Structure II Recitation 4/5

Composite Section

Before we start …

Today's Tasks:

Homework Example (Composite Section)

Lab Session (Composite Section)

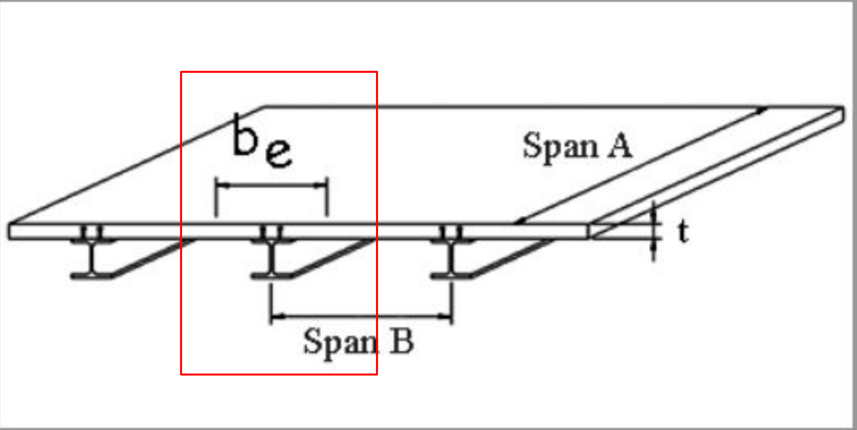
Reminder:

Final Report Due Date: **4/12!!!!!!!!!!**

Tower Project Score Sheet

PRELIMINARY REPORT (re-submit with final report)	**40**	
TESTING	**60**	
Tower weight ≤ 4oz (15 pts); height = 48" (5 pts); holds ≥ 50 lbs (5 pts) Correct Materials (5 pts) (scaled if doesn't meet requirements)	30	
Efficiency (4/weight OZ)+(load LBS/50)+(load LBS/weight OZ)x1.5 (scaled based on class rank)	30	
FINAL REPORT REQUIREMENTS	**150**	
Preliminary Design Development	**20**	
How cross-sectional design of preliminary tower was chosen	4	
How elevation of preliminary tower was developed (e.g. bracing, taper, etc.)	4	
Why/how cross-section was or was not adjusted from preliminary report	4	
Why/how elevation of tower was or was not adjusted from preliminary report	4	
Discussion of how basic principles of columns supported these decisions	4	
Revised/Tested Tower Design Analysis [SHOW WORK AND UNITS!]	**50**	
Calculated/modeled axial forces and derivation of required member cross-sectional areas from axial forces (consider both crushing and buckling)	10	
Estimated weight calculation using actual member sizes used – include weight from members, glue, and gussets, etc.	7	
Member properties table: A, r, L, slenderness ratio (L/r), utilization ratio (actual load / allowable load)	7	
Indicate critical member (largest utilization ratio)	8	
Tower stability (as a whole) - buckling calculation	8	
Prediction of capacity of tower and mode of failure	10	
Illustration of Final/Tested Design	**20**	
Cross-section and elevations(s) of tower	5	
Perspective(s) or isometric of tower (no screenshots!)	5	
Overall dimensions labeled (height, width, etc.) with units	5	
Member sizes labeled (cross-sectional area, length of vertical members and cross-bracing) with units	5	
Testing Results	**30**	
Final weight and height of tower	6	
Tested capacity of tower	6	
Observations of testing (loading, any buckling observed, etc.)	6	
Description of mode of failure	6	
Images of failure	6	
Post-Testing Analysis	**30**	
Comparison of testing results with predicted capacity and modes of failure	10	
Discussion of discrepancies between results	10	
Suggested improvements for future designs with reasoning discussed	10	
FINAL GRADE	**250**	

Using the strength method, determine the required amount of flexural steel reinforcement, As, for the simple span beam (shown in section). The beam carries a dead and live floor load from a one-way slab in addition to its own self weight at 150 PCF. For the given bar size, determine the number of bars to obtain the required As. Check As,min and epsilon_t. Calculate the strength moment, Mn for the final beam design and check that phi Mn is > Mu.



DATASET: 1 -2- -3-

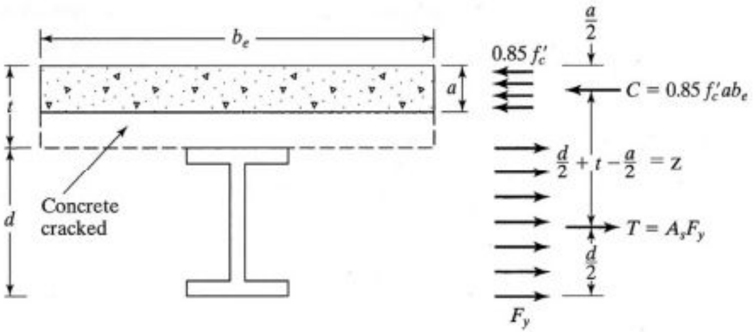
W-section	W18X71
span A	57 FT
span B	12 FT
slab thickness, t	9 IN
steel yield stress, Fy	50 KSI
concrete ultimate stress, f'c	7 KSI

Analysis Procedure (LRFD)

Case1 – PNA within slab

Given: Slab and beam geometry
W-section size and steel grade
(floor loads)

Find: pass/fail or capacities



1. Define effective flange width, b_e
2. Calculate the effective depth of the concrete stress block, a
3. If a is within concrete slab, the full steel section is in tension and:

   $Mp = T\,z$

   $Mn = Mp = As\,Fy\,(d/2 + t - a/2)$
4. $Mu \le \Phi\, Mn$

$$T = C$$

$$A_s f_y = 0.85 f'_c\, a\, b_e$$

$$a = \frac{A_s f_y}{0.85 f'_c\, b_e}$$

be – a – Mu – wu – DL – LL

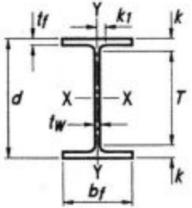


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Distance Workable Gage	Nominal Wt.	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria $\frac{h}{t_w}$
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.	lb/ft		
W21×93	27.3	21.6	21 5/8	0.580	9/16	5/16	8.42	8 3/8	0.930	15/16	1.43	1 5/8	15/16	18 3/8	5 1/2	93	4.53	32.3
×83[c]	24.4	21.4	21 3/8	0.515	1/2	1/4	8.36	8 3/8	0.835	13/16	1.34	1 1/2	7/8			83	5.00	36.4
×73[c]	21.5	21.2	21 1/4	0.455	7/16	1/4	8.30	8 1/4	0.740	3/4	1.24	1 7/16	7/8			73	5.60	41.2
×68[c]	20.0	21.1	21 1/8	0.430	7/16	1/4	8.27	8 1/4	0.685	11/16	1.19	1 3/8	7/8			68	6.04	43.6
×62[c]	18.3	21.0	21	0.400	3/8	3/16	8.24	8 1/4	0.615	5/8	1.12	1 5/16	13/16			62	6.70	46.9
×55[c]	16.2	20.8	20 3/4	0.375	3/8	3/16	8.22	8 1/4	0.522	1/2	1.02	1 3/16	13/16			55	7.87	50.0
×48[c,f]	14.1	20.6	20 5/8	0.350	3/8	3/16	8.14	8 1/8	0.430	7/16	0.930	1 1/8	13/16			48	9.47	53.6
W21×57[c]	16.7	21.1	21	0.405	3/8	3/16	6.56	6 1/2	0.650	5/8	1.15	1 5/16	13/16	18 3/8	3 1/2	57	5.04	46.3
×50[c]	14.7	20.8	20 7/8	0.380	3/8	3/16	6.53	6 1/2	0.535	9/16	1.04	1 1/4	13/16			50	6.10	49.4
×44[c]	13.0	20.7	20 5/8	0.350	3/8	3/16	6.50	6 1/2	0.450	7/16	0.950	1 1/8	13/16			44	7.22	53.6
W18×311[h]	91.6	22.3	22 3/8	1.52	1 1/2	3/4	12.0	12	2.74	2 3/4	3.24	3 7/16	1 3/8	15 1/2	5 1/2	311	2.19	10.4
×283[h]	83.3	21.9	21 7/8	1.40	1 3/8	11/16	11.9	11 7/8	2.50	2 1/2	3.00	3 3/16	1 5/16			283	2.38	11.3
×258[h]	76.0	21.5	21 1/2	1.28	1 1/4	5/8	11.8	11 3/4	2.30	2 5/16	2.70	3	1 1/4			258	2.56	12.5
×234[h]	68.6	21.1	21	1.16	1 3/16	5/8	11.7	11 5/8	2.11	2 1/8	2.51	2 3/4	1 3/16			234	2.76	13.8
×211	62.3	20.7	20 5/8	1.06	1 1/16	9/16	11.6	11 1/2	1.91	1 15/16	2.31	2 9/16	1 3/16			211	3.02	15.1
×192	56.2	20.4	20 3/8	0.960	15/16	1/2	11.5	11 1/2	1.75	1 3/4	2.15	2 7/16	1 1/8			192	3.27	16.7
×175	51.4	20.0	20	0.890	7/8	7/16	11.4	11 3/8	1.59	1 9/16	1.99	2 7/16	1 1/4	15 1/8		175	3.58	18.0
×158	46.3	19.7	19 3/4	0.810	13/16	7/16	11.3	11 1/4	1.44	1 7/16	1.84	2 3/8	1 1/4			158	3.92	19.8
×143	42.0	19.5	19 1/2	0.730	3/4	3/8	11.2	11 1/4	1.32	1 5/16	1.72	2 3/16	1 3/16			143	4.25	22.0
×130	38.3	19.3	19 1/4	0.670	11/16	3/8	11.2	11 1/8	1.20	1 3/16	1.60	2 1/16	1 3/16			130	4.65	23.9
×119	35.1	19.0	19	0.655	5/8	5/16	11.3	11 1/4	1.06	1 1/16	1.46	1 15/16	1 3/16			119	5.31	24.5
×106	31.1	18.7	18 3/4	0.590	9/16	5/16	11.2	11 1/4	0.940	15/16	1.34	1 13/16	1 1/8			106	5.96	27.2
×97	28.5	18.6	18 5/8	0.535	9/16	5/16	11.1	11 1/8	0.870	7/8	1.27	1 3/4	1 1/8			97	6.41	30.0
×86	25.3	18.4	18 3/8	0.480	1/2	1/4	11.1	11 1/8	0.770	3/4	1.17	1 5/8	1 1/16			86	7.20	33.4
×76[c]	22.3	18.2	18 1/4	0.425	7/16	1/4	11.0	11	0.680	11/16	1.08	1 9/16	1 1/16			76	8.11	37.8
W18×71	20.9	18.5	18 1/2	0.495	1/2	1/4	7.64	7 5/8	0.810	13/16	1.21	1 1/2	7/8	15 1/2	3 1/2[g]	71	4.71	32.4
×65	19.1	18.4	18 3/8	0.450	7/16	1/4	7.59	7 5/8	0.750	3/4	1.15	1 7/16	7/8			65	5.06	35.7
×60[c]	17.6	18.2	18 1/4	0.415	7/16	1/4	7.56	7 1/2	0.695	11/16	1.10	1 3/8	13/16			60	5.44	38.7

W-section W18X71

Look at AISC 14, Table 1-1 and get the values we need based on your W- Section type:

Area (A) = 20.9 in^2
Depth (d) = 18.5 in
Width (bf) = 7.64 in
Nominal Weight = 71 lb/ft

Q1: Effective Width of the Concrete Flange (be)

Choose the smallest value of the three:

<u>1/4 the span of the steel beam (1/4 x Span A)</u>

1/4 x (57 x 12) = 171 in

Covert Unit (ft to in)

<u>2 x (8 x slab thickness) + bf</u> ← AISC 14, Table 1-1

2 x (8 x 9) + 7.64 = 151.64 in

<u>On center spacing</u>

Span B = 12 x 12 = 144 in

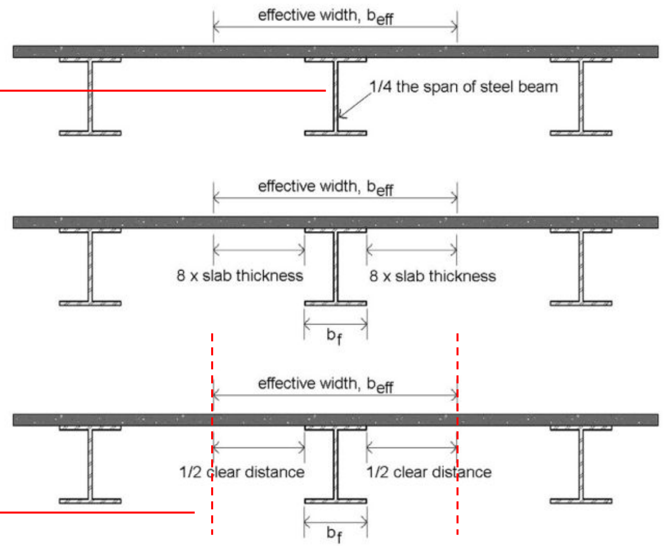
Covert Unit (ft to in)

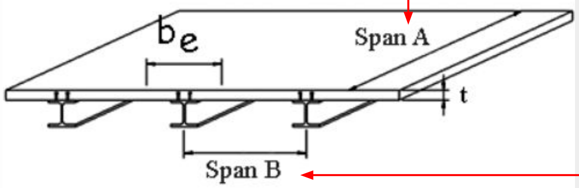
<u>Answer = 144 in</u>

W-section	W18X71
span A	57 FT
span B	12 FT
slab thickness, t	9 IN
steel yield stress, Fy	50 KSI
concrete ultimate stress, f'c	7 KSI

b_e is the **least** total width :

- Total width: ¼ of the beam span
- Overhang: 8 x slab thickness
- Overhang: ½ the clear distance to next beam (i.e. b_e is the web on center spacing)





Q2: Depth of Concrete Stress Block (a)

AISC 14, Table 1-1

a
= <u>As x fy / 0.85 x fc’ x b</u>
= 20.9 x 50000 / 0.85 x 7000 x 144
= <u>**1.21965 in**</u>

be (from Q1)

W-section	W18X71
span A	57 FT
span B	12 FT
slab thickness, t	9 IN
steel yield stress, Fy	50 KSI
concrete ultimate stress, f'c	7 KSI

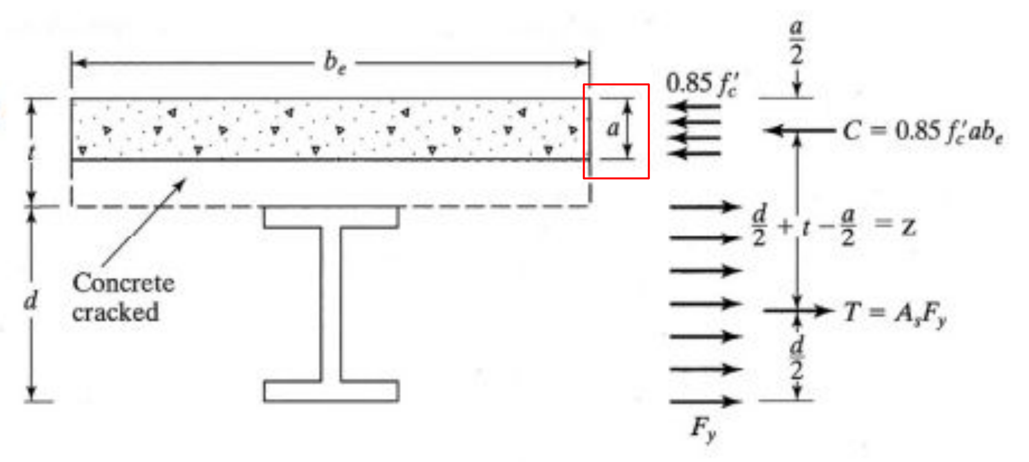
$$a = \frac{A_s f_y}{0.85 f_c' b}$$

Area (A) = 20.9 in^2
Depth (d) = 18.5 in
Width (bf) = 7.64 in
Nominal Weight = 71 lb/ft

Q3: Is Depth (a) Within the Slab?

See if <u>a</u> is smaller than <u>slab thickness</u>,
For my situation, a (1.21965 in) < t (9 in)

Answer = <u>**Yes!**</u>



Q4: The Nominal Bending Moment (Mn)

Mn
= As x Fy x (d/2 + t - a/2)
= 20.9 x 50000 x (18.5 / 2 + 9 - 1.21965 / 2) / 1000
= **18433.98 k-in**

AISC 14, Table 1-1 — Q2 — Covert Unit (lb to k)

Q5: The Factored Bending Resistance (ΦMn)

0.9 x Mn = 0.9 x 18433.98 = **16590.58 k-in**

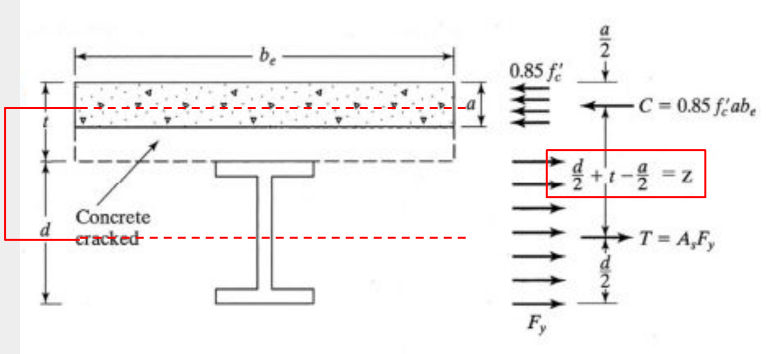
Q6: The Factored Design Moment (Mu)

Mu = Φ Mn / 12 = 16590.58 / 12 = **1382.548 k-ft**

Covert Unit (k-in to k-ft)

W-section	W18X71
span A	57 FT
span B	12 FT
slab thickness, t	9 IN
steel yield stress, Fy	50 KSI
concrete ultimate stress, f'c	7 KSI

Area (A) = 20.9 in^2
Depth (d) = 18.5 in
Width (bf) = 7.64 in
Nominal Weight = 71 lb/ft



$$Mp = T\,z$$

$$Mn = Mp = As\,Fy\,(d/2 + t - a/2)$$

Tensile Force (As Fy) — Moment Arm (d/2 + t - a/2)

Q7: The Total Factored Design Load (wu)

Mu = wu x L^2 / 8

wu = Mu x 8 / L^2 = 1382.548 x 8 / 57^2 = **3.4042 KLF**

Q6 Span A

Q8: The Self Weight of the Concrete Slab

Concrete Density x Slab Thickness (t) = 150 x 9 /12 = **112.5 PSF**

Covert Unit (in to ft)

Q9: The Total Unfactored Dead Load (Concrete+Steel) on the Beam (w_DL)

w_DL

= DL (Concrete) + DL (Steel)

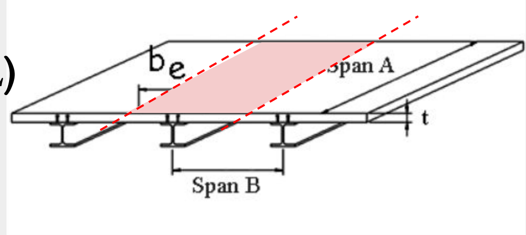
= ((112.5 x 12) + (71)) / 1000 = **1.421 KLF**

Q8 Span B Covert Unit (lb to k)

AISC 14, Table 1-1

W-section	W18X71
span A	57 FT
span B	12 FT
slab thickness, t	9 IN
steel yield stress, Fy	50 KSI
concrete ultimate stress, f'c	7 KSI

Area (A) = 20.9 in^2
Depth (d) = 18.5 in
Width (bf) = 7.64 in
Nominal Weight = 71 lb/ft



$$M_u = \frac{(1.2w_{DL} + 1.6w_{LL})l^2}{8}$$

Q10: The Actual Unfactored Beam Live Load (w_LL)

wu = 1.2 (w_DL) + 1.6 (w_LL)

w_LL
= (wu - 1.2 (w_DL)) / 1.6
= (3.4042 - 1.2 x 1.421) / 1.6
= **1.0619 KLF**

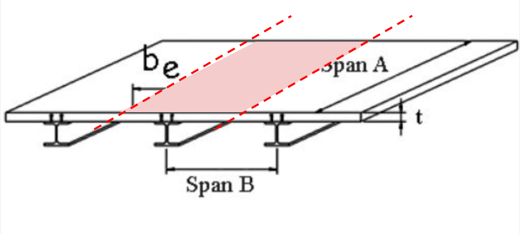
Q11: The Actual Floor Live Load (Floor Capacity) (LL)

LL = w_LL / Span B = 1.0619 / 12 x 1000 = **88.492 PSF**

Q10 ↑   Covert Unit (k to lb) ↑

W-section	W18X71
span A	57 FT
span B	12 FT
slab thickness, t	9 IN
steel yield stress, Fy	50 KSI
concrete ultimate stress, f'c	7 KSI

Area (A) = 20.9 in^2
Depth (d) = 18.5 in
Width (bf) = 7.64 in
Nominal Weight = 71 lb/ft

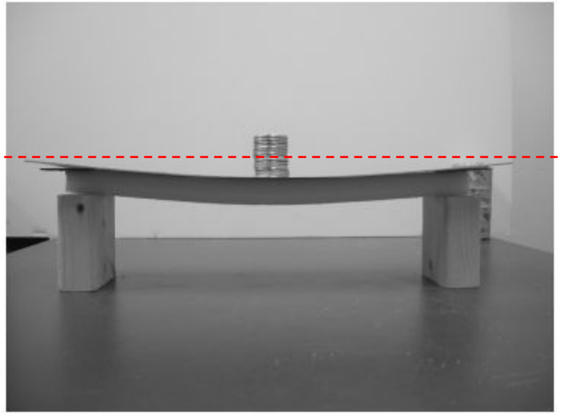


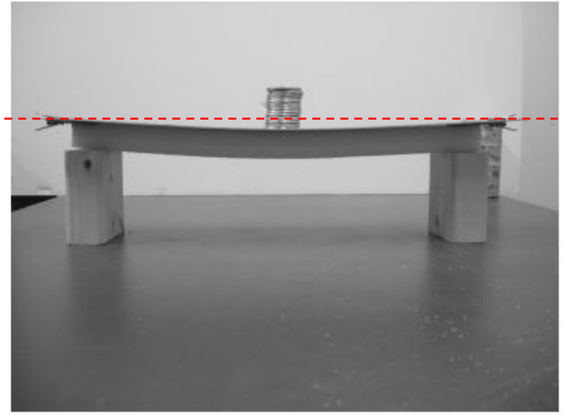
$$M_u = \frac{(1.2w_{DL} + 1.6w_{LL})l^2}{8}$$


SO IT BEGINS
THE GREAT BATTLE OF OUR SEMESTER

Goals

To observe the bending behavior of non-connected beams and slabs
To observe the bending behavior of a composite section.
To compare the deflection of the two systems.





Procedure

1. Place the chipboard slab on the foam beam but do not attach the end clips.
2. Place the 10 washer weights in the center and measure the deflection.
3. Repeat the procedure but now with the ends of the slab and the beam clipped together.
4. Again, measure the deflection.
5. Compare the deflections of the two systems.