TAUBMAN COLLEGE
ARCHITECTURE & URBAN PLANNING
UNIVERSITY OF MICHIGAN

Arch324
STRUCTURES II

Winter 2024
Recitation

FACULTY: Prof. Peter von Bülow
GSI: Mohsen Vatandoost

Welcome to Recitation session 02/16

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Office: Room 3104

hours:

Fri: 11:30 – 14:30

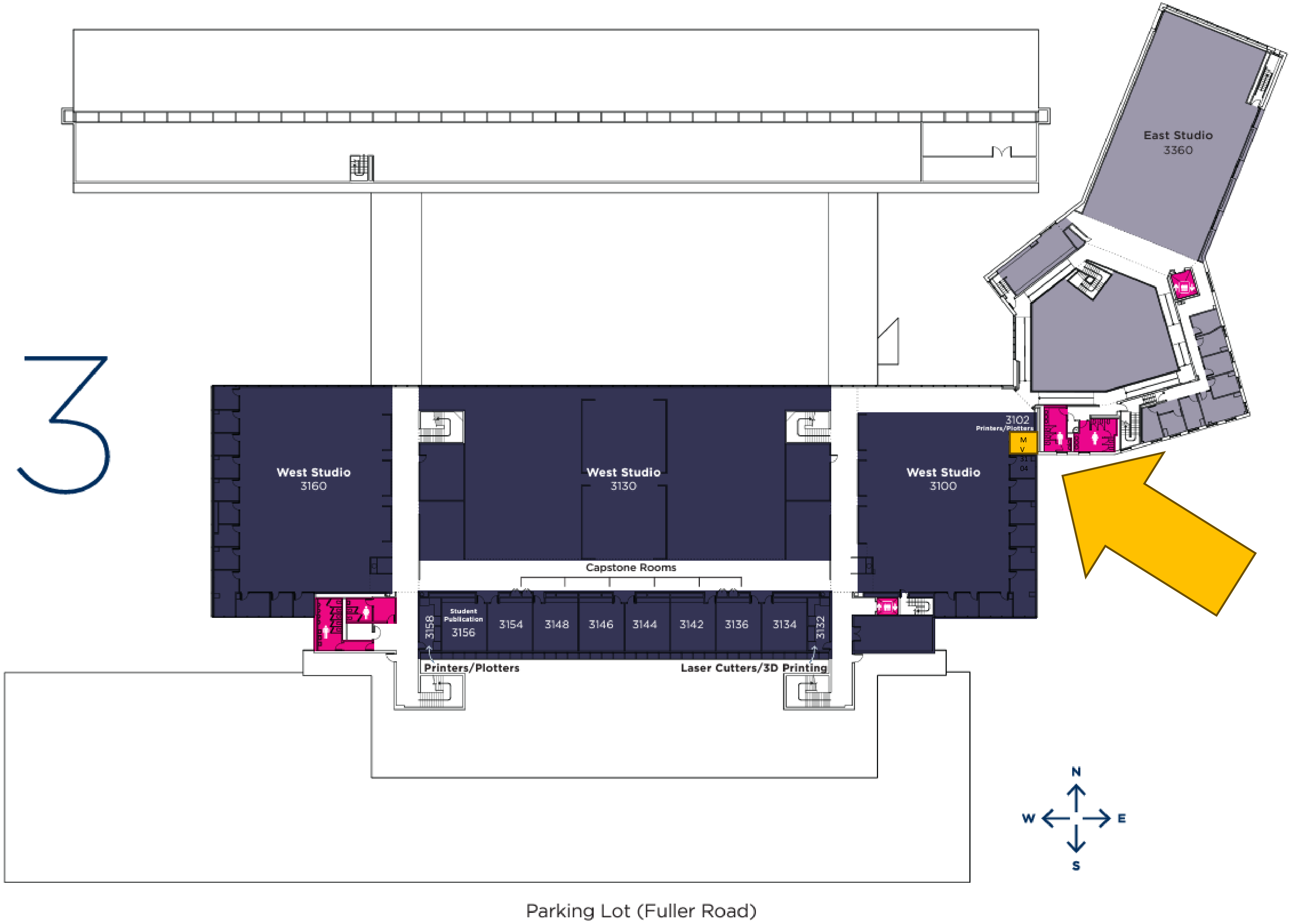
Mon, Wed: 11:00 - 12:00

walk-ins welcome!

Click here to make an appointment

Please feel free to ask questions.

Where can you find me?



Welcome to Recitation session 02/16

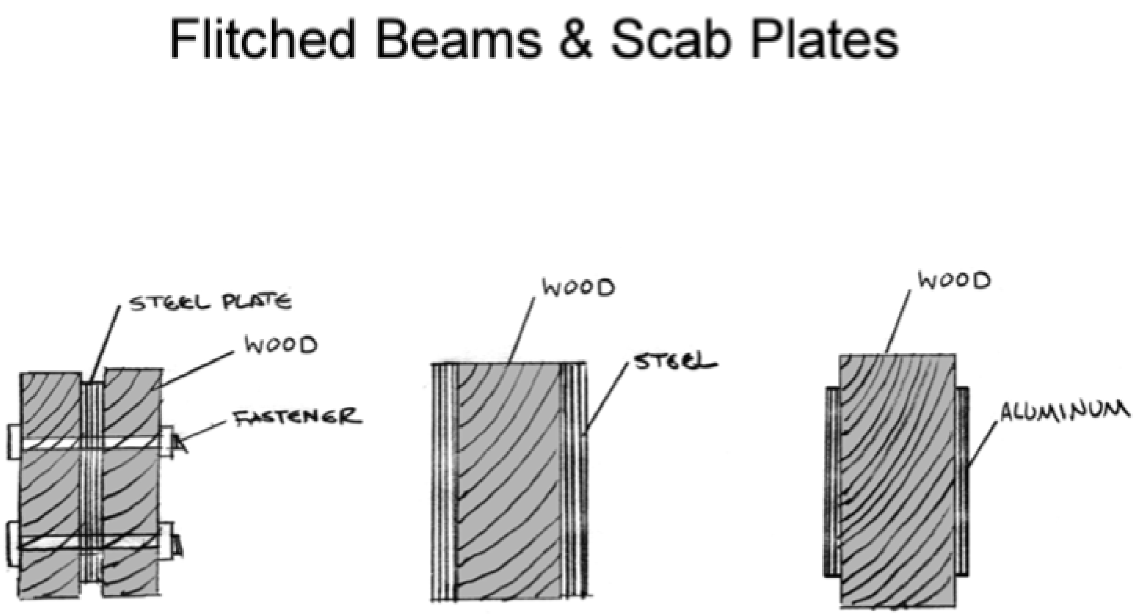
Outline:

- Quick **Recap** of the week
- Provide the solution for the assignment **(Homework 5)**
- Answering student's questions
- Lab: **Steel Columns**
- **Tower Project:** Preliminary report, due date: Extended Feb 23

Please feel free to ask questions.

Contact: Mohsenv@umich.edu

Recap of the week



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 $h/tw < 59$ (case 1, most common)
6. Determine A_w: $Aw = d\ t_w$
7. Calculate V_n: $V_n = 0.6\ F_y\ A_w$
8. Calculate Vu 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 – **HW5**

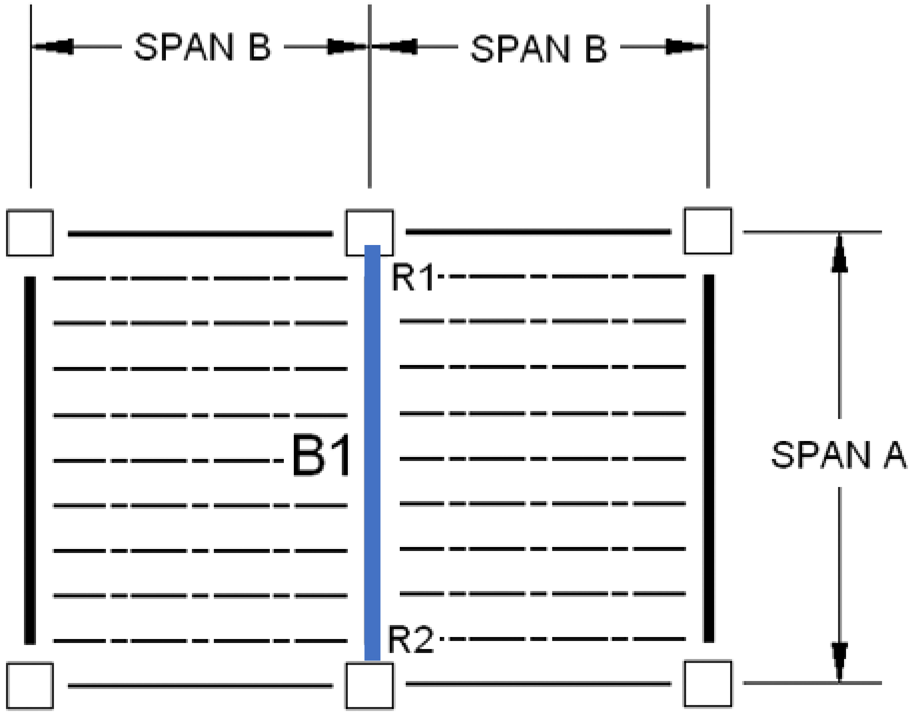
- Problem:

5. Steel Beam Design

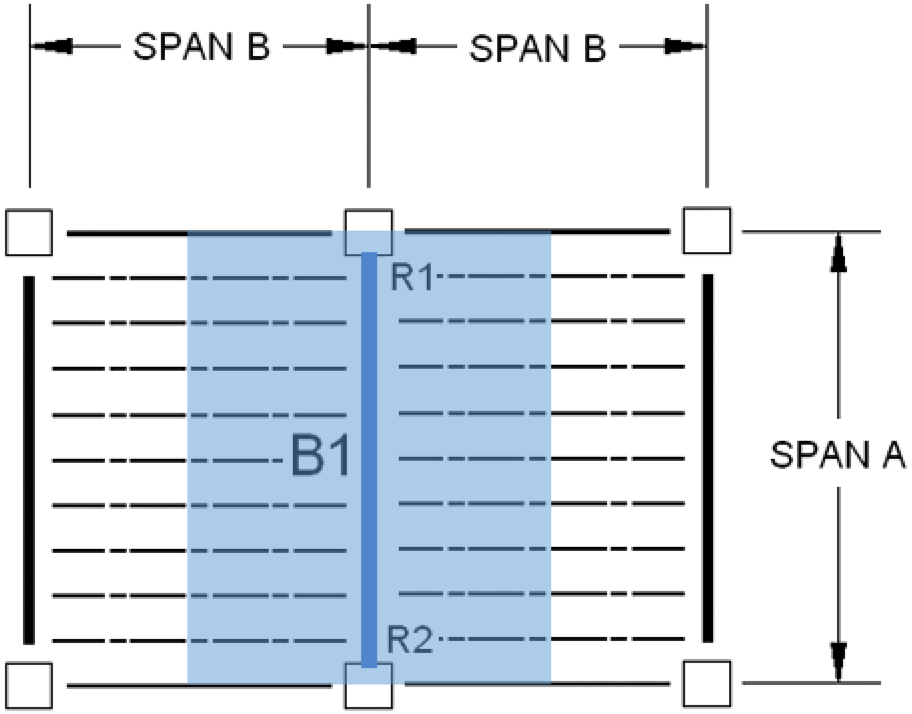
Choose the lightest steel W-section to support the applied dead and live floor loads on Beam B1. Choose a steel W-section from AISC Table 3-2 (posted on Canvas). For the selection of the beam, neglect selfweight (for loads marked with *). After selecting the lightest section from Table 3-2, revise the DL to include the beam selfweight. Check that the final Mu including selfweight is less than the beam strength, phi Mn. Assume the beam is fully braced, Lb < Lp.

DATASET: 1 -2- -3-

Fy	50 KSI
Span A	33 FT
Span B	15 FT
Floor Dead Load	18 PSF
Floor Live Load	80 PSF



Provide the solution for the assignment – **HW5**



#	Question	Your Response
1	The unfactored floor dead load on beam B1 (neglecting selfweight), w_DL*	PLF
2	The unfactored floor live load on the beam, w_LL	PLF
3	The total factored design load on the beam (neglecting selfweight), wu*	KLF
4	The factored design moment (neglecting selfweight), Mu*	K-FT
5	The nominal bending moment (neglecting selfweight), Mn*	K-IN
6	The plastic modulus of the section (neglecting selfweight), Zx*	IN3
7	The nominal depth of the lightest passing W-section from Zx table (include selfweight)	IN
8	The weight of the lightest passing W-section from Zx table	PLF
9	The plastic modulus of the section for the chosen section, Zx	IN3
10	The revised unfactored dead load on the beam (including selfweight), w_DL	PLF
11	The total factored design load on the beam (including selfweight), wu	KLF
12	The factored design moment (including selfweight), Mu in KIP-FT	K-FT
13	The factored design moment (including selfweight), Mu in KIP-IN	K-IN
14	The nominal factored bending moment for the chosen section, phi Mn	K-IN

Provide the solution for the assignment – **HW5**

unfactored Floor dead load on beam B1:

$$w_D = 18 \times 2\left(\frac{\text{Span } B}{2}\right) = 270$$

psf → (Span B → 15) → plf

Live load:

$$w_L = 80 \times 15 = 1200 \text{ plf}$$

w_u (Total Factored design load):

$$w_u = 1.2\, w_D + 1.6\, w_L$$

$$w_u = 1.2(270) + 1.6(1200) = 2294 \text{ plf} \times \frac{1}{1000} = 2.294 \text{ KLF}$$

Provide the solution for the assignment – **HW5**

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

$$= \frac{2.244 \times 33^2}{8} = 305.4645 \text{ K-FT}$$

Nominal bending moment:

$$M_u \leq \phi M_n$$

Assumption: $M_u = \phi M_n \longrightarrow$

$$M_n = \frac{M_u}{\phi = 0.9} = \frac{305.4645}{0.9} = 339.405 \text{ K-FT} \times 12 = 4072.86 \text{ K-IN}$$

unit conversion

Provide the solution for the assignment – **HW5**

problem Assumption: Fully braced (Zone_1)

$M_n = Z_x F_y$

$4072.86 \ (K\_IN) = Z_u \ (IN^3) \cdot (50) \ KSI(K/IN^2) \rightarrow$ Required $Z_u = 81.4572 \ IN^3$

look up in the table:

From the bott go upward and Find nearest Z

(Choose Bold row) ⟶ lightest + strongest in the Series

W21x44 — 21: height / depth; 44: weight

$\rightarrow Z = 95.4 \ IN^3$

Z_x

Table 3-2 (continued)
W-Shapes
Selection by Z_x

F_y = 50 ksi

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF/Ω_b	$\phi_b BF$	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.³	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.⁴	ASD	LRFD
W21×44	95.4	238	358	143	214	11.1	16.8	4.45	13.0	843	145	217
W16×50	92.0	230	345	141	213	7.69	11.4	5.62	17.2	659	124	186
W18×46	90.7	226	340	138	207	9.63	14.6	4.56	13.7	712	130	195
W14×53	87.1	217	327	136	204	5.22	7.93	6.78	22.3	541	103	154
W12×58	86.4	216	324	136	205	3.82	5.69	8.87	29.8	475	87.8	132
W10×68	85.3	213	320	132	199	2.58	3.85	9.15	40.6	394	97.8	147
W16×45	82.3	205	309	127	191	7.12	10.8	5.55	16.5	586	111	167
W18×40	**78.4**	**196**	294	**119**	180	**8.94**	13.2	**4.49**	**13.1**	**612**	**113**	169
W14×48	78.4	196	294	123	184	5.09	7.67	6.75	21.1	484	93.8	141
W12×53	77.9	194	292	123	185	3.65	5.50	8.76	28.2	425	83.5	125
W10×60	74.6	186	280	116	175	2.54	3.82	9.08	36.6	341	85.7	129
W16×40	**73.0**	**182**	274	**113**	170	**6.67**	10.0	**5.55**	**15.9**	**518**	**97.6**	146
W12×50	71.9	179	270	112	169	3.97	5.98	6.92	23.8	391	90.3	135
W8×67	70.1	175	263	105	159	1.75	2.59	7.49	47.6	272	103	154
W14×43	69.6	174	261	109	164	4.88	7.28	6.68	20.0	428	83.6	125
W10×54	66.6	166	250	105	158	2.48	3.75	9.04	33.6	303	74.7	112
W18×35	**66.5**	**166**	249	**101**	151	**8.14**	12.3	**4.31**	**12.3**	**510**	**106**	159
W12×45	64.2	160	241	101	151	3.80	5.80	6.89	22.4	348	81.1	122
W16×36	64.0	160	240	98.7	148	6.24	9.36	5.37	15.2	448	93.8	141
W14×38	61.5	153	231	95.4	143	5.37	8.20	5.47	16.2	385	87.4	131
W10×49	60.4	151	227	95.4	143	2.46	3.71	8.97	31.6	272	68.0	102
W8×58	59.8	149	224	90.8	137	1.70	2.55	7.42	41.6	228	89.3	134
W12×40	57.0	142	214	89.9	135	3.66	5.54	6.85	21.1	307	70.2	105
W10×45	54.9	137	206	85.8	129	2.59	3.89	7.10	26.9	248	70.7	106
W14×34	**54.6**	**136**	205	**84.9**	128	**5.01**	7.55	**5.40**	**15.6**	**340**	**79.8**	120
W16×31	**54.0**	**135**	203	**82.4**	124	**6.86**	10.3	**4.13**	**11.8**	**375**	**87.5**	131
W12×35	51.2	128	192	79.6	120	4.34	6.45	5.44	16.6	285	75.0	113
W8×48	49.0	122	184	75.4	113	1.67	2.55	7.35	35.2	184	68.0	102
W14×30	**47.3**	**118**	177	**73.4**	110	**4.63**	6.95	**5.26**	**14.9**	**291**	**74.5**	112
W10×39	46.8	117	176	73.5	111	2.53	3.78	6.99	24.2	209	62.5	93.7
W16×26[v]	**44.2**	**110**	166	**67.1**	101	**5.93**	8.98	**3.96**	**11.2**	**301**	**70.5**	106
W12×30	43.1	108	162	67.4	101	3.97	5.96	5.37	15.6	238	64.0	95.9

ASD	LRFD
$\Omega_b = 1.67$	$\phi_b = 0.90$
$\Omega_v = 1.50$	$\phi_v = 1.00$

[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with F_y = 50 ksi; therefore, $\phi_v = 0.90$ and $\Omega_v = 1.67$.

Provide the solution for the assignment – **HW5**

revise the dead load and include self weight:

$$w_D = \underset{\text{plF}}{270} + \underset{\text{plF}}{44} = \underset{\text{plF}}{314}$$

$$w_u = 1.2(314) + 1.6(1200) = \underset{\text{plF}}{2296.8} \times \frac{1}{1000} = \underset{\text{KLF}}{2.2968}$$

$$M_u = \frac{w_u L^2}{8} = \frac{2.2968 \times 33^2}{8} = 312.6519 \text{ K-FT}$$

$$\underset{\text{unit conversion}}{\times 12} = \underset{\text{K-IN}}{3751.8228}$$

$$\varnothing M_n = \varnothing Z F_y = 0.9(95.4)(50) = \underset{\text{K-IN}}{4293}$$

$$4293 > 3751.82 \quad \text{O.K.} \checkmark$$

Lab: Steel Columns

Description

This project gives the opportunity to identify steel sections and determine their properties and strength using the AISC tables.

Goals

To identify a steel section based on dimensions.
To determine the sectional properties using AISC table
To determine the load capacity based on AISC column table.

Procedure

1. Measure the steel column section shown below. (your GSI will tell you which one)
2. Based on the sectional dimensions find the shape in the steel table.
3. Use the column table and the given height to find the load capacity. Both columns are A-36 steel (F_y = 36 ksi).

L= 15 ft. – 4 in.

or

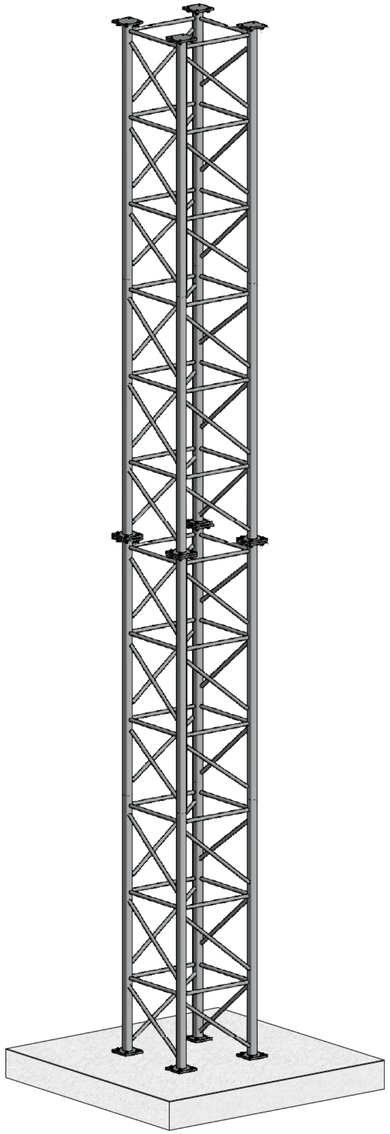
L = 13 ft. 4 in.

Tower Project: Prelim Report Guidelines 2024

Tower Project – Preliminary Report Requirements

Explanation – describe how the design was developed, the basis of the structural concept, and how the principles of column behavior influenced the design decisions.

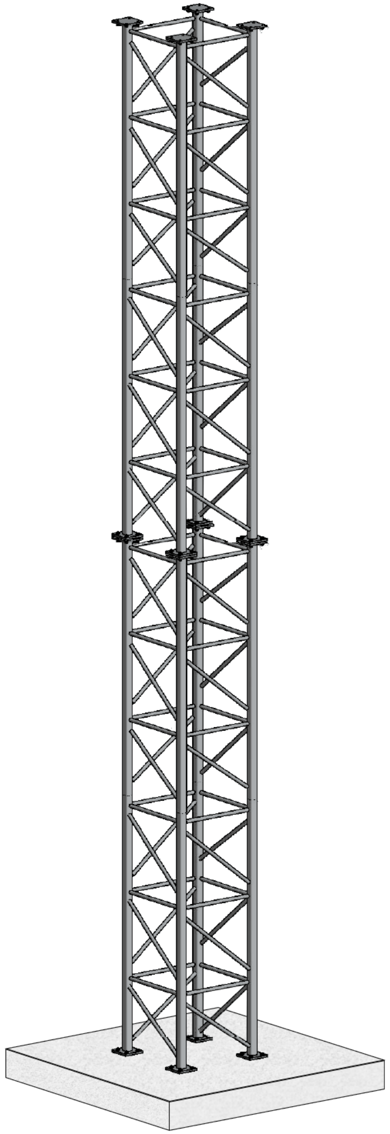
Illustration – include diagrams/drawings that describe the structure in its entirety. **At least a horizontal cross-section and an elevation of the tower are required**. Dimensions are to be included and the member sizes labeled.



Tower Project: Prelim Report Guidelines 2024

The report should include the following:

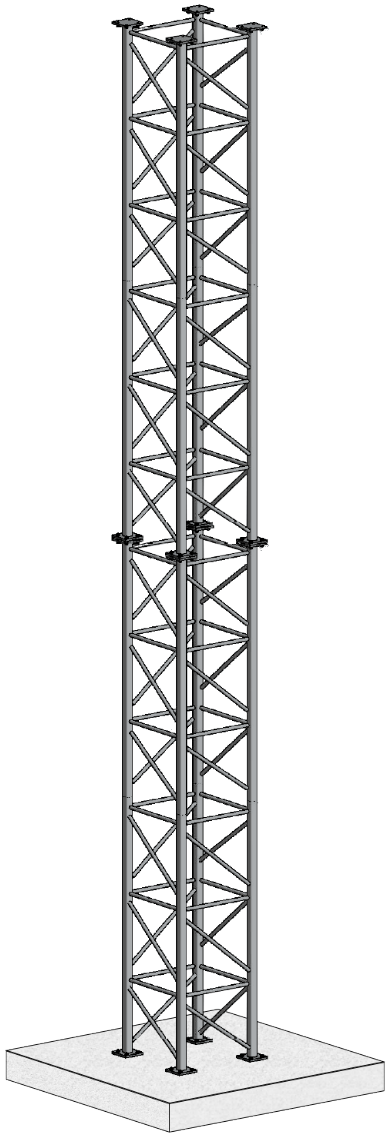
- Choose **wood type** and stress properties
- Determine the **cross-sectional area** of each member
  (Find the axial force P and the allowable stress F'c.)
  Then size the members based on the force in each member.
- Predict the **total weight** of the tower.
  The total weight should be under 4 OZ.
- Predict **Capacity**
  - **Construct a table**, for each member type
  (e.g. main vertical, horizontal tie, diagonal brace)
  - **calculate the ratio of fc/F'c**
  (This ratio should be below 1.0 for all members.)
- Calculate the **buckling capacity** of the tower as a whole.
  This is done by treating the tower as one column loaded at the top



Tower Project: How to start

Due date for the Preliminary report is Feb 16 (Extended to Feb 23)

Tower Test : March 18



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:

  (4/weight in OZ) + (load in LBS/50) + (load LBS/weight OZ)x1.5

- 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).

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

$$f_c = \frac{P}{A} \leq F'_c$$

Capacity

$$P = F'_c A$$

Design

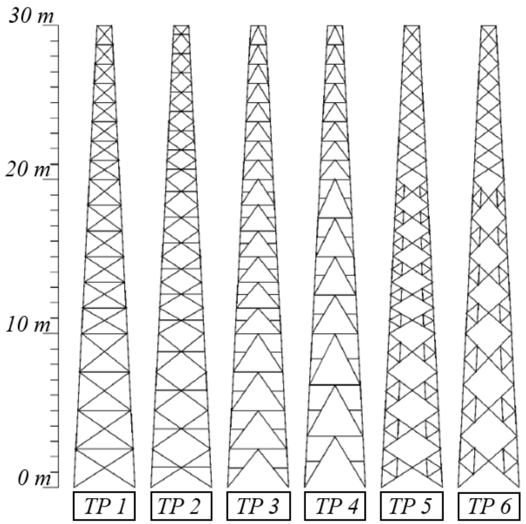
$$A = \frac{P}{F'_c}$$

Tower Project: How to start

- ✓ Team up!
- ✓ Look at examples online: similar towers and high-rise buildings
- ✓ Look at student’s work in the last semester in the course website
- ✓ Familiar yourself with Dr. Frame (download it on the course website)
- ✓ Test different material
- ✓ Sketch your idea
- ✓ Develop your design

Tower Project: How to start

- ✓ Taper tower (optional)
- ✓ For the sake of material saving, the top and bottom sections, could be different
- ✓ Control the Lateral stability
- ✓ Test different patterns
- ✓ Test different geometry
- ✓ Be creative!



lattice tower structure

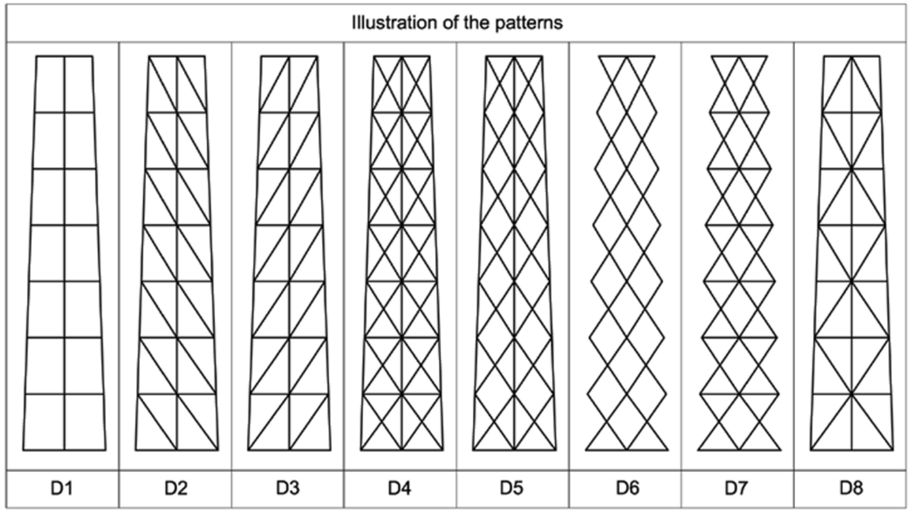


Figure 3: The patterns that are used in designing the lattice tapered towers

Khodadadi, A., & Buelow, P. V. (2014, September). Form exploration and GA-based optimization of lattice towers comparing with Shukhov water tower. In *Proceedings of IASS Annual Symposia* (Vol. 2014, No. 16, pp. 1-8). International Association for Shell and Spatial Structures (IASS).

Thank you.

Any question?

Please feel free to ask questions.

Contact: Mohsenv@umich.edu