Name: ____________________

University of California, Berkeley
Semester 200x

Department of Civil EngineeringFall
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CE 124 -- Design of Timber Structures

"Trial" FINAL EXAMINATION

This examination is open book and notes. Please show all calculations and indicate all relevant assumptions.

Unless indicated otherwise, typical California coastal climatic conditions and standard mill practices may be assumed. When in doubt regarding lumber grading, use **WWPA** rules.

1. ______________(25)
2. ______________(10)
3. ______________(20)
4. ______________(15)
5. ______________(30)

HAPPY HOLIDAYS

Total: ______________(100)

Problem 1

a. While inspecting a construction site you notice that the carpenters are using extremely short nails to attached the diaphragm to the framing. The contractor says not to worry because these are 10d nails common nails as specified on the drawings. Sure enough, the box they come in says that they are 10 d common nails. You make them stop and change the nails, because...

b. You also note that the contractor is installing tongue and groove floor panels at a location on the drawings which calls for a blocked diaphragm. The contractor says not to worry since the code allows for tongue and groove panels or clips as alternatives for blocking. You say you are not sure if this is the case in this situation, because....

c. What are the main differences between interior and exterior plywood?

d. Above what equilibrium moisture content is it necessary to reduce the allowable stresses for most species of glulam ?

EMC =

e. You notice on inspecting a building you designed several years ago that the nuts on the bolted connections are now loose (but not in danger of falling off). Your colleague asks if the bolts should be re-tightened. You say....

f. Describe what is meant by a "rigid" diaphragm.

Problem 2

The spacing of joists on a floor (not roof) system is 24 inches on center. The design floor load is 175 psf (total DL + LL). The dead load is about 10 psf. The floor is to utilize APA Rated Sheathing that conforms to APA Heavy Duty Floor recommendations. Indicate the required plywood grade, span rating (PII), thickness(es), edge support requirements, and panel orientations for the floor sheathing. **Please** specify the table in Breyer that you use for your design.

Problem 3

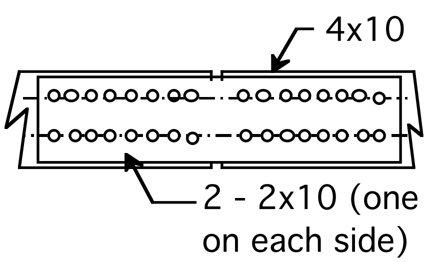
The bolted connection shown below uses two rows of 5/8-inch diameter bolts with eight fasteners in each row on each side of the splice. The load applied is due to dead plus roof live load. The wood members are Douglas fir-Larch (No. 2) and the main member is 4 by 10 inches (nominal) in dimension, while the two side members are 2x10's. The wood is initially wet and seasons in place to an EMC = 11%.

a. What is the load capacity provided by the bolts?

b. What would this load capacity be if two separate side plates were used on each side?

c. What is the minimum length of the side members considering spacing between bolts for you answer to parts a and b? The applied load may be tension or compression.

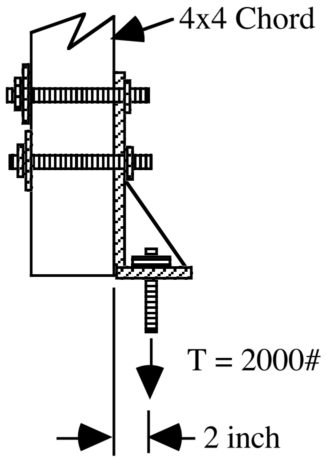
d. What is the stress in the wood main member? Consider the load you computed in part b. How does this value compare to the allowable stress in the wood?



Problem 4

The base of a chord in a shear wall used to resist earthquake forces is attached to the supporting foundation by a standard commercially available metal bracket as shown below. The load in the bracket is applied to the member eccentically so that the chord experiences tension plus bending.

Check the adequacy of the chord (only) for the load shown. You need not check the bracket, anchor rod or the bolts! The lumber is Douglas Fir - Larch, No. 2. Consider only the gross section of the chord.



Problem 5

The roof diaphragm in the single level commercial building shown in plan view below is to be designed for lateral loads. Plywood shear walls are located on all four perimeter elevations of the building. The uniformly distributed lateral loads on the diaphragm due to wind and earthquake are tabulated below. You may ignore gravity load effects for this problem (roof live loads are nominal, i.e., 20 psf).

Direction/ Load	Wind	Earthquake
Longitudinal	350 plf	660 plf
Transverse	350 plf	360 plf

a. Is the UBC span-to-width ratio satisfied? Show allowable ratio!

UBC Ratio:_________ Yes____ No____

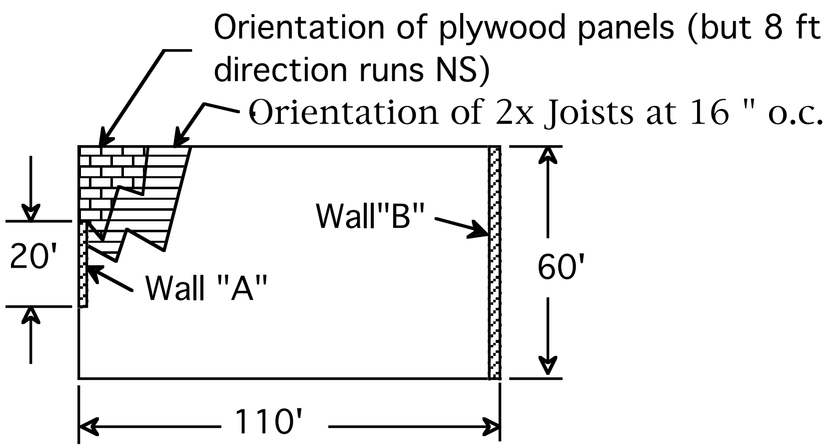
b. For the upper left hand corner of the building indicate required plywood thickness and grade, nailing schedule and blocking, if any. Check both directions of loading! Be sure to indicate what diaphragm case(s) you are considering. **Draw a sketch to show your design and the location of *all* typical nailing.**

c. Indicate where in the diaphragm blocking may be deleted (consider both directions). Draw a simple sketch.

d. Compute the maximum diaphragm chord forces and indicate in a sketch where they occur (do not size the members).

e. Determine the shear flow (plf) in walls "A" and "B" due to loading in the transverse direction.

f. Find the maximum axial force in the "collector" attached to wall "A" due to transverse loading. Wall "A" is symmetrically positioned on the exterior elevation of the building.



Other possible topics include:

Nailing: definitions, adjustments, connection design/evaluation, spacing

Bolting: Loading perpendicular to grain, spacing, etc.

Design problem, for example, find the required size and spacing of floor joists to carry a specified load. Carry the design all the way through.

Load resisting systems: cantilever beam systems, lateral load resisting systems, etc.

Beams: Other topics not covered previously

Solution to Problem 1

Part (a)

Contractor is using ***shortened*** 10d nails commonly referred to as short or plywood nails, which come in three lengths: 2-1/8, 2¼ & 2-3/8-inches. These nails are typically used for attaching the non-structural elements, such as non-structural plywood to serve as tile backing. Because of their shallower penetration, short nails are less likely to split framing members, but are more likely to withdraw. Thus, they may not be used as a substitution to 10d common nails.

Part (b)

Tongue-and Groove or panel clips constitute edge support and cannot be used instead of blocking when the floor plywood is used as a diaphragm (which is the case almost always). The exception is when the diaphragm is 1-1/8 inch thick 2-4-1 plywood with stapled T&G.

Part (c)

Exterior panels have a fully waterproof bond and are suitable for applications subject to long-term exposure to the weather or to moisture. Exterior plywood is made with nothing but waterproof glue and should always be used for any exposed application. Interior plywood, made with highly resistant glues, can actually withstand quite a bit of moisture. There is interior plywood made with IMG (intermediate glue), which is resistant to bacteria, mold, and moisture, but no interior plywood is made for use outdoors.

Part (d)

$EMC = 16\%$

Part (e)

It should be re-tightened. Connections fastened with shear plates or split rings may become loose after shrinkage takes place and separate, thus reducing the bearing area of the wood and its ability to resist loads. Impact and extent of the shrinkage on the bolted connections should be carefully evaluated and, if periodic tightening is required - it should be specified on the drawings!!!

Part (f)

Diaphragms are permitted to be idealized as rigid or semi-rigid where the computed maximum in- plane deflection of the diaphragm under lateral load is less than two times the average story drift of adjoining vertical elements.

Solution to Problem 2

$S_j := 24in$ Joist spacing

$TL := 175psf$ Total floor load

$DL := 10psf$ Dead load

$LL := TL - DL = 165 \cdot psf$ Live load

NOTE : Heavy Duty rating has been removed from the APA Tables in 2005. Instead, Structural Use rating is selected.

$C_D := 1.0$ Load duration factor (interior floor loads are dead and live)

$\frac{L}{360}$ live load deflection limit and $\frac{L}{240}$ total load deflection limit

Required floor span is 24", so use 48/24 span rating.

From APA Load-Span Tables for Structural-Use panels, Table 1a:

$\frac{L}{360}$ live load deflection limit $191psf > 165psf$ OK

$\frac{L}{240}$ total load deflection limit $286psf > 175psf$ OK

Bending strength: $C_D \cdot 194psf = 194 \cdot psf$ $> 175psf$ OK

Shear strength: $C_D \cdot 267psf = 267 \cdot psf$ $> 175psf$ OK

From the ASD Manual: edge support is not required for up to 36 inch spans

From the ASD Manual Table C9.2.3 select 23/32 thick structural panel.

Use 23/32 thick Structural Use panel with 48/24 span rating, strong axis bending, no edge support and continuous over 3 spans.

Solution to Problem 3

Note that shrinkage is not a problem in this connection, since side members are made out of same wood and will shrink approximately the same.

Part (a)

This is a double shear connection for the bolts. See Example 13.5 for applicable equations. Note the capacity is provided by ONLY ONE side of the connection - that is 2 time 8 = 16 bolts. These 16 bolts will resist the tension in double shear wood-to-wood connection. Following adjustment factors apply for Z:

$D := \frac{5}{8}in$ Diameter of bolt $F_{yb} := 45000psi$

$Z := 1760lb$ From Table 11F for both members parallel to load

$n := 8$ $N := 16$ Number of bolts

Main member: Douglas Fir-Larch, No 2, 4x10:

$l_m := 3.5in$ $t_m := 3.5in$ $F_{em} := 5500psi$ $d := 9.25in$

Side members: Douglas Fir-Larch, No 2, 2x10:

$l_s := 1.5in$ $t_s := 1.5in$ $F_{es} := 5500psi$ $d_s := 9.25in$

Adjustments factors are: $C_t := 1.0$ $C_{di} := 1.0$ $C_{eg} := 1.0$ $C_{tn} := 1.0$

$C_M := 0.4$ For initially wet, then seasoned in place

$C_\Delta := 1.0$ For base spacing requirements

$s := 4D = 2.5 \cdot in$ Spacing between bolts in a row

$$\gamma := 270000 \cdot \left(\frac{D}{in}\right)^{1.5} \cdot \frac{lb}{in} = 133408.59 \cdot \frac{lb}{in}$$

$E_m := 1600000psi$ $A_m := t_m \cdot d = 32.38 \cdot in^2$ Modulus of elasticity and area of main member

$E_s := 1600000psi$ $A_s := 2 \cdot t_s \cdot d_s = 27.75 \cdot in^2$ Modulus of elasticity of steel and area of two side members

$$R_{EA} := \frac{E_m \cdot A_m}{E_s \cdot A_s} = 1.1667 \qquad u := 1 + \gamma \cdot \frac{s}{2} \cdot \left[\frac{1}{(E_m \cdot A_m)} + \frac{1}{(E_s \cdot A_s)}\right] = 1.007$$

$$m := u - \sqrt{u^2 - 1} = 0.8887$$

$$C_g := \frac{m \cdot \left(1 - m^{2n}\right)}{n \cdot \left[\left(1 + R_{EA} \cdot m^n\right) \cdot (1 + m) - 1 + m^{2n}\right]} \cdot \left(\frac{1 + R_{EA}}{1 - m}\right) = 0.967$$

$Z' := C_D \cdot C_M \cdot C_t \cdot C_g \cdot C_\Delta \cdot C_{eg} \cdot C_{di} \cdot C_{tn} \cdot Z = 680.88\,lb$ Adjusted Lateral Design Value

$P' := N \cdot Z' = 10894.07\,lb$ Adjusted allowable force

Part (b)

Side members: A36 plates, 2- 1/4x4 (assumed):

$l_s := 0.25\text{in} \quad t_s := 0.25\text{in} \quad F_{es} := 87000\text{psi} \quad d_s := 8\text{in}$

From Table 11G of NDS: $Z := 2390\text{lb}$

$$\gamma := 270000\cdot\left(\frac{D}{\text{in}}\right)^{1.5}\cdot\frac{\text{lb}}{\text{in}} = 133408.59\cdot\frac{\text{lb}}{\text{in}}$$

$E_s := 29000\text{ksi} \quad A_s := 2\cdot t_s\cdot d_s = 4\cdot\text{in}^2$ Modulus of elasticity of steel and area of two side members

$$R_{EA} := \frac{E_m\cdot A_m}{E_s\cdot A_s} = 0.4466 \qquad u := 1 + \gamma\cdot\frac{s}{2}\cdot\left[\frac{1}{(E_m\cdot A_m)} + \frac{1}{(E_s\cdot A_s)}\right] = 1.005$$

$$m := u - \sqrt{u^2 - 1} = 0.908$$

$$C_g := \frac{m\cdot\left(1 - m^{2n}\right)}{n\cdot\left[\left(1 + R_{EA}\cdot m^n\right)\cdot(1 + m) - 1 + m^{2n}\right]}\cdot\left(\frac{1 + R_{EA}}{1 - m}\right) = 0.926$$

$Z' := C_D\cdot C_M\cdot C_t\cdot C_g\cdot C_\Delta\cdot C_{eg}\cdot C_{di}\cdot C_{tn}\cdot Z = 885.67\,\text{lb}$ Adjusted Lateral Design Value

$P' := N\cdot Z' = 14170.71\,\text{lb}$ Adjusted allowable force

Allowable force is higher than in previous case, because the design was governed by the side members.

Part (c)

Length of side members:

$\frac{l_s}{D} = 0.4 \qquad \frac{l_m}{D} = 5.6 \qquad 1.5D = 0.94\cdot\text{in}$ Required edge distance Table 11.5.1A

$7\cdot D = 4.38\cdot\text{in}$ Required end distance Table 11.5.1B

$4\cdot D = 2.5\cdot\text{in}$ Required bolt spacing Table 11.5.1C

There are 4 required end spacings - 2 at ends and **2 at center**!!! There are 14 bolt spacings.

$$L_{req} := 4\cdot(7\cdot D) + 14\cdot(4\cdot D) = 52.5\cdot\text{in}$$

Part (d)

Allowable tension:

$f_t := \frac{P'}{A_m} = 437.71 \cdot psi$ Tension stress in main member

Proceed to calculate the allowable tension in the wood with $C_M = 0.4$

Problem 4

This is a standard combined tension and bending problem. Refer to Example 7.15 on page 7.47. Forces are:

$T := 2000 lb$ Tension force

$M := T \cdot \left(2in + \frac{3.5in}{2}\right) = 625\, lb \cdot ft$ Bending moment

Per problem statement - you will consider only gross section area.

$A_g := 12.25\ in^2$ Area (gross)

$S := 7.146 in^3$ Section modulus

$f_t := \frac{T}{A_g} = 163.27 \cdot psi$ Tensile stress

$f_b := \frac{M}{S} = 1049.54 \cdot psi$ Bending stress

Check: $\frac{f_f}{F'_t} + \frac{f_b}{F'_b} \le 1.0$

Allowable stresses are found as before.

Problem 5

This is similar to the homework problem 9.4.

Part (a)

IBC span to width ratio limit is 3:1 $\frac{110\text{ft}}{60\text{ft}} = 1.83$ OK

Part (b)

Note that earthquake governs in longitudinal direction and wind governs in transverse direction since:

$L := 110\text{ft}$ $B := 60\text{ft}$ Longitudinal and transverse dimensions

$W := 350\text{plf}$ Wind load

$E_{lon} := 0.7 \cdot 660\text{plf} = 462 \cdot \text{plf}$ $E_{tra} := 0.7 \cdot 360\text{plf} = 252 \cdot \text{plf}$ Earthquake load

$v_{lon} := E_{lon} \cdot \frac{B}{2} \cdot \frac{1}{L} = 126 \cdot \text{plf}$ Diaphragm shear for longitudinal direction

$v_{tra} := W \cdot \frac{L}{2} \cdot \frac{1}{B} = 320.83 \cdot \text{plf}$ Diaphragm shear for transverse direction

Go to IBC Tables and select required plywood thickness, grade, nailing and blocking (if required). Draw a plywood shear diagram (shear will be zero at the center and linearly increasing towards the ends) and see in which region (if any) can nailing be reduced, i.e. from 4" on center to 6" on center. It is recommended to use not more than 2-3 different nail spacings (IBC Tables provide 4 different spacings).

This is diaphragm Case 1.

Part (c)

Again, draw a plywood shear diagram (shear will be zero at the center and linearly increasing towards the ends) and see in which region (if any) can blocking be omitted. You do this by comparing the shear with the allowable shear for unblocked case.

Part (d)

Cord forces are:

$P_1 := \frac{W \cdot L^2}{8} \cdot \frac{1}{B} = 8822.92\,\text{lb}$ Force in the transverse cords (short side)

$P_2 := \frac{E_{lon} \cdot B^2}{8} \cdot \frac{1}{L} = 1890\,\text{lb}$ Force in the longitudinal cords (long side)

Part (e)

Shear flows are:

$L_A := 20\text{ft} \qquad L_B := B = 60\,\text{ft}$ Length of walls

$q_A := \frac{W \cdot L}{2} \cdot \frac{1}{L_A} = 962.5 \cdot \text{plf}$ Shear flow in wall A

$q_B := \frac{W \cdot L}{2} \cdot \frac{1}{L_B} = 320.83 \cdot \text{plf}$ Shear flow in wall B

Part (f)

Collector forces are obtained plotting the diagrams as in the homework problem 9.4 or Example 9.12 on page 9.34.