Arch324
STRUCTURES II

Winter 2025
Recitation

FACULTY: Prof. Peter von Bülow

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Arch324: STRUCTURES II

Welcome to Recitation session 02/14

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Office: Room 3122
hours:
Fri: 11:30 – 12:30
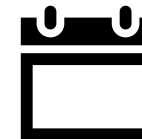Mon, Wed: 11:00 - 12:00
walk-ins welcome!

Click here to make an appointment

Please feel free to ask questions.

Where can you find me?

3

East Studio
3360

West Studio
3160

West Studio
3130

West Studio
3100

3102
Printers/Plotters

Capstone Rooms

Student
Publication
3156

3158

3154 3148 3146 3144 3142 3136 3134

3132

Printers/Plotters

Laser Cutters/3D Printing

Parking Lot (Fuller Road)

N
W — E
S

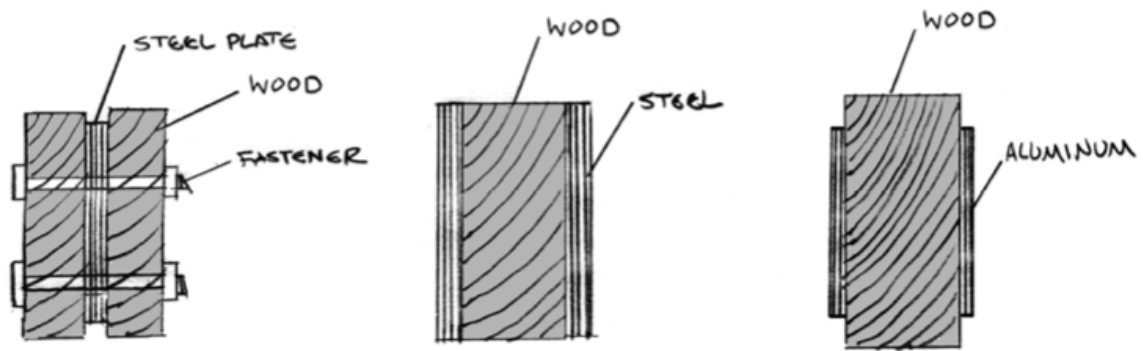# Arch324: STRUCTURES II

Welcome to Recitation session 02/14

Outline:

- Quick **Recap** of the week

- Provide the solution for the assignment **(Homework 4)**

- Answering student's questions

- Lab: **Steel beam**

- **Tower Project:** due date is extended! Feb 16

Please feel free to ask questions.

Recap of the week

Flitched Beams & Scab Plates

STEEL PLATE
WOOD
FASTENER

WOOD
STEEL

WOOD
ALUMINUM

Recap of the week

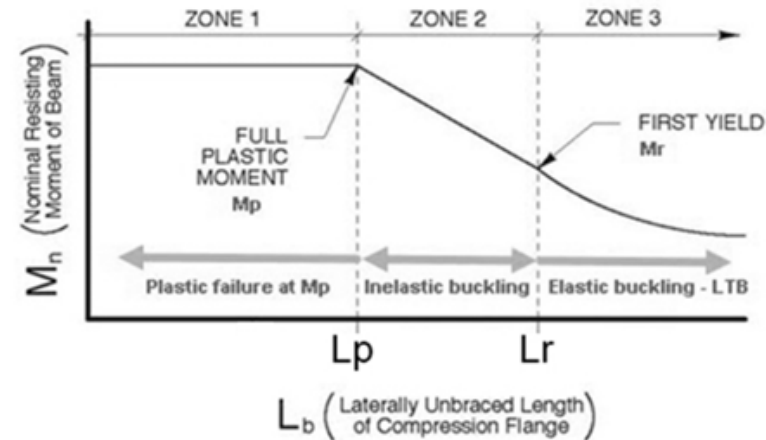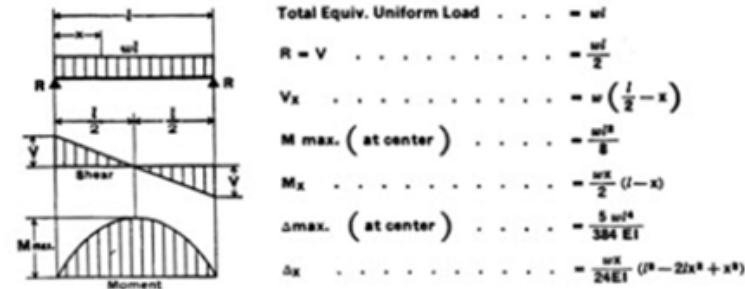## Procedure - Analysis of Steel Beams – **for Zone 1** $L_b < L_p$

Pass/Fail

Given: yield stress, steel section, loading, bracing (L_b)
Find: pass/fail of section

1. Calculate the factored design load w_u
   $w_u = 1.2w_{DL} + 1.6w_{LL}$

2. Determine the design moment M_u.
   M_u will be the maximum beam moment using the factored loads

3. Insure that $L_b < L_p$ (zone 1)
   $L_p = 1.76\ r_y\ \sqrt{E/Fy}$

4. Determine the nominal moment, Mn
   $M_n = F_y\ Z_x$ (look up Z_x for section)

5. Factor the nominal moment
   $\phi M_n = 0.90\ M_n$

6. Check that $M_u < \phi M_n$

7. Check shear

8. Check deflection

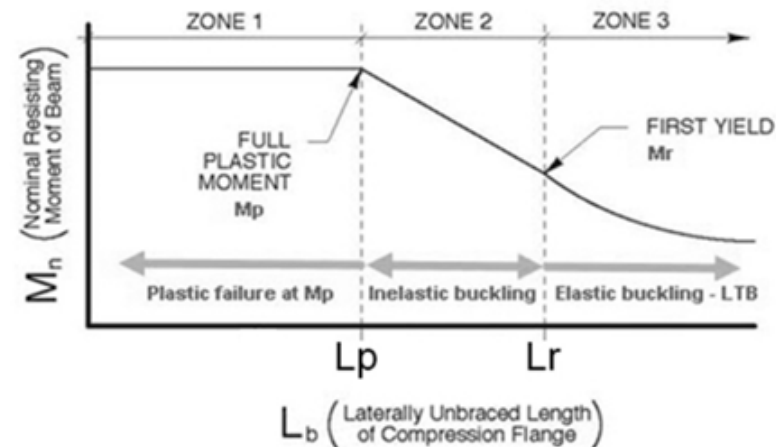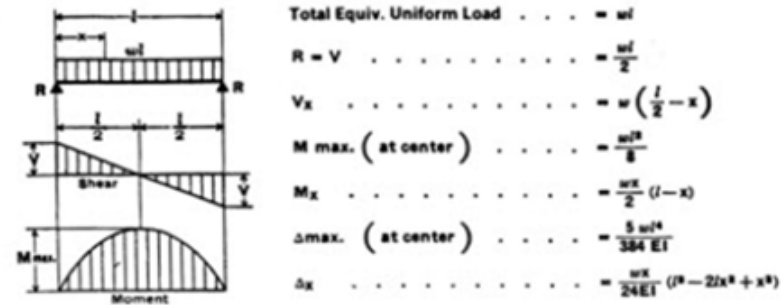1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD

Recap of the week

Procedure - Analysis of Steel Beam - **Capacity**

Given: yield stress, steel section, bracing

Find: moment or load capacity

1. Determine the unbraced length of the compression flange (L_b).

2. Find the L_p and L_r values from the AISC Z_x Table 3-2

3. Compare L_b to L_p and L_r and determine which equation for M_n or M_{cr} to be used.

4. Determine the beam load equation for maximum moment in the beam.

5. Calculate load based on maximum moment. $M_u = \phi_b \ M_n$

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Recap of the week

Design of Steel Beam –Procedure (zone 1)

1. Use the maximum moment equation, and solve for the ultimate moment, M_u.

2. Set $\phi M_n = M_u$ and solve for M_n

3. Assume Zone 1 to determine Z_x required

4. Select the lightest beam with a Z_x greater than the Z_x required from AISC table

5. Determine if $h/t_w < 59$ (case 1, most common)

6. Determine A_w:
   $A_w = d\ t_w$

7. Calculate V_n:
   $V_n = 0.6\ F_y\ A_w$

8. Calculate V_u for the given loading
   $V_u = w_u\ L\ /\ 2$ (e.g. unif. load)

9. Check $V_u < \phi\ V_n$
 ϕ for $V = 1.0$

10. Check deflection

# Provide the solution for the assignment – **HW4**

- ## Problem:

4. Steel Beam Analysis

Analyze the given W-section for beam B1, to determine the maximum live load capacity the floor can carry. Determine the shear and bending forces and check the maximum deflection against an allowable of L/180. Assume the beam is fully braced, Lb < Lp (zone 1).

DATASET: 1   -2-   -3-

W-section	W12X19
Fy	50 KSI
Span A	21 FT
Span B	14 FT
Floor DL	10 PSF
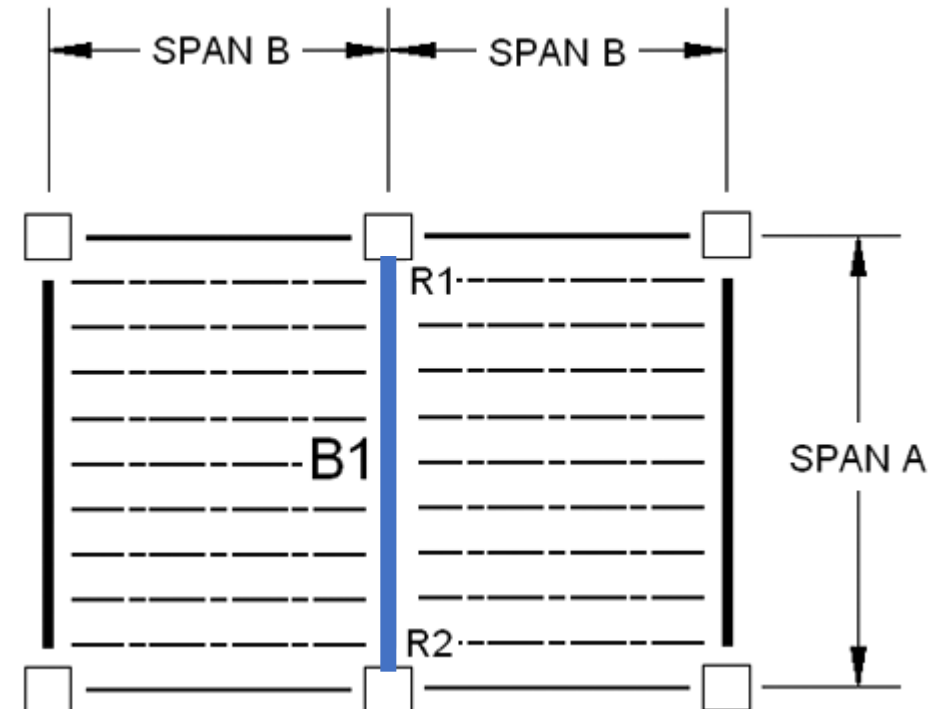
Provide the solution for the assignment – **HW3**
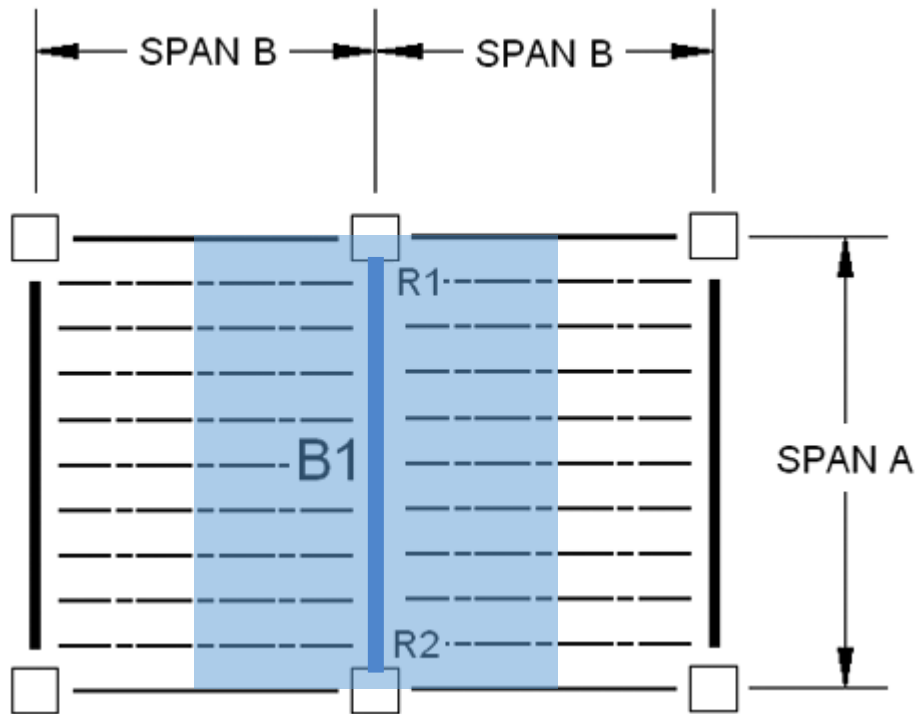
#	Question	Your Response	
1	The plastic modulus of the section, Zx		IN3
2	The nominal bending moment, Mn		K-IN
3	The factored bending resistance, phi Mn		K-IN
4	The factored design moment, Mu		K-FT
5	The total factored design load, wu		KLF
6	The total unfactored dead load on the beam, w_DL		KLF
7	The total factored dead load on the beam, wu_DL		KLF
8	The factored live load on the beam, wu_LL		KLF
9	The actual beam live load (capacity), w_LL		KLF
10	The actual floor live load (floor capacity), LL		PSF
11	The maximum factored design beam shear force, Vu_max		K
12	The web area, Aw		IN2
13	The factored shear resistance, phi Vn		K
14	Is the section safe for shear? (1=yes, 0=no)		
15	The actual (unfactored) deflection due to total DL + LL		IN
16	The deflection limit L/180		IN
17	Is the actual deflection less than the limit L/180? (1=yes, 0=no)		

Provide the solution for the assignment – HW4

Given W-section : W12x19   → AISC , Table 1-1

Provide the solution for the assignment – **HW4**

$F_y = 50 \text{ kSI}$

plastic modulus of the section,

$w\ 12 \times 19 \longrightarrow$ Table 1-1 : $\ \ Z_x = 24.7\ in^3$

Assume the beam is fully braced, $L_b < L_p$ (Zone 1)

$M_n = M_p$

nominal bending moment

$$\left(M_n\right) = Z_x F_y \ = \ \left(24.7\right)\left(50\right) = 1235 \ \ K\_IN$$
$\quad\quad\quad\quad\quad\quad\ in^3 \quad\ \frac{k/b}{in^2}$

$\emptyset$ in bending : 0.9

$\emptyset M_n = 0.9 \times 1235 = 1111.5 \ \ K\_IN$

The factored bending resistance

Provide the solution for the assignment – HW4

$$M_u \leq \phi M_n$$

The factored design moment

we Assume M_u equal to ϕM_n

$$1111.5 \ K\text{-}IN \times \frac{1}{12} = 92.625 \ K\text{-}ft$$

IN to FT

$$M_u = \frac{w_u \ell^2}{8}$$

w_u

L

$$M_u = \frac{w_u \ell^2}{8}$$

M
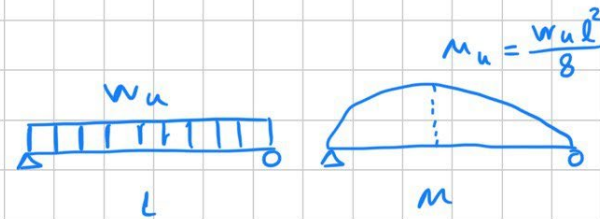
$$92.625 = \frac{w_u \times 21^2}{8} \longrightarrow w_u = 1.68027 \ \ KLF$$

The total factored design load,

Provide the solution for the assignment – HW4

Total unfactored Dead load: Floor DL + beam selfweight

$$10 \text{ psf} \times 2\left(\frac{Span B}{2}\right) + 19 \text{ PLF} = 159 \text{ PLF} \xrightarrow{\times \frac{1}{1000}} 0.159 \text{ KLF}$$

unite Convertion

Q6

Factored DL : $1.2 \times 0.159 = 0.1908$ Q7

$W_u = 1.2 \, w_{DL} + 1.6 \, w_{LL}$

$1.68027 = 1.2 (0.159) + 1.6 (w_{LL})$

$\longrightarrow 1.6 \, w_{LL} = 1.98947$ KLF   Factored Live load   Q8

$w_{LL} = 0.9309$ kLF   Actual live load   Q9

$$\frac{W_{LL}}{Span B} = \frac{\overset{KLF}{0.9309}}{19} = 0.06699 \times 1000 = 66.49 \; \overset{PLF}{}$$ Q10

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Provide the solution for the assignment – HW4

Shear:

$w_u = DL + LL$

$R_1 = R_2 = \dfrac{1.68027 \text{ kLF} \times 21 \text{ FT}}{2} = 17.6428 \text{ k} \quad V_u$

$R_1 \uparrow = \dfrac{w_u l}{2} \qquad R_2 = \uparrow \dfrac{w_u l}{2}$

L

$\begin{cases} \text{if } \dfrac{h}{t_w} < 2.45 \sqrt{\dfrac{E}{F_y}} = 50 \quad (\text{for } 50 \text{ KSI steel}) \\ \\ V_n = 0.6 \, F_y \, A_w \end{cases}$
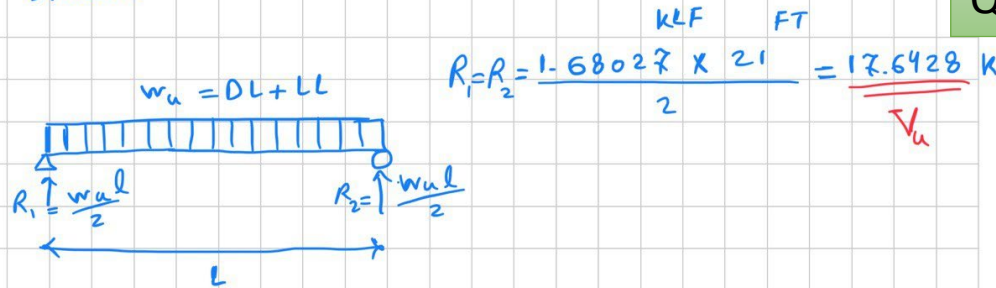
Table 1-1: 46.2 < 50 ✓

Q11

Zone 1:
WEB YIELDING (Most beam sections fall into this category)

if $\dfrac{h}{t_w} \leq 2.45 \sqrt{E/F_y} = 59$ (for 50 ksi steel)

then: $V_n = 0.6 \, F_y \, A_w$

$A_w = d \, t_w = (12.2)(0.235) = 2.867 \text{ in}^2$

$V_n = 0.6 \, F_y \, A_w = 0.6 (50)(2.867) = 86.01$

Check Shear: $V_u < V_n$?

$17.6428 < 86.01 \quad ✓ \quad \text{O.k.}$

Q12

Q13

Q14

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Provide the solution for the assignment – HW4

Deflection:

limit $\frac{L}{180} = \frac{21 \times 12}{180} = (1.4)$ in

unfactored load
DL+LL

$\Delta_{max} = \frac{5wl^4}{384EI} = \frac{5\left(1089.90 \times \frac{1}{12}\right) \times \left(21 \times 12\right)^4 \, in^4}{384 \left(29 \times 10^6\right) \left(130\right) in^3} = 1.2650$ in

Convert to IN

Table 1-1

$\frac{PSI}{\frac{lb}{IN^2}}$

Total unfactored load $\longrightarrow$ (DL) + (self-weight) + (LL)

$140 + 19 + 930.9 = 1089.90$ plf
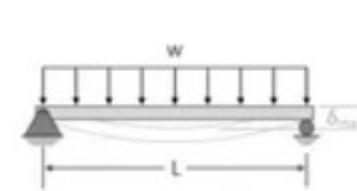
$$\delta_{max} = \frac{5wL^4}{384EI}$$

Lab: Steel Beam Analysis
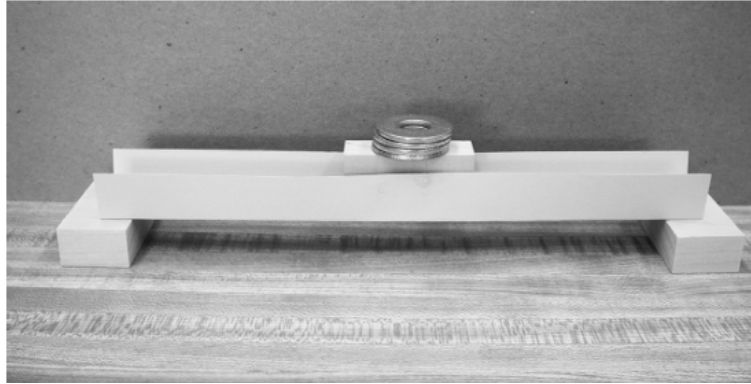
Description

This project uses observation to understand how unbraced compression edges and lateral torsional buckling reduce the ultimate load capacity of steel beams.

Goals

To observe the behavior of unbraced section edges in compression vs tension.
To measure capacity loss due to lateral torsional buckling.

Lab: Steel Beam Analysis
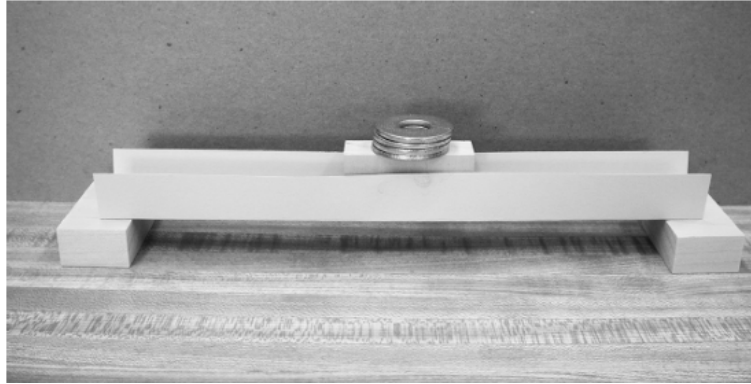
Procedure
1. Position the U shaped section with the free edges on the upper side of the span.
2. Test how many washers the section can support at mid span. Use a wood block to position the load. Observe the mode (how) it fails.
3. Repeat the procedure with the section inverted and the free edges downward.
4. Compare the load level carried by each orientation of the paper beam and describe the behavior under load.

Tower Project: How to start

Criteria

- The tower is to be made of wood. Either linear wood (sticks) or wood panels (sheets) can be used. Glue can be used to connect the elements. Gusset plates at the joints are allowed and can also be glued. But **no steel pins** or fasteners may be used.

- Wood: **any species**. **maximum cross-sectional** dimension = **1/4"**.

- **NO** paper, mylar or plastic or string or dental floss.

- If a member is made by laminating multiple pieces together, the maximum cross-sectional dimension or thickness still cannot exceed 1/4".

- The **height of the tower = 48"**.

- The tower **must hold at least 50 lbs**.

- The entire tower **can weigh no more than 4 oz**.

- The top of the tower must be loadable. The weights will be stacked on top of the tower, but you may optionally use a loose piece of MDF or plywood as a tray under the weights. (It will not be counted in either weight or load)

- Towers will be graded on their low weight, high load-carrying capacity, and the load/weight ratio. The evaluation formula is:

$$\text{(4/weight in OZ)} + \text{(load in LBS/50)} + \text{(load LBS/weight OZ)} \times 1.5$$

- The score will be normalized to a range of 50 to 100. It is used together with report scores to assess your project (a detailed evaluation form is given separately).

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Tower Project: How to start

Scoring
Preliminary Report   40 pts
Testing   60 pts
Final Report   150 pts

Procedure

1. Develop a structural concept for a tower meeting the above criteria.
2. Analyze the design concept with **either** hand calculations or a computer program (e.g. Dr. Frame)
3. Determine the capacity of the major members and of the overall tower (total capacity in LBS)
4. Estimate your expected score using the formula above.
5. Write the preliminary report.
6. Construct the structural model.
7. Test the model. 5-pound steel bars will be placed on top of the model, until the model fails. (bar size: 1 ½" x 2" x 5 13/16").
8. Produce final report documenting requirements and process. See also score sheet.

Use NDS approach

Find load P and stress F'c for each member

Use 1.0 for all factors except C_P

Analysis	Capacity	Design
$f_c = \dfrac{P}{A} \leq F'_c$	$P = F'_c A$	$A = \dfrac{P}{F'_c}$

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Thank you.

Any question?

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