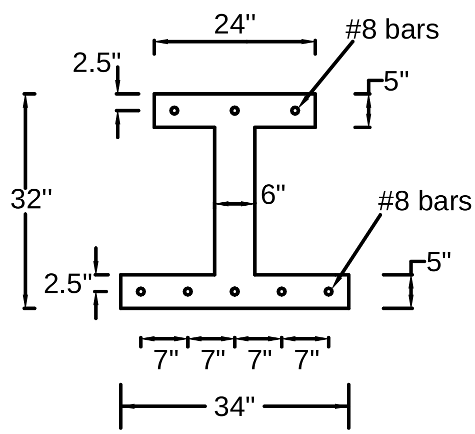
Problem 1 (30 points)

A beam is has the I-section shown with different flange widths. $f_c^{'}$ = 4 ksi, and f_y = 60 ksi. **Considering the full width of the flanges effective both in tension and compression and ignoring the contribution of steel in compression** calculate:

1.1) The nominal flexural strength when the top reinforcement is in tension. **(12 points)**

1.2) The nominal flexural strength when the bottom reinforcement is in tension. **(12 points)**

1.3) What is the effective width of the flanges, according to ACI, for the two cases considered? **(6 points)**

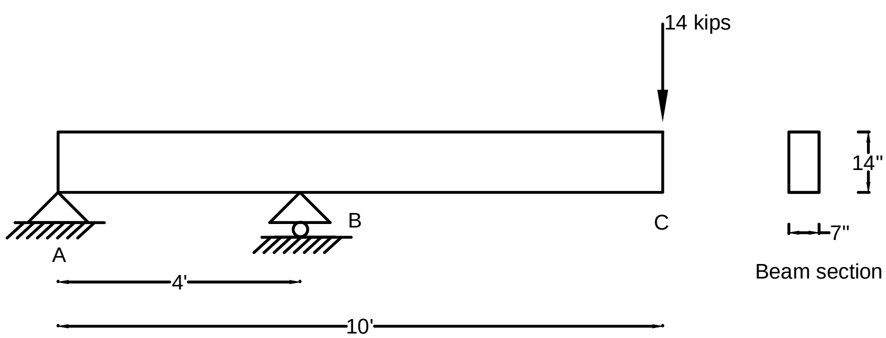


Problem 2 (35 points)

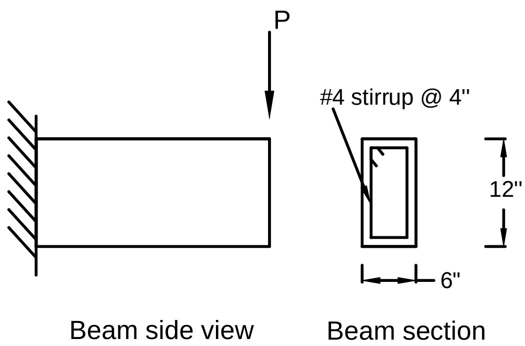
2.1) The beam ABC with rectangular cross section is considered. $f_c^{'}$ = 4 ksi, and f_y = 60 ksi. The effective depth of the beam is d=12."

2.1.1 - ***Using #4 stirrups*** design the required shear reinforcement of spans AB, and BC. The 14 kips load is already factored. Ignore the self weight of the beam. Assume that the flexural strength of the beam is adequate everywhere. Show a side view as well as a beam section sketch of your shear reinforcement design. **(23 points)**

2.1.2 - Using the requirements of the ACI 318 code, determine whether the depth of the beam is adequate so that a detailed deflection calculation is not required. **(4 points)**



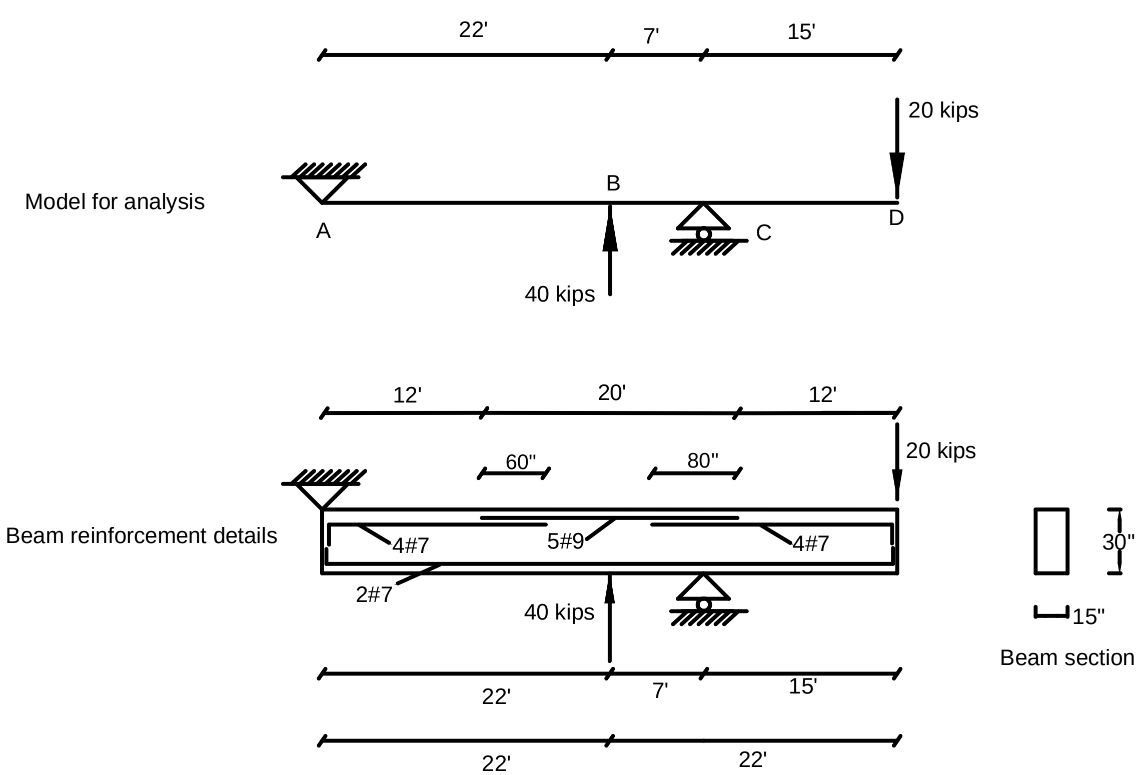
2.2) Calculate the maximum load P that the short cantilever with the rectangular section shown can resist. $f_c' = 4$ ksi, and $f_y = 60$ ksi. Assume that that the flexural strength is adequate everywhere. **(8 points)**



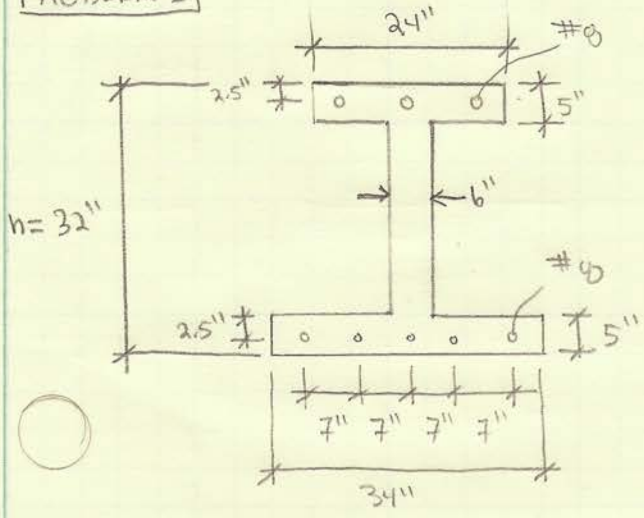
Problem 3 (35 points)

For $f_c' = 4$ ksi, and $f_y = 60$ ksi check if the length of the splices as well as the development length of the bars is adequate. The loads shown are already factored. All the bar hooks shown are standard and satisfy ACI requirements. Contact splices are considered. The bars are uncoated and the concrete is normal weight. The nominal flexural strength of the beam section with 5#9 in tension is $M_n = 552$ kips-ft. The nominal flexural strength of the beam section with 4#7 in tension is $M_n = 282$ kips-ft. The effective depth of the beam is d = 27".

Note**: Do <u>not</u> check rules 3 to 7 for reinforcement cutoff.**



PROBLEM 1

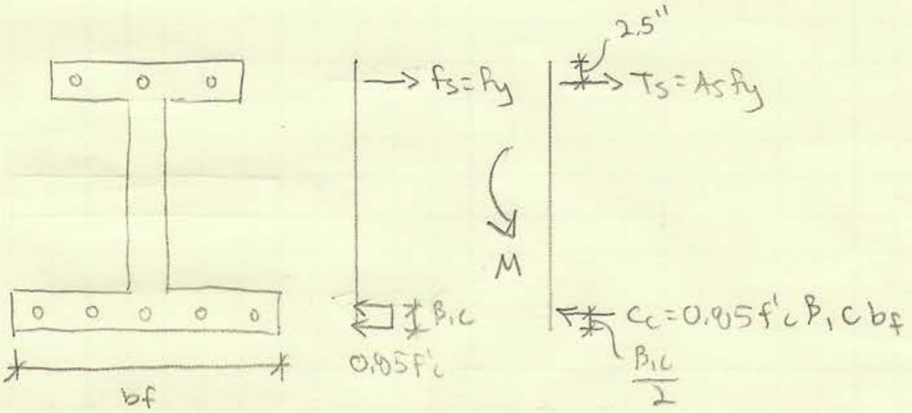


$f'_c = 4ksi \longrightarrow \beta_1 = 0.85$
$f_y = 60ksi$

*USE FULL WIDTH OF FLANGES AS EFFECTIVE WIDTHS IN BOTH TENSION & COMPRESSION

FIND:

1.1) NOMINAL FLEXURAL STRENGTH WHEN TOP IS IN TENSION



ASSUME $\beta_1 c \leq t_f$ (CASE I)

② FIND $\beta_1 c$ & CHECK ASSUMPTION

$$\Sigma F = 0 \Rightarrow A_s f_y - 0.85 f'_c \beta_1 c b_f = 0 \Rightarrow \beta_1 c = \frac{A_s f_y}{0.85 f'_c b_f}$$

$$\beta_1 c = \frac{3(0.79 in^2)(60 ksi)}{0.85(4 ksi)(34'')} = 1.23'' \leq 5'' = t_f \checkmark \text{ ASSUMPTION OK}$$

③ FIND M_n

CHECK:

$$\varepsilon_s = \frac{\varepsilon_c(d-c)}{c} = \frac{0.003(29.5'' - \frac{1.23''}{0.85})}{1.23''/0.85}$$

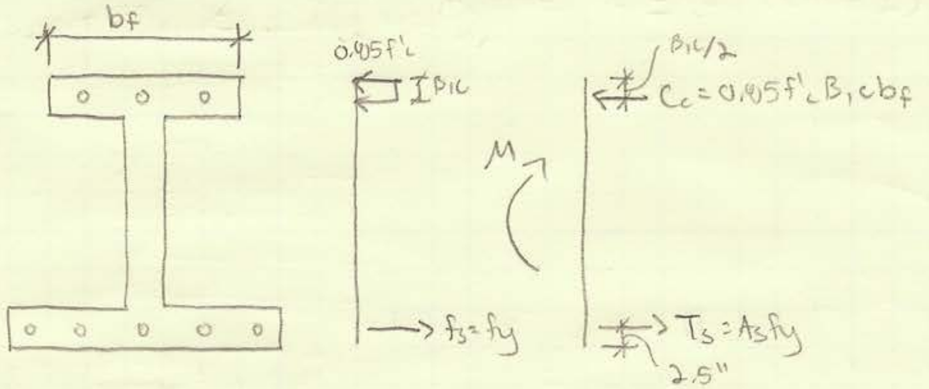
$$\varepsilon_s = 0.058 \geq 0.002 = \varepsilon_y \checkmark OK$$

$$\Sigma M_{cc} = 0 \Rightarrow M_n = A_s f_y \left(h - 2.5'' - \frac{\beta_1 c}{2}\right)$$

$$M_n = 3(0.79 in^2)(60 ksi)(32'' - 2.5'' - (1.23''/2))$$

$$\Rightarrow \boxed{M_n = 4107 \text{ kip-in}}$$

1.2) NOMINAL FLEXURAL STRENGTH WHEN BOTTOM IS IN COMPRESSION



ASSUME $\beta_1 c \leq t_f$ (CASE I)

② FIND $\beta_1 c$ & CHECK ASSUMPTION

$$\beta_1 c = \frac{A_s f_y}{0.85 f'_c b_f} = \frac{5(0.79 in^2)(60 ksi)}{0.85(4 ksi)(24")} = 2.90" \leq 5" = t_f \quad \checkmark \text{ ASSUMPTION OK}$$

③ FIND M_n

$$\Sigma M_c = 0 \Rightarrow M_n = A_s f_y \left(h - 2.5" - \frac{\beta_1 c}{2}\right) = 5(0.79 in^2)(60 ksi)\left(32" - 2.5" - \left(\frac{2.90"}{2}\right)\right)$$

$$\Rightarrow \boxed{M_n = 6647 \text{ kip-in}}$$

CHECK: $\varepsilon_s = \frac{\varepsilon_c(d-c)}{c} = \frac{0.003\left(29.5" - \frac{2.90"}{0.85}\right)}{2.90"/0.85}$

$\varepsilon_s = 0.023 \geq 0.002 \checkmark$ OK

1.3) WHAT IS EFFECTIVE FLANGE WIDTH FOR CASE ABOVE ACCORDING TO THE ACI?

→ FOR FLANGES IN TENSION & COMPRESSION:

- ACI §8.12.2: $b_o \leq \min \begin{cases} 8t_f \\ \frac{L_c}{2} \end{cases}$ & $b_f \leq \frac{L}{4}$

  b_o = EFFECTIVE OVERHANG FLANGE WIDTH

$\therefore b_f = \min \begin{cases} L/4 \\ b_w + 16t_f \\ b_w + L_c \end{cases}$ SINCE L & L_c NOT GIVEN, ASSUME $(b_w + 16t_f)$ GOVERNS

$b_f \leq 6" + 16(5") = 86"$

→ FOR FLANGES IN COMPRESSION ONLY:

- ACI §8.12.4: $b_f \leq 4b_w = 4(6") = 24"$

CASE 1.1: TOP IN TENSION, BOTTOM IN COMPRESSION

TENSION FLANGE: $b_f = 24" \leq 86"$ ✓ OK

COMPRESSION FLANGE: $b_f = 34" \leq 86"$ ✓ OK

$\not\leq 24"$ ✗ NG

CASE 1.2: TOP IN COMP., BOT. IN TENSION:

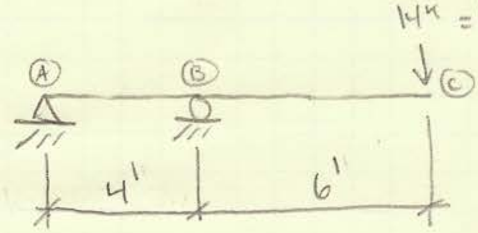
TENSION FLANGE: $b_f = 34" \leq 86$ ✓ OK

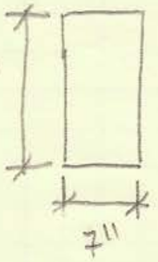
COMPRESSION FLANGE: $b_f = 24" \leq 86$ ✓ OK

$\leq 24"$ ✓ OK

PROBLEM 2)

2.1)





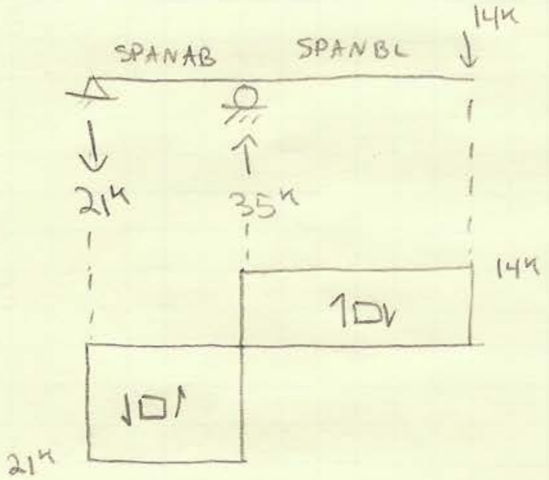
SECTION

$f'_c = 4ksi$
$f_y = 60ksi$
$d = 12"$

2.1.1) DESIGN REQ'D SHEAR REINF. FOR SPANS AB & BC

*NO FLEXURAL DESIGN NECESSARY
*IGNORE SW

DRAW [V]



SPAN AB

① FIND V_u

V_u @d from F.O.S. $= 21^k$

② FIND V_c & CHECK IF STIRRUPS REQ'D. FIND V_s

$V_c = 2\lambda\sqrt{f'_c}\, b_w d = 2(1.0)(\sqrt{4000psi})(7")(12") = 10{,}625\,lb$

$\frac{\phi V_c}{2} = \frac{0.75(10625lb)}{2 \cdot 1000\,lb/kip} = 3.98^k < 21^k = V_u$ → NEED STIRRUPS

$V_s = \frac{V_u}{\phi} - V_c = \frac{21^k}{0.75} - 10.6^k = 17.375^k$

③ GIVEN A_v, FIND s FROM V_s EQ'N

$A_v = (0.20in^2) \times 2\,legs = 0.40in^2$

$V_s = A_v f_y \frac{d}{s} \Rightarrow s = \frac{A_v f_y d}{V_s} = \frac{(0.40in^2)(60ksi)(12'')}{17.375^k} \simeq 16.5''$

④ CHECK $s \le s_{max}$

$4\sqrt{f'_c}\,b_w d = 4\sqrt{4000psi}\,(7'')(12'')/1000 = 21.25^k$

$V_s \le 4\sqrt{f'_c}\,b_w d \therefore s_{max} = \min\begin{cases} d/2 = 12''/2 = 6'' \\ 24'' \end{cases}$

$s \not\le s_{max} \therefore$ SET $s \cong 6''$

SPAN BC

① FIND V_u

V_u @ d from F.O.S. $= 14^k$

② FIND V_c & CHECK IF STIRRUPS ARE REQ'D, FIND V_s

$V_c = 2\lambda\sqrt{f'_c}\,b_w d = 10.6^k$

$\frac{\phi V_c}{2} = 3.98^k < 14^k \longrightarrow$ NEED STIRRUPS

$V_s = \frac{V_u}{\phi} - V_c = \frac{14^k}{0.75} - 10.6^k = 8.04^k$

③ GIVEN A_v, FIND s

$A_v = 0.40in^2$

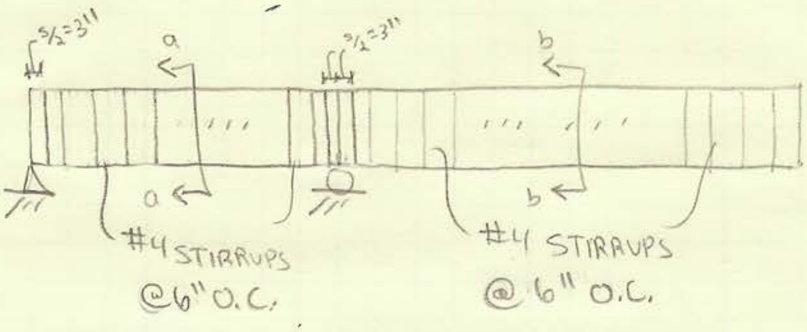
$s = \frac{A_v f_y d}{V_s} = \frac{(0.40in^2)(60ksi)(12'')}{8.04^k} \cong 27''$

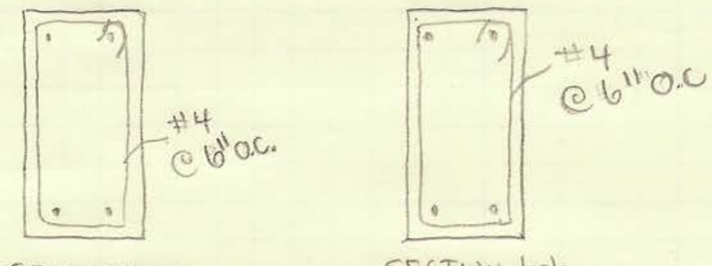
④ CHECK $s \le s_{max}$

$4\sqrt{f'_c}\, b_w d = 21.25^k$

$V_s \le 4\sqrt{f'_c}\, b_w d \quad \therefore \quad s_{max} = \min \begin{cases} d/2 = 12''/2 = 6'' \\ 24'' \end{cases}$

$s \not\le s_{max} \Rightarrow \therefore$ SET $s \cong 6''$





SECTION a-a

SECTION b-b

2.1.2) DOES THE BEAM HAVE ADEQUATE THICKNESS S.T. DEFLECTION CALC NOT REQ'D?

CANTILEVER SECTION $\therefore$ $h_{min} = \frac{l}{8} = \frac{6'(12''/')}{8} = 9'' \le 14'' = h$ ✓ OK

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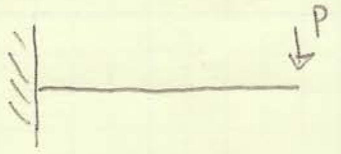
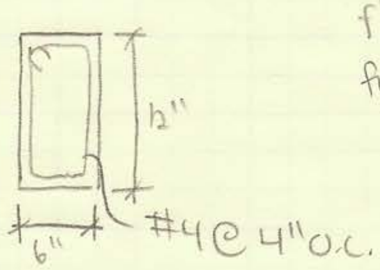
2.2) WHAT IS MAX P THIS CANTILEVER CAN CARRY CONSIDERING SHEAR REQ'MENTS ONLY?





$f'_c = 4ksi$
$f_y = 60ksi$

ASSUME $d = 9.5''$

$V_u \leq \phi V_n$

$V_u = P$

$V_n = V_c + V_s$

$\Rightarrow P \leq \phi (V_c + V_s)$

$8\sqrt{f'_c}\, b_w d = \dfrac{8\sqrt{4000psi}\,(6'')(9.5'')}{1000} = 28.8^k$

$V_c = 2\lambda\sqrt{f'_c}\, b_w d = 7.2^k$

$V_s = A_v f_y \dfrac{d}{s} = \dfrac{(0.40in^2)(60ksi)(9.5'')}{4''} = 57^k \nleq 28.8^k \quad \therefore \text{SET } V_s = 28.8^k$

$P \leq \phi (V_c + V_s) = 0.75(7.2^k + 28.8^k)$

$\Rightarrow \boxed{P_{max} = 27 kips}$

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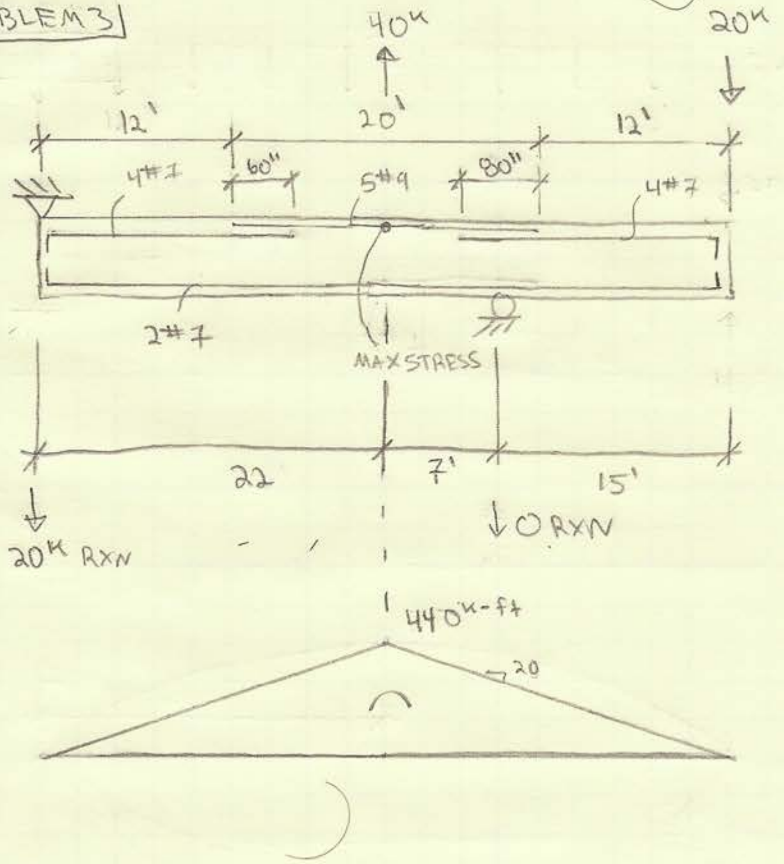
PROBLEM 3



$f'_c = 4ksi$

$f_y = 60ksi$

$h = 30"$

$b = 15"$

$d = 27"$

CHECK SPLICES:

$$l_d \text{ for \#9 bar} = \left(\frac{f_y \psi_t \psi_e}{20\lambda\sqrt{f'_c}}\right) d_b = \frac{(60ksi)(1.3)(1.0)}{20(1.0)\sqrt{4000psi}/1000} \; 9/8" = 69.4"$$

$\psi_t = 1.3$ (ASSUME $h - c - d_b \geq \max\{12", b\}$) MORE CONSERVATIVE ANYWAY

$\psi_e = 1.0$ (UNCOATED)

$\lambda = 1.0$ (NWC)

ASSUME C & Cs ARE ADEQUATE TO BE ABLE TO USE THIS l_d EQ'N

Lsp = Ld,#9=69.4" (see ACI 12.15.3)

Thus the 60" splice length is not adequate

NO POS. MOMENT ∴ ONLY CHECK NEG. REINF. BARS

① CHECK IF 5 #9 BARS IS ADEQUATE FOR MAX. MOMENT

$\phi M_n = 0.9(552^{k\text{-}ft}) = 497 \geq 440 \text{ kip-ft} = M_u$ ✓ OK

② RULE #1 . BARS MUST EXTEND $\max\{d, 12d_b\}$ PAST THEORETICAL CUT-OFF PT.

$\phi M_n^{4\#7} = 0.9(282\,k\text{-}ft) = 254 \text{ kip-ft}$

$M(x) = 440 \text{ kip-ft} - 20^k x$ (X MEASURED FROM PT. OF MAX $M - M_u$)

$254^{k\text{-}ft} = 440 \text{ kip-ft} - 20^k x \Rightarrow x = 9.3'$ FROM PT. OF MAX STRESS

THEORET. CUT-OFF PT. + $\max\{d, 12d_b\}$: $9.3'(12''/1) + \max\{27'', 12(9/8'')\}$

$= 138.6''$ < 144 + 60 =204" ok

see also the supplement included in the last page

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③ RULE #2: BARS MUST EXTEND l_d (a) FROM PT. OF MAX STRESS & (b) FROM THEOR. CUT-OFF PTs OF ADJACENT BARS THAT ARE CUT OFF

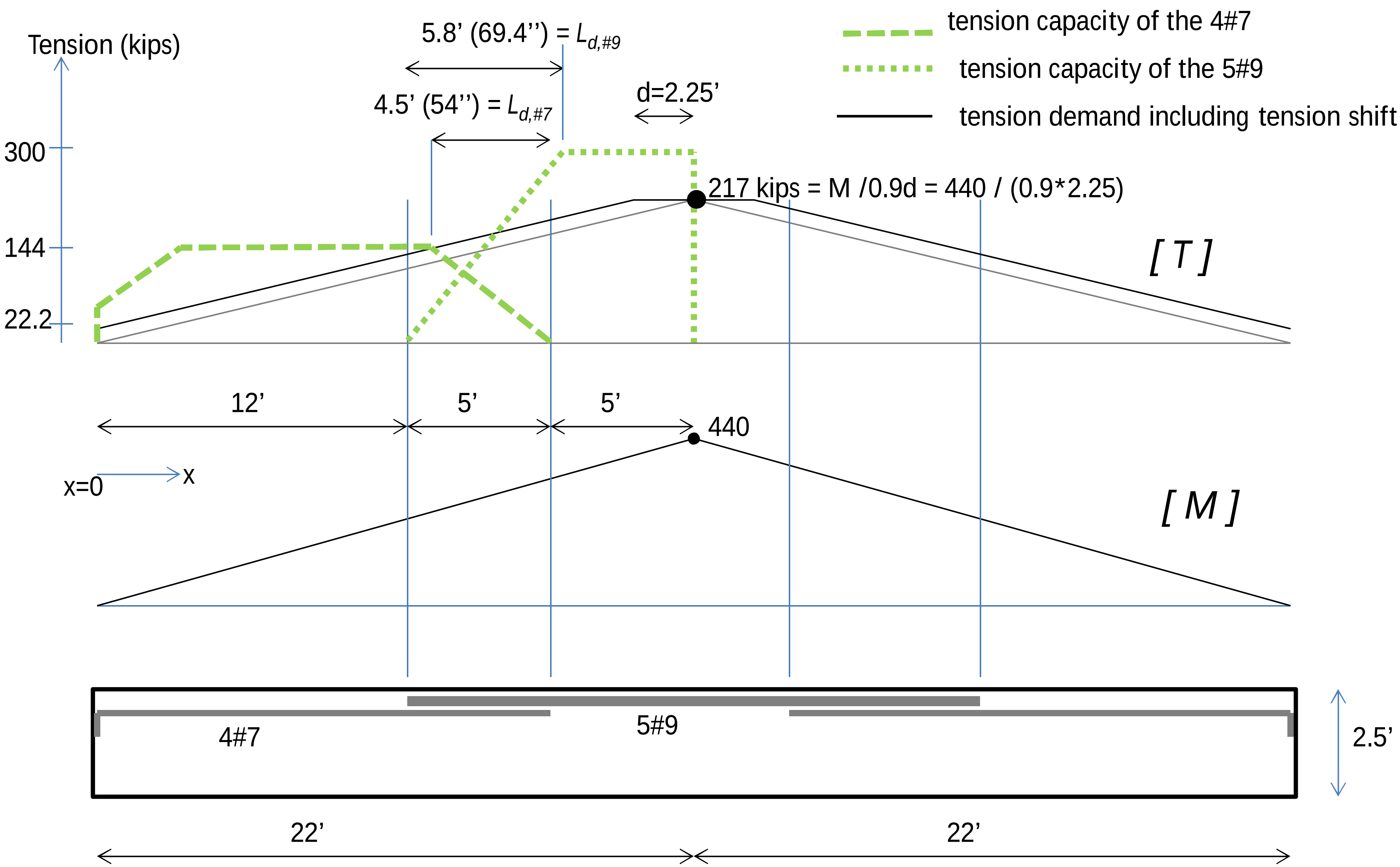
(a) $l_d^{\#9} = \boxed{69.4'' \le \frac{20'}{2} \cdot 12''/' = 120'' \checkmark \text{ OK}}$

NO MOD. FACTORS → MORE CONSERVATIVE

(b) $l_{dh}^{\#7} = \frac{0.02 \psi_e f_y d_b}{\lambda \sqrt{f'_c}} = \frac{0.02(1.0)(60ksi)}{1.0(\sqrt{4000psi})/1000} (7/8) = 16.6'' \ge 6'' \checkmark$

$\ge 8d_b = 7'' \checkmark$

Supplement - problem 3 – midterm 1 – Fall 2011



<u>Assumption close to reality:</u>
T = M /0.9d, d=27'' (2.25')

Increase of tension force due to tension shift:
$M_{x=d}$ / 0.9d = (2.25/22)*440/(0.9*2.25) = 22. 2 kips

$M_{x=12'}$ = 240kips-ft < 0.9*282=254
$M_{x=14.25'}$ = 285 kips-ft