CE311 Final Exam
Saturday, December 13, 2014
*Exam designed for 3 hours. Maximum time limit: 4 hours
You may use the Steel Manual, Calculator, Drawing Supplies, only
100 points

Given
Steel Properties: \( E = 29000 \text{ ksi}, \ G = 11200 \text{ ksi}; \ \text{A36 Steel } (F_y = 36 \text{ ksi}, \ F_u = 58 \text{ ksi}); \ \text{A992 Steel } (F_y = 50 \text{ ksi}, \ F_u = 65 \text{ ksi})

Strength of Materials Formulae:
Stress
\[ \sigma = \frac{E \epsilon}{2(1 + \nu)} \]
\[ \tau = \frac{G \gamma}{2(1 + \nu)} \]
Bending Flexural (normal) Stress
\[ \frac{M}{EI} = \frac{1}{\rho} \]
\[ \varepsilon = -\frac{y}{\rho} \]
\[ \sigma = \frac{My}{I} \]
\[ M = EI \]
\[ I = \left(\frac{\pi}{4}\right)r^4 \text{ for a solid circular cross-section} \]

Beam Shear Stress
\[ \tau = \frac{VQ}{It} \]
\[ q = \frac{VQ}{I} \]
\[ q = \frac{F}{s} \]
\[ I = \left(\frac{\pi}{4}\right)r^4 \text{ for a solid, circular shape of radius } r \]

Torsional Formulae - J
J Formulae for a Closed Rectangle
\[ J = \frac{bh^2}{12} \]

J Formula for Open Sections, Composed of Thin Plates
\[ J = \frac{1}{3} \sum b'h' \]
Where \( b \) is the length of the long dimension of each plate and \( t \) is the thickness.

Reinforced Concrete:
\[ \rho = \frac{A_s}{b_d} \leq \left[ 0.75 \beta_1 \left( \frac{0.85 f'_c}{f_y} \right) \left( \frac{87000}{87000 + f_y} \right) \right] \text{ (psi)} \]
\( \beta_1 \) depends on the strength of the concrete, as follows:
If \( f'_c < 4 \text{ ksi}, \ \beta_1 = 0.85 \)
If \( f'_c > 8 \text{ ksi}, \ \beta_1 = 0.65 \)
If \( f'_c \) is between 4 and 8 ksi, then \( \beta_1 = 0.65 + 0.05(8-f'_c) \) (units are ksi)

<table>
<thead>
<tr>
<th>Bar size</th>
<th>Designation</th>
<th>Nominal cross section area, sq. in.</th>
<th>Weight, lb per ft</th>
<th>Nominal diameter, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>0.11</td>
<td>0.376</td>
<td>0.375</td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>0.20</td>
<td>0.668</td>
<td>0.500</td>
<td></td>
</tr>
<tr>
<td>#5</td>
<td>0.31</td>
<td>1.043</td>
<td>0.625</td>
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</tr>
<tr>
<td>#6</td>
<td>0.44</td>
<td>1.502</td>
<td>0.750</td>
<td></td>
</tr>
<tr>
<td>#7</td>
<td>0.60</td>
<td>2.044</td>
<td>0.875</td>
<td></td>
</tr>
<tr>
<td>#8</td>
<td>0.79</td>
<td>2.670</td>
<td>1.000</td>
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</tr>
<tr>
<td>#9</td>
<td>1.00</td>
<td>3.400</td>
<td>1.128</td>
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<tr>
<td>#10</td>
<td>1.27</td>
<td>4.303</td>
<td>1.270</td>
<td></td>
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<tr>
<td>#11</td>
<td>1.56</td>
<td>5.313</td>
<td>1.410</td>
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<tr>
<td>#12</td>
<td>2.25</td>
<td>7.650</td>
<td>1.693</td>
<td></td>
</tr>
<tr>
<td>#18</td>
<td>4.00</td>
<td>13.600</td>
<td>2.257</td>
<td></td>
</tr>
</tbody>
</table>

Truss Degree of Indeterminacy:
\[ \text{DOI} = b + r - 2j \]
\( b \) = number of bars
\( r \) = no. of reaction components
\( j \) = number of reaction joints
BONUS QUESTIONS (0.1 points each):

1. Is the Principle of Virtual Work more like bacon or is it more like scrapple (credit not given without justification. Use the back of this page, if necessary)? ANSWERS: The Principle of Virtual Work is more like bacon because it works with everything. Or, The Principle of Virtual Work is more like scrapple because only God knows what is in it.

2. What college’s football stadium is nicknamed “The Big House?” MICHIGAN

3. What college’s football stadium is nicknamed “The Horseshoe?” THE OHIO STATE UNIVERSITY

4. What college’s football stadium is nicknamed “The Swamp?” FLORIDA

5. What college’s football stadium is nicknamed “The House that Rockne Built?” NOTRE DAME

6. What is the current name of the city that was formerly known as Constantinople? ISTANBUL

7. What is the current name of the city that was formerly known as Leningrad? ST. PETERSBURG

8. What city is home to the Joe Louis Arena? DETROIT

9. What country suffered the two deadliest earthquakes in history, killing 830,000 in 1556 and 750,000 in 1976? CHINA

10. Who famously said that life's three important things were "family, religion and the Green Bay Packers”? LOMBARDI

11. Who was the first US President to resign while in office? NIXON

12. Who is the only person to receive the Heisman Trophy twice? ARCHIE GRIFFIN

13. On what date did D-Day take place? JUNE 6, 1944

14. What was the name of the B-29 bomber that dropped the atomic bomb on Hiroshima, Japan? ENOLA GAY

15. What is the unit weight of steel, in lbs per cubic foot? 490

16. According to the 2015 National Students Steel Bridge Competition Rules, what is minimum distance that the bridge must span? 18’6”

17. According to the 2015 National Students Steel Bridge Competition Rules, what is minimum width of the vehicle passageway? 3’7”

18. According to the 2015 National Students Steel Bridge Competition Rules, what is minimum clearance that the bridge must provide, over the river? 1’6”

19. According to the 2015 National Students Steel Bridge Competition Rules, what is the size of the member box, into which a legal member must fit? 6”X4”X36”

20. How many gallons of beer are contained in a standard US beer barrel? 31

21. What NHL hockey player played from the 1946/1947 season until retiring at the end of the 1970/1971 season, then came back and played the 1979/1980 season at the age of 52? GORDIE HOWE

22. What NHL hockey player has the record for most career goals in the regular season? WAYNE GRETZKY

23. What African-American athlete won 4 gold medals at the 1936 Berlin Olympic games, famously snubbing Adolf Hitler's attempt to showcase the resurgent Nazi Germany and its ideals? JESSE OWENS

24. Who played professional baseball, basketball, and football, in addition to winning 2 gold medals in the 1912 Olympics, and later had the town of Mauch Chunk, PA renamed after him (though he never even visited the town)? JIM THORPE
1. (3 points) What is the degree of indeterminacy (DOI) of the frame shown? All supports are pinned. The diagonal brace is pin-ended. The beam to column connections are as shown in the Detail.

TRUSS:
\[ b = 8 \]
\[ r = 8 \]
\[ d = 8 \]
\[ DOI = 8 + 8 - 2(8) = 0 \]

DOI of the frame, as shown.

\[ DOI = 0 \]

2. (2 points) For the plane shown, what is the theoretical K value for column AB? Given: W12x40 columns, W24x103 girder, pinned base (foundation), pinned (non-moment-resisting) column-girder and brace connections.

Simple Braced
\[ K = 1 \]
3. (22 points). ASD. Determine the most severe load combination and the corresponding load on column B2 at the base of the building. Then, determine the allowable load \( P_n/\Omega \) on that column and specify whether or not the column is safe.

Do apply the live load reduction factor (it has already been applied)

Consider all given dead loads

**Use Exact K Values**

**Given:**

Dead Loads: All columns are W10x77. All fill beams are W18x35. All girders are W24x55. The second floor slab is 6” thick (unit weight of concrete is 150 lb/ft^3). The roof is composed of corrugated metal decking and standard roofing materials that apply a total pressure of 14 psf, not including the weight of fills or girders.

2nd Floor Live Load: 60 psf (do not use the live load reduction factor: assume it has already been applied, giving a value of 60 psf, for this problem).


Connections: For one direction, the beam-column connections are moment resisting. All other connections are pins.
DEAD LOAD PRESSURES

ROOF
14 psf (deckings, etc.)
14 \text{ psf} \left( \frac{35}{10} \right) \text{ (fins)}
14 \text{ psf} \left( \frac{35}{50} \right) \text{ (ceiling)}
\text{Total} = 18.6 \text{ psf}

2ND FLOOR:
75 psf (scabs)
35 \text{ psf} \left( \frac{35}{10} \right) \text{ (fins)}
55 \text{ psf} \left( \frac{55}{50} \right) \text{ (ceiling)}
\text{Total} = 79.6 \text{ psf}

LOADS:
\begin{align*}
A_T &= 40' \times 50' = 2000 \text{ ft}^2 \text{ / floor} \\
D &= (2000 \text{ ft}^2)(18.6) = 37,200 \text{ kips} \\
L &= (2000 \text{ ft}^2)(60 \text{ psf}) = 120,000 \text{ kips} \\
L_T &= (2000 \text{ ft}^2)(20 \text{ psf}) = 40,000 \text{ kips}
\end{align*}

COMBINATIONS:
\begin{align*}
D + L &= 198.9 \text{ kips} \\
D + 0.15(L + L_T) &= 318.9 \text{ kips}
\end{align*}

K_L = 20', K_L = 10', A = 1

\begin{align*}
\gamma &= \frac{455}{20} + \frac{455}{12} = 60.7 \text{ kips/ft} \\
\gamma_B &= \frac{1/2}{2} = 0.25 \\
W_{1/2} \times 35 \text{ stabilizes} \\
K_L &= 2.3 \Rightarrow K_L = 46'
\end{align*}

TABLE 26' \rightarrow 237' \Rightarrow \frac{P}{A} = 227' \text{ kips} \Rightarrow P = 319' \text{ kips}

\text{Inadequate} \left( \frac{P}{A} = 227' \text{ kips} \right) \times (P = 319' \text{ kips})
4. (7 points). Circle the correct answer. The nominal strength $P_n$ for an A992 W14x145 in axial compression with $KL_y = 24$' and $KL_x = 12$' is (to 3 digits of precision):

A. $1100$ kips
B. $1930$ kips
C. $1830$ kips
D. $872$ kips
E. $1450$ kips
F. None of the Above

\[
\frac{P_{n}}{A} \rightarrow \frac{P_{n}}{A} (\text{Table 4-1}) \rightarrow P_{n}
\]

$KL_y = 12' \rightarrow 1160 \rightarrow 1933$

$KL_x = 15' \rightarrow 1093 \rightarrow 1825$

5. (2 points) TRUE or FALSE. A $\frac{3}{4}''$ Group A Slip Critical bolt has the same nominal strength with respect to the bolt shear limit state as a $\frac{1}{2}''$ Group A N bolt.

6. (7 points). Using AISC, determine the force $P$ that will cause the collapse of the A992 W8x58. Assume that the beam self-weight is negligible. Given: Braced at the end-points, only.

Circle the closest answer
A. $56.2$ kips
B. $74.5$ kips
C. $37.3$ kips
D. $62.2$ kips
E. $31.1$ kips

\[
\begin{align*}
L &= 16' \\
C_{b} &= 1.32 \text{ (Table 3-1)} \\
M_{p} &= 1.32 (135) = 178.2 \\
\frac{M_{p}}{A} &= \frac{5}{3} (149) = 248.33 = \left( \frac{P}{E} \right) 8' \\
\Rightarrow P &= 62.1 \text{ kips}
\end{align*}
\]

7. (3 points). TRUE or FALSE. The hypothetical A992 rolled wide-flange beam shown has continuous lateral support of its compression flange and flange slenderness $\lambda$ that is exactly equal to $\lambda_y$. This implies that, for strong-axis bending, local buckling would be the controlling limit state with the extreme tips of the flanges just reaching yield, when this occurs.
8. (16 points) Determine the maximum load $P$ that the 13'-long A992 W16x36 pin-ended beam-column can safely support per ASD specifications. Given: equal-magnitude strong-axis end-moments of 10 ft-kips, and equal-magnitude weak-axis end-moments of 2 ft-kips, as shown. The column is in a braced frame, braced at its ends, only, for both axes. Assume that self-weight is negligible. Assume that the $B_i$ factor is 1.05 for strong-axis moment and 1.10 for weak-axis moment.

View 1: X-Y

$$\frac{M_x}{x} = \frac{M_y}{y} = \frac{100}{10} \text{ ft}-\text{ft}$$

$$L_{AB}: C_b = 1, L_b = 13'$$

$$\Rightarrow \frac{M_x}{x} = \frac{113.2}{10} \text{ ft}-\text{ft}$$

$$\Rightarrow M_{x,7e} = \frac{10.5}{113.2} = 0.09276$$

$$\Rightarrow M_{y,7e} = \frac{2.2}{26.9} = 0.08178$$

$$P = P_{7e} + \frac{\theta}{\alpha} \left( 0.09276 + 0.08178 \right)$$

$$\Rightarrow P_{7e} = 0.8448$$

$$\frac{P_n}{x} = K_{x,y} \Rightarrow K_{x,y} \text{ Controls} \Rightarrow \left( \frac{K_{x,y}}{y} \right) = \frac{(13)(12)}{1.52} = 102.6$$

$$\Rightarrow F_{xt} = 13.86 \text{ ksi} \text{ (TABLE 4.22)}$$

$$\frac{P_n}{x} = (13.86 \text{ ksi}) (10.61^2) = 146.92 \text{ k}$$

$$P = (0.8448)(146.92) = 124 \text{ kips}$$

Answer:
Max $P$: \underline{124} kips
(report 3 significant digits)

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9. (2 points) A beam is shown below, along with the Influence Line for Internal Bending Moment at Point C. Explain what the “-3.5” value means.

INFLUENCE LINE FOR MOMENT AT C (KIP-FT)

-3.5 KIP-FT IS THE INTERNAL M AT C WHEN 1 K IS PLACED AT D.

10. (13 points) Determine the maximum magnitudes of positive and negative bending moments that are possible at point B. Given

- Dead Load – 1 kip/ft distributed load
- Live Load – 1 kip/ft distributed load
- Live Load – 10 kip point load

\[ M^+ = 2^{\text{WT}} \text{ A to C, } 1^{\text{WT}} \text{ overhangs, } 10^\circ \text{ at B} \]

\[ M^+ = \left( \frac{1}{2} \right) (10)(2.4)(2^{\text{WT}}) + (10)(2.4) - \frac{1}{2} (2)(0.8)(1) - \frac{1}{2} (2)(2.4)(1) \]

\[ = 24 + 24 - 0.8 - 4.8 = 42.4 \text{ kip-ft} \]

\[ M^- = 2^{\text{WT}} \text{ overhangs, } 1^{\text{WT}} \text{ A to C, } 10^\circ \text{ at right end} \]

\[ M^- = \left( \frac{1}{2} \right) (10)(2.4)(1^{\text{WT}}) - (10)(2.4) - \frac{1}{2} (2)(0.8)(2) - \frac{1}{2} (2)(2.4)(2) \]

\[ = 12 - 24 - 1.6 - 9.6 = -23.2 \text{ kip-ft} \]

Answer

Max M+ 42.4 kip-ft
Max M- -23.2 kip-ft
Among the many wonderful failure modes that Dragon Fire dodged or succumbed to was this one, shown below. Determine the force that must have been present in the girder tubing at the instant of failure using AISC specifications (do not include \( \Omega \), however. We want to know the actual force in the flange).

Given: 1”x1” (0.0625” wall thick.) square tube, connected with 3/8” x 1/8” side plates and 3/8” diameter bolts

Tubing and plate material: Yield and ultimate tensile strengths - \( F_y = 60 \text{ ksi} \), \( F_u = 75 \text{ ksi} \)

Bolt: Ultimate tensile strength – \( F_u = 120 \text{ ksi} \)

CONNECTION DETAIL

PHOTO OF FAILURE

\[
R_n = 1.2 L_c + F_u
\]

\[
L_c = \frac{3}{8}'' - \frac{1}{8}'' = \frac{1}{4}''
\]

\[
t = 2 \text{ wall thickneses} = \frac{1}{8}''
\]

\[
R_n = 1.2 \left( \frac{1}{4} \right) \left( \frac{1}{8}'' \right) (75 \text{ ksi}) = 2.81 \text{ kips}
\]

Answer

Failure Force in Tube: \( 2.81 \text{ kips} \)