Name: SOLUTION

University of California, Berkeley
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Department of Civil Engineering
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CE 124 -- DESIGN OF TIMBER STRUCTURES

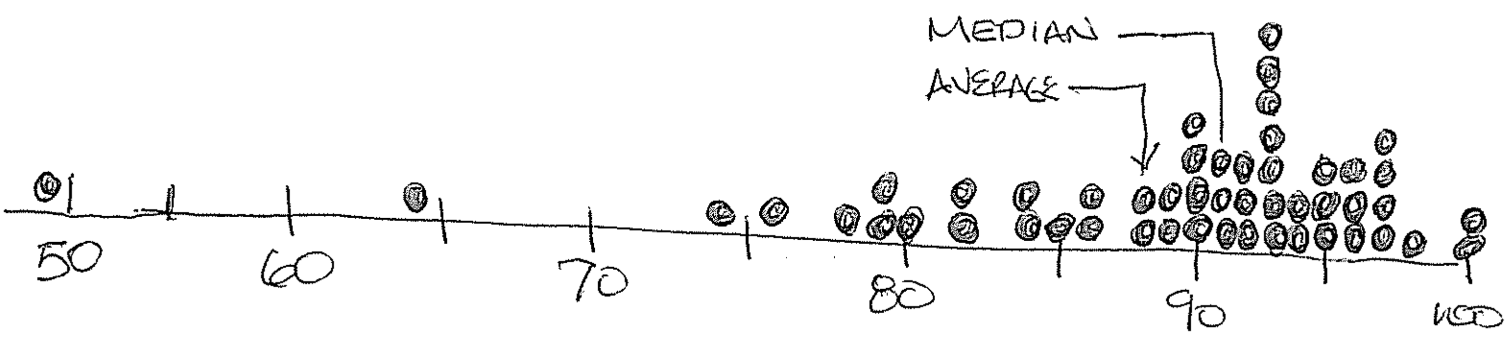
MIDTERM EXAMINATION NO. 2

This examination is open book, code and notes. Show all calculations and indicate all relevant assumptions. Clearly highlight all of your answers.

Unless indicated otherwise, typical California coastal (Berkeley) climatic conditions and standard mill practices may be assumed. Cross sectional dimensions of solid sawn members are given as *nominal values, but you should use actual dimensions when performing calculations*. When in doubt regarding lumber grading, use **WWPA** rules.

Where appropriate, indicate all adjustment factors that need to be considered for a problem (including factors that have a value of one.

Good Luck



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1. 25 (25)

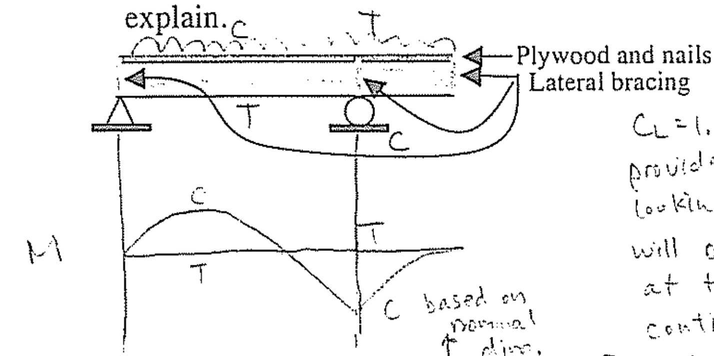
2. 35 (35)

3. 40 (40)

Total: 100 (100)

Problem 1

a. A uniformly loaded, 4x10 solid sawn beam is used in strong axis bending as shown in elevation below. It is laterally supported throughout its entire length by plywood and nails attached to its top face. It has been braced to prevent rotation about its longitudinal axis at its ends and at the supports. **According to the NDS, do you need to compute a value of C_L, or can you use a default value of unity?** Briefly explain.



NDS 3.3.3

$C_L = 1.0$ when continuous lateral support is provided throughout compression edge. looking at the moment diagram, compression will occur on the bottom of the cross-section at the cantilever end, where there's no continuous support.

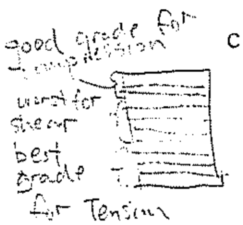
C based on nominal dim.

$4\times10: \frac{d}{b} = \frac{10}{4} = 2.5$ or It meets NDS 4.4.1.2 requirement stated below

$C_L = 1.0$

$2 < \frac{d}{b} < 3$: design requirement needs ends to be held in place by full depth solid blocking, bridging or other framing memb.

c. List two reasons engineered wood products such as glulams may be better than solid sawn lumber products.



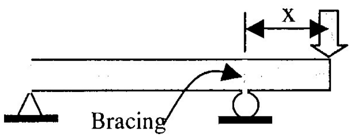
1. Glulam has different grade and/or species of wood on the outside laminations and the center laminations, which is a more efficient use of wood.

2. The Best wood is used for Tension on the bottom and the next best is for compression on top. Since V doesn't govern typically the grade in the center laminations does not have to be as good

2. Since laminations are made of different wood, and glued together, the chance of all the laminations having the defect is lower, thus glulam is generally stronger

3. We can make curved wood member or member w/ a camber easier w/ glulam than w/ solid sawn lumber as well.

d. The 4x10 solid sawn beam shown below is used in strong axis bending. It is only laterally braced and restrained against rotation about the longitudinal axis at the two supports. It has a single concentrated live load applied at the tip of the cantilever section; dead loads can be ignored. Considering only calculations associated with the cantilevered portion of the beam, **what is the longest length "x" one can use for the cantilever**, according to the NDS? Show your calculations. The applied load may be assumed to not overstress the wood.



FOR A CANTILEVER, TABLE 3.3.3 SAYS

$\frac{l_u}{d} < 7: \quad l_e = 1.87\, l_u$

$\frac{l_u}{d} \geq 7: \quad l_e = 1.44\, l_u + 3d$

FOR ALL CASES:

$R_B = \sqrt{\frac{l_e d}{b^2}} \leq 50$

SO: $l_e \leq 50^2 (b^2)/d = 50^2 (3.5)^2/9.25 = 3311''$

$l_u = l_e/1.87 = 3311/1.87 = 1770''$

$l_u/d = 1770''/9.25'' = 191 > 7$ SO NOT VALID

$l_u = (l_e - 3d)/1.44 = \frac{3311 - 3(9.25)}{1.44} = \underline{\underline{2280''}}$

not really feasible, but provides max. length permitted by code

d. You have specified a 20F-V7 glulam (5-1/2 x 27) for a project. The contractor says delivery is delayed for weeks, but that they can get the same size immediately with a combination symbol 20F-V3. **Is this an acceptable substitution?** Briefly justify your answer (or what would you need to check to see if it were acceptable).

THE 20F-V7 and 20F-V3 have same F_b VALUE SO LONG AS TENSION ZONE IS LOADED IN TENSION. HOWEVER, $F_b = 1450$ if compression zone is in tension, and for this case 20FV7 permits $F_b = 2000$ psi. Similarly, $F_{c\perp}$ differs on the compression FACE DIFFER FOR THE TWO COMBINATIONS.

THUS, ONE NEEDS TO CHECK ACTUAL STRESSES AT VARIOUS LOCATIONS

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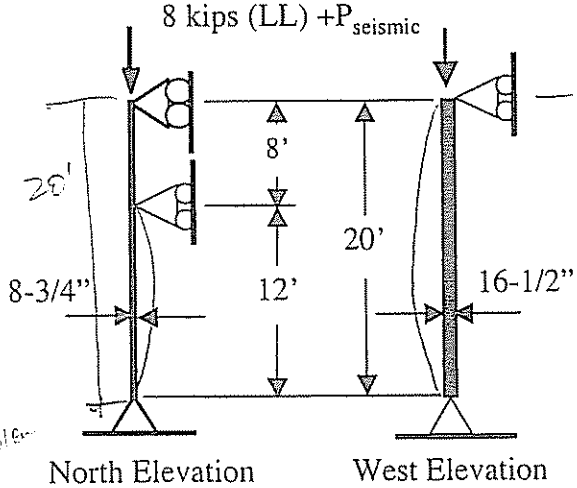
Problem 2

An 8-3/4 x 16-1/2 inch section of a visually graded Western Species glulam with an Identification Symbol 5 is used as a part of an earthquake load resisting system on the interior of a building. As shown below, the member is pined ended, has an applied axial live load of 8 kips; the dead load can be ignored. The column has an overall length of 20 feet. The column is laterally braced in both directions at its top and bottom. In one direction it is braced at a distance 8 feet down from its top. **What is the maximum value of Seismic Force that can be applied to the column concurrently with the specified live load?** You may ignore bending, bearing, shear and deflection considerations in your calculations.



$P_T = L + P_{EQ}$ not load combo problem

$f_c = \frac{P_T}{A} = \frac{8+P}{(144.4 in^2)} \le F_c'$

$\frac{8+P}{144.4 in^2} \le 2606.2 psi$

$8+P \le 376330.$ lbs

$P \le 368330$ lbs $= 368$ k

$P \le 368k$

NICE!

Table 5B — for EQ

$F_c' = F_c C_D C_M C_t C_P = 2400 psi (1.6)(0.679) = 2606.2 psi$ (1.6, 1.0, 1.0, 0.679)

assuming EMC ≤ 16% ∴ $C_M = 1.0$

$C_D = 1.6$ for EQ

assuming the glulam has 4 or more laminations

$F_c = 2400 psi$

$C_P = b - \sqrt{b^2 - \frac{a}{c}}$

$a = F_{cE}/F_c^*$; $F_{cE} = \frac{0.822 E_{min}'}{(l_e/d)^2}$

North Elev.

$l_e = K l_u$, $K = 1.0$ for pin-pin

$l_u = 12' = 12(12) = 144" \rightarrow l_e = 144"$

$d = 8.75"$

$F_{cE} = \frac{0.822 (1.04 \times 10^6 psi)}{(144/8.75)^2} = 3156.4$ psi — controls.

West Elev.

$l_e = K l_u = (1.0)(20 \times 12) = 240"$

$d = 16.5"$

$F_{cE} = \frac{0.822 (1.04 \times 10^6 psi)}{(240/16.5)^2} = 4040.6 psi$

$a = \frac{3156.4 psi}{2400(1.6)} = 0.822$; $b = \frac{1+a}{2c} = 1.012$

$c = 0.9$ for glulam

$C_P = 0.679$

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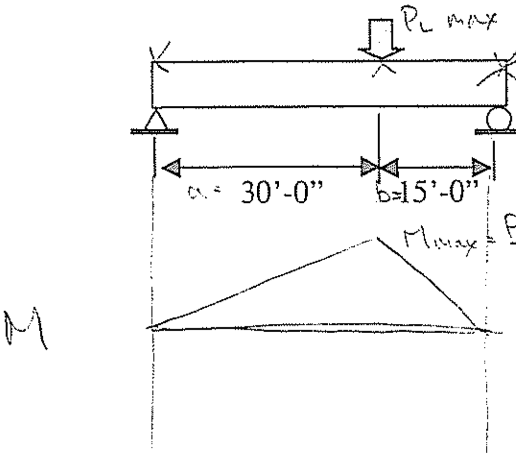
Problem 3

Considering only criteria related to bending moment, what is the maximum allowable value of the single concentrated live load that can be resisted by a glulam beam with a cross section of 12-1/4 by 48 inches? The beam is in an industrial exposure with an Equilibrium Moisture Content (EMC) of 21%. The beam acts in the strong axis direction. Dead load should be neglected! The Douglas Fir beam has a combination symbol 24F-V4. The 45-ft. long beam is simply supported at its ends, and the ends and load point are laterally braced against translation and rotation about the longitudinal axis; there is no other lateral bracing. The single vertical live load is placed 15 feet from one end as shown below.



EMC = 21%

DF 24F-V4 : ✓

$M_{max} = \frac{Pab}{l} = \frac{P(30')(15')}{45'} = 10P$ (lb-ft)

$f_b = \frac{M}{S_x} = \frac{10P}{4704 in^3} = \frac{10(12)P}{4704 in^3} = 0.0255P$ (psi)

$F_b' = F_b C_D C_M C_t C_L C_V C_{fu} C_c$ (1, 0.8, 1, 0.782, 1, 1)

$F_b^+ = F_b = 2400$ psi (assuming LL only downward)

$C_D = 1.0$ for LL

$C_M = 0.8$ for EMC = 21% > 16%

$C_t = 1.0$

$C_V = \left(\frac{21}{L}\right)^{1/x}\left(\frac{12}{d}\right)^{1/x}\left(\frac{5.125}{b}\right)^{1/x} \le 1.0$

L = 45'   x = 10 for DF

d = 48"   b = 12.25"

$C_V = 0.739$ ✓

$C_L = \frac{1+\alpha}{1.9} - \sqrt{\left(\frac{1+\alpha}{1.9}\right)^2 - \frac{\alpha}{0.95}} \le 1.0$ ✓

$\alpha = F_{bE}/F_b^*$ $F_{bE} = \frac{1.20 E_{min}'}{R_B^2}$

$R_B^2 = \frac{l_e d}{b^2}$ $= \frac{1.2(0.67 \times 10^6 psi)}{232.6} = 3456$ psi

$l_u = 30'(12) = 360"$

$l_u/d = \frac{360}{48} = 7.5 \rightarrow 7 \le \frac{l_u}{d} \le 14.3$

footnote: $l_e = 1.63 l_u + 3d = 1.63(360) + 3(48) = 727.2"$ ✓

$R_B^2 = \frac{(727.2")(48)}{(12.25)^2} = 232.6$

$F_b^* = F_b'$ w/o C_v, C_V, C_L = 2400 psi (0.8) = 1920 psi

$\alpha = \frac{3456}{1920} = 1.800$

$C_L = 0.947$ ✓

since $C_V < C_L$, use $C_V = 0.782$ for F_b'

$F_b' = 2400$ psi $(0.8)(0.739) = 1419.6$ psi

$f_b \le F_b'$

$0.0255P \le 1419.6$ psi

$P \le 55668$ lbs = 55.7k

$P_{max} = 55.7k$ ✓