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CE 120 – Spring 2021
Instructor: M.J. DeJong

CE 120 – Structural Engineering

Final Examination

Instructions (as posted on bcourses prior to the exam):

Instructions:

- The exam is open book (i.e. reader) and open notes (including HW solutions). You are not permitted to use other materials.
- You may use a calculator and watch, but no other electronic devices are permitted. (Note: you may use a tablet to write your solution).
- You are not permitted to communicate with any other people during the exam.
- Do all problems. Show all relevant work.
- You may write your solutions on the exam directly, immediately following the problem statements, or you may use your own paper, but please clearly write the problem number at the top of each page, and use a new piece of paper for each problem.
- Organize and write solutions neatly. Points may be taken off for messy solutions.
- Indicate units in final solutions. Points will be taken off if units are missing or signs are unclear.

Zoom Meeting ID: 982 0166 1368 (same as lecture)

****IMPORTANT:**
By submitting your exam, you are agreeing to the following Honor Pledge:

"I have neither given nor received aid during this examination. I have not concealed any violation of the Honor Code. I did not use any unapproved notes or electronic devices during the examination."

Point Breakdown	
Problem 1:	16 points
Problem 2:	26 points
Problem 3:	26 points
Problem 4:	16 points
Problem 5:	16 points
TOTAL:	100 points

Problem 1 (16 points) – A 12-foot-long wood column is pinned at both ends and must carry a maximum load of 5 kips, which results from both dead load and snow load. The wood is Douglas Fir – Larch (North), Dense Select Structural.

Determine whether a 4 x 4 column (actual dimensions of 3.5 inches by 3.5 inches) is an acceptable column size.

$P = 5k$

$C_D = 1.15$

1650 | Derived below | 1.15

$f_c = \frac{P}{A} \leq F_c' = F_c \times C_p \times C_D$

1.0

$\left(\frac{kL}{d}\right) = \frac{(1 \times 12' \times 12"/')}{3.5"} = 41.1 < 50$ OK✓

$f_c = \frac{5k}{(3.5")^2} = 0.408\,ksi = 408\,psi \leq \underbrace{1650\,psi \times 1.15}_{F_c^* = 1898\,PSI} \times C_p$

$E_m = \frac{1{,}900{,}000}{1.76} = 1.08 \times 10^6\,PSI$

$F_{cE} = \frac{0.82 E_m}{(kL/d)^2} = \frac{0.82(1.08 \times 10^6\,PSI)}{(41.1)^2} = 524\,PSI$

$C_p = \frac{1 + 524/1898}{2(0.8)} - \sqrt{\left(\frac{1 + 524/1898}{2(0.8)}\right)^2 - \frac{524/1898}{0.8}}$

$C_p = 0.258$

$F_c' = F_c^* \cdot C_p = 1898 \times 0.258 = 489.7\,PSI$

$F_c' \cdot A = P_{CR}$

$489.7 \times (3.5in)^2 = 5998\# > 5k$ OK

$f_c = 408\,psi \leq F_c' = 489.7\,psi$

$\boxed{\therefore 4 \times 4 \text{ is acceptable}}$

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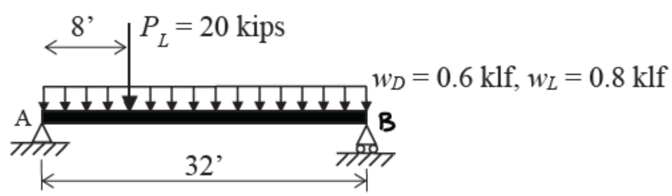
Problem 2 (26 points) – The figure below shows a steel floor beam with distributed dead load of $w_D = 0.6$ klf, a distributed live load of $w_L = 0.8$ klf, and a point live load of $P_L = 20$ kips at the location shown below. The beam is a W-shape and the steel is Grade A36.

Design the beam considering only bending and shear <u>at the midspan</u>. Do not consider deflections.



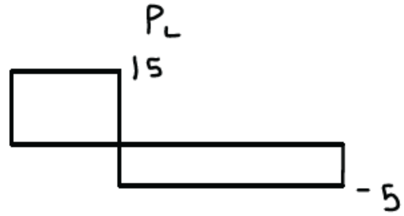
V

$\cancel{0}$ at midspan for distributed loads

$\circlearrowleft \Sigma M_A = 0 = -20k(8') + B_y(32') \Rightarrow B_y = 5k$

$\therefore A_y = 15k$

1VL



$V_{P_L} = 5k$

$$V_u = \begin{cases} 1.4(0) \\ 1.2(0) + 1.6(0+5) = 8k \end{cases}$$

$$V_n \geq \frac{V_u}{\phi} \Rightarrow t_w d \geq \frac{V_u}{\phi(0.6 f_y)} = \frac{8k}{0.9(0.6(36ksi))} = \underline{\underline{0.41 in^2}}$$

$t_w d$

M

$$M_{w_D} = \frac{wL^2}{8} = \frac{(0.6klf)(32')^2}{8} \times 12"/' = 921.6 \text{ k-in}$$

$$M_{w_L} = \frac{wL^2}{8} = \frac{(0.8 klf)(32')^2}{8} \times 12"/' = 1228.8 \text{ k-in}$$

$$M_{P_L} = 15k \times 8' - 5^k \times \left(\frac{32'}{2} - 8'\right) = 80 \text{ k·ft} \times 12"/' = 960 \text{ k-in}$$

$$M_u \begin{cases} 1.4D = 1.4(921.6) = 1290 \\ 1.2D + 1.6L = 1.2(921.6) + 1.6(1228.8 + 960) = \underline{4608 \text{ k-in}} \quad \text{MAX} \end{cases}$$

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Problem 2 (continued)

$$M_n \geq \frac{M_u}{\phi} \Rightarrow Z \geq \frac{M_u}{\phi f_y}$$

$$Z \geq \frac{4608\text{ k-in}}{0.9(36\text{ ksi})} = \underline{\underline{142.22}}$$

$Z \geq 142.2\text{ in}^3$

$t_w d \geq 0.41\text{ in}^2$

$\therefore$ $\boxed{\text{use W18×71}}$

			d		t_w			Z
W18X71	71.0	20.9	18.5	7.64	0.495	0.810	1170	146

18.5×0.495
= 9.157 in² ok ✓✓

ok ✓✓

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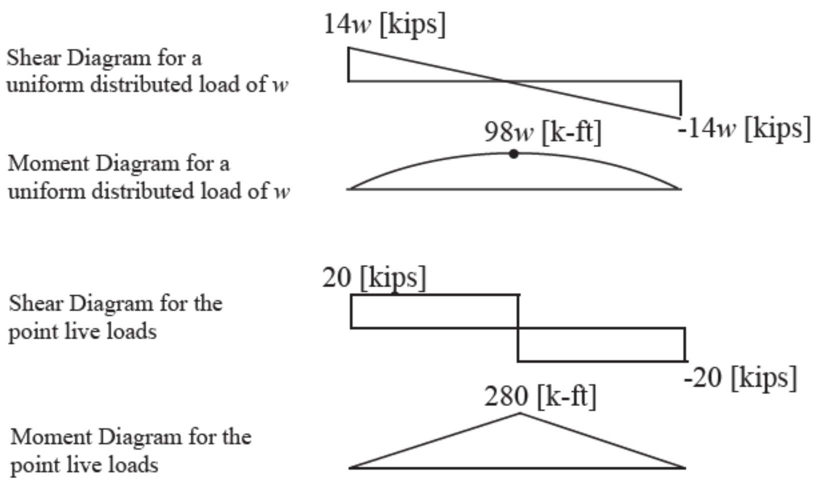
Problem 3 (26 points) – A concrete beam is to be designed for uniformly distributed dead and live loads acting along the whole length of the beam, and a point live load at the midspan. The uniform loads, not including the self-weight of the beam, are $w_D = 0.5$ klf, $w_L = 0.75$ klf. The point load at the middle of the beam is 40 kips.

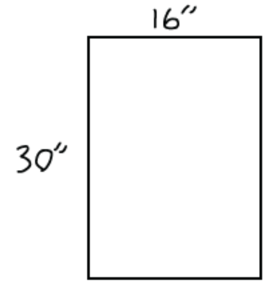
The beam cross-section is 16 inches wide and 30 inches deep. The reinforcing bar is grade 60 steel and the concrete compressive strength is 4 ksi.

(a) Design both the moment and shear reinforcing at the midspan of the beam.

(b) Design the shear reinforcing at the ends of the beam.

The following shear and bending moment diagrams should be used.





$f'_c = 4\text{ ksi} = 4000\text{ psi}$

a) $\text{Self-weight} = \left(\frac{16''}{12''} \times \frac{30''}{12''}\right) \times 150\text{ pcf} = 500\text{ plf} = 0.5\text{ klf}$

$W_{D,tot} = 0.5\text{ klf} + 0.5\text{ klf} = 1\text{ klf}$

$W_L = 0.75\text{ klf}$

$\frac{280\text{ k-ft}}{20\text{ k}} = 14'$
$\therefore \text{span} = 28'$

At midspan...

$M_{WD} = 98(1\text{ klf}) = 98\text{ k-ft}$

$M_{WL} = 98(0.75\text{ klf}) = 73.5\text{ k-ft}$

$M_{PL} = 280\text{ k-ft}$

$$M_u = \begin{cases} 1.4D \\ 1.2D + 1.6L = 1.2(98) + 1.6(73.5 + 280) = 683.2\text{ k-ft} \end{cases}$$

Initial assumption of $d = 30'' - 1.5 - \frac{1''}{2} - \frac{1''}{2} = 27.5''$

$M_u \le \phi M_n = \phi A_s f_y (0.9d)$

$A_s \ge \frac{M_u}{0.9(f_y(0.9d))} = \frac{683.2\text{ k-ft} \times 12''/'}{0.9(60\text{ksi}(0.9(27.5'')))} = 6.13\text{ in}^2 \Longrightarrow \boxed{\text{use (4) \#11 bars}}$ $\Rightarrow 4 \times 1.56\text{ in}^2 = 6.24\text{ in}^2$
$6.24 > 6.13 \therefore \text{OK} \checkmark\checkmark$

$\rho = \frac{A_s}{bd} = 0.014$ $\begin{matrix} > 0.005 \\ < 0.02 \end{matrix}$ $\checkmark$ ok

check spacing $\Rightarrow \left(16'' - 2.5(2) - 3\left(\frac{11}{8}''\right)\right)/3 = 2.3'' > 1.5''$
$\therefore$ OK

more accurate $d = 30'' - 1.5'' - \frac{11}{8}/2'' - \frac{1}{2}'' = 27.3''$

Problem 3 (continued)

$V_{w_D} = 0$

$V_{w_L} = 0$

$V_{P_L} = 20^k$

$$V_u = \begin{cases} 1.4D \\ 1.2D + 1.6L = 1.6(20k) = 32k \end{cases}$$

$V_u \leq \phi V_n$

$V_n \geq \frac{V_u}{\phi} = \frac{32k}{0.75} = 42.7k$

$V_c = 2bd\sqrt{f'_c} = 2(16'')(27.3'')\sqrt{4000psi} = 55.3k$

$V_c > V_n$ $\therefore$ concrete capacity is already sufficient

so use $\boxed{\#3 \text{ rebar for stirrups}}$ at $\left(\frac{d}{2} = \frac{27.3''}{2} = 13.65''\right)$ $\boxed{13'' \text{ o.c.}}$

↳ say 13''

b)

at ends...

$V_{WD} = 14(1\,klf) = 14k$

$V_{WL} = 14(0.75\,klf) = 10.5k$

$V_{P_L} = 20^k$

$$V_u \begin{cases} 1.4D = 19.6k \\ 1.2D + 1.6L = 65.6k \quad \text{MAX} \end{cases}$$

$V_u \leq \phi V_n$

$V_n \geq \frac{V_u}{\phi} = \frac{65.6k}{0.75} = 87.5k$

$V_c = 55.3k \Rightarrow V_s \geq 87.5k - 55.3k = 32.2k$

$V_s \geq \frac{A_v f_y d}{s} \geq 32.2k$

assume #4

$= \frac{2(0.2in^2)(60ksi)(27.3'')}{32.2k} \geq s$

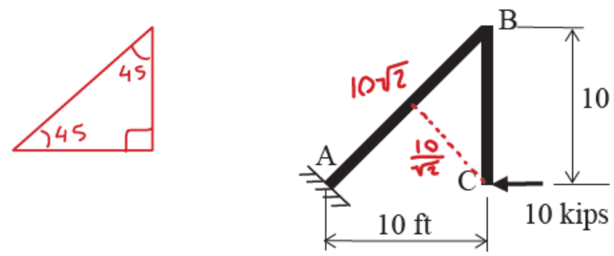
$= 20.3'' \sim 20'' > \frac{d}{2} = 13''$

$\Rightarrow$ try #3 $\frac{2(0.11in^2)(60ksi)(27.3'')}{32.2k} = 11.2''$

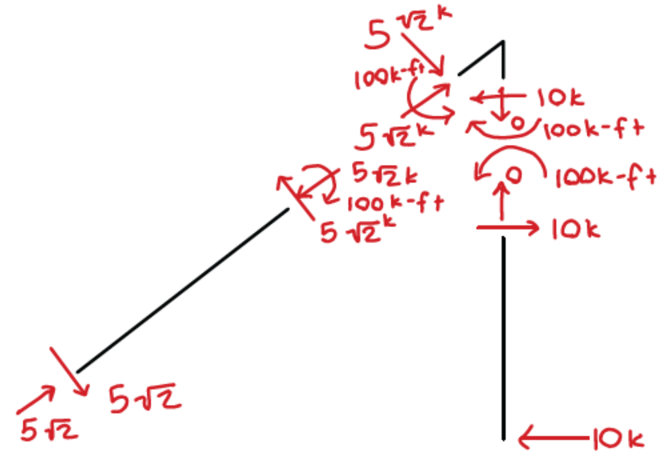
say $\boxed{\#3 \text{ stirrups at } 11'' \text{ o.c.}}$

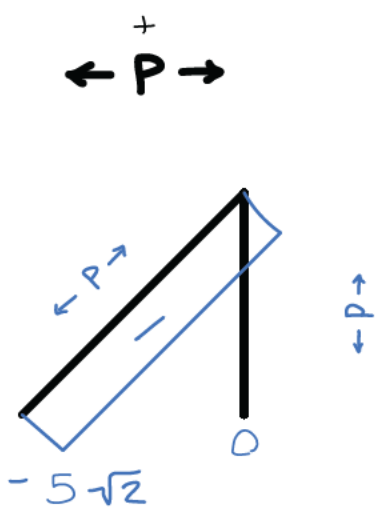
Problem 4 (16 points) –The beam shown below is fixed at point A and is subjected to a point load at point C.

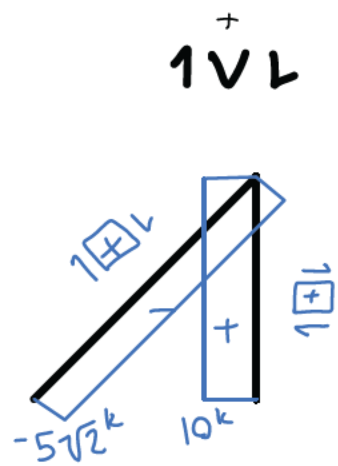
Draw the axial, shear and moment diagrams.

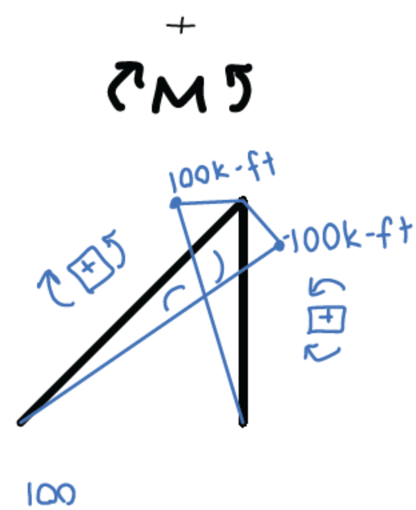


$$\xrightarrow{+} \Sigma F_x = 0 = -10^k + P_{ab}\cos 45$$
$$P_{ab} = 10\sqrt{2}\,k$$









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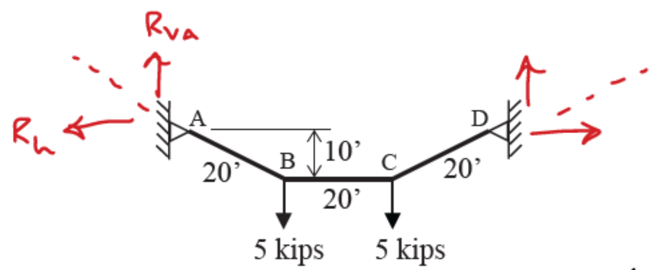
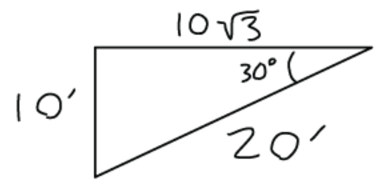
Problem 5 (16 points) – The cable shown below is subjected to 5 kip point loads at points B and C. The length of each segment of the cable is 20 feet. The middle segment of cable is horizontal and is 10 feet below the supports. Assume the self weight of the cable is zero.

(a) Determine maximum tension in the cable.

(b) Assume that the point load at point C is removed, the cable changes shape accordingly, and the maximum sag of the cable becomes 11.53 ft. Determine the new maximum tension in the cable.

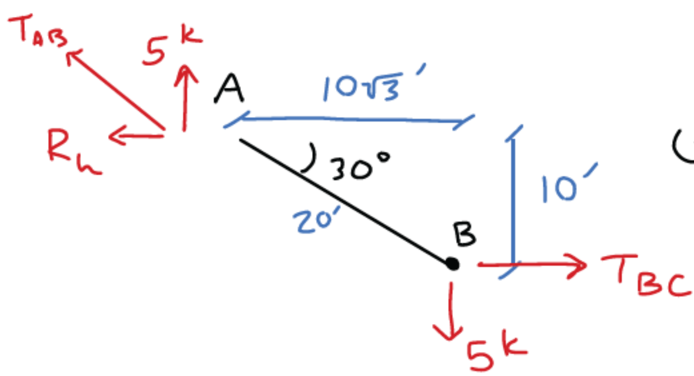




$10\sqrt{3} + 20 + 10\sqrt{3} = 54.6'$

a) $\circlearrowleft{+}\ \Sigma M_D = 0 = -R_{VA}\left(2(10\sqrt{3}) + 20'\right) + 5k\left(10\sqrt{3} + 20\right) + 5k\left(10\sqrt{3}\right)$

$R_{VA} = 5 \quad , \quad R_{VB} = 5$



$\circlearrowleft{+}\ \Sigma M_B = 0 = R_h(10') - 5^k(10\sqrt{3})$

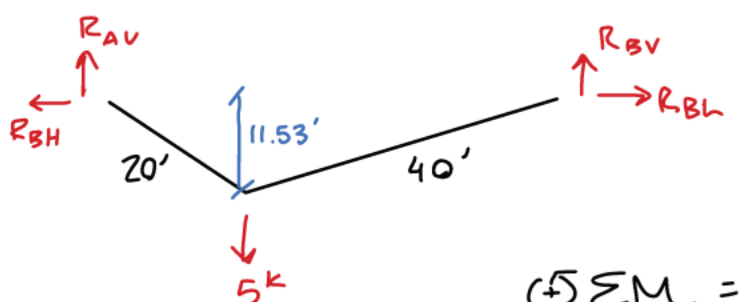
$R_h = 5\sqrt{3}\ k$

$\therefore T_{BC} = 5\sqrt{3}\ k$

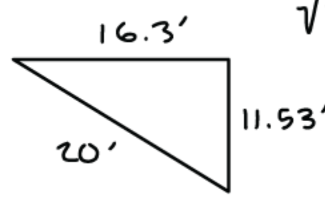
$T_{AB} = \sqrt{5k^2 + (5\sqrt{3})^2 k} = \underline{\underline{10k}}$

$\boxed{T_{max} = T_{AB} = 10k}$

b)



$\sqrt{20^2 - 11.53^2} = 16.3'$



$\circlearrowleft{+}\ \Sigma M_A = 0 = -5_k(16.3') + R_{BV}(54.6')$

$R_{BV} = 1.5^k \quad \therefore R_{AV} = 3.5^k$

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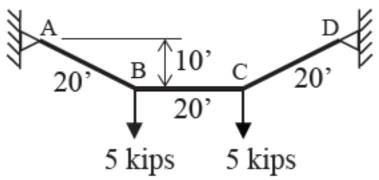
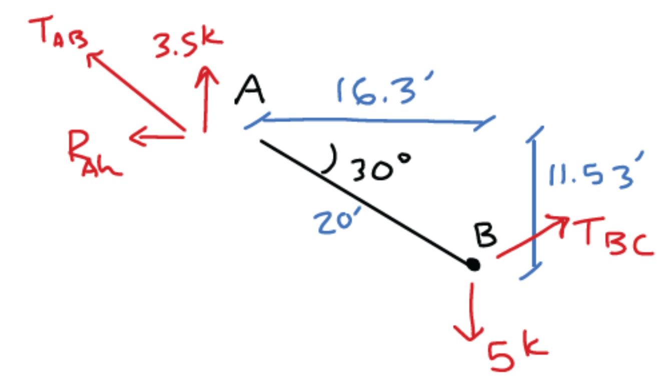
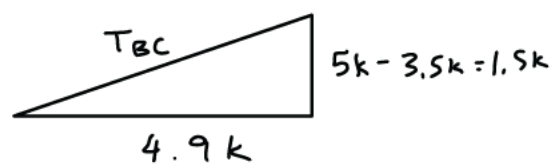


b) CONTINUED



$\circlearrowleft^{+} \Sigma M_B = 0 = -3.5k(16.3') + R_h(11.53')$

$\Rightarrow R_{Ah} = 4.9k$



$T_{AB} = \sqrt{3.5^2 + 4.9^2}$

$\boxed{T_{AB} = 6k = T_{MAX}}$

$T_{BC} = \sqrt{4.9^2 + 1.9^2}$

$= 5.3k$