CVEN 446 – Fall 2020 **Take Home Exam AA** **September 17, 2020**
Dr. Brackin

Section: **501**

Name: PRELIMINARY KEY

Student UIN: ____________________

"An Aggie does not lie, cheat, or steal, or tolerate those who do." – Aggie Code of Honor

By my signature below I pledge that my conduct on this exam is consistent in every way with the Aggie Code of Honor:

Signature: ____

1. This exam consists of ***five (5)*** problems that are equally weighted
2. Some problems may have multiple parts.
3. Be sure to carefully read and properly analyze each question that is asked. Do not jump to unfounded conclusions, but also do not overlook or oversimplify problems either.
4. Be sure to show all work, including sketches, and calculations, and organize your solution procedure as clearly and systematically as possible.
5. Neatly work the problems on a separate sheet of ENGINEERING paper. **DO NOT WRITE ON THE BACK OF ANY PAGE.**
6. You need only to present your solution (i.e. Given, Required, not necessary)
7. Work efficiently, neatly, and use pencil.
8. Clearly indicate final answers by enclosing in a "box" or place answer in the blank if a blank is provided. Include any and all appropriate units.
9. **CLOSED FRIEND, CLOSED GOOGLE, AND CLOSED EVERYTHING NOT ON THE FOLLOWING LIST.** You may use the 15th Edition AISC Manual, the course textbook, and your course notes.

Problem 1: ________ / 10

Problem 2: ________ / 10

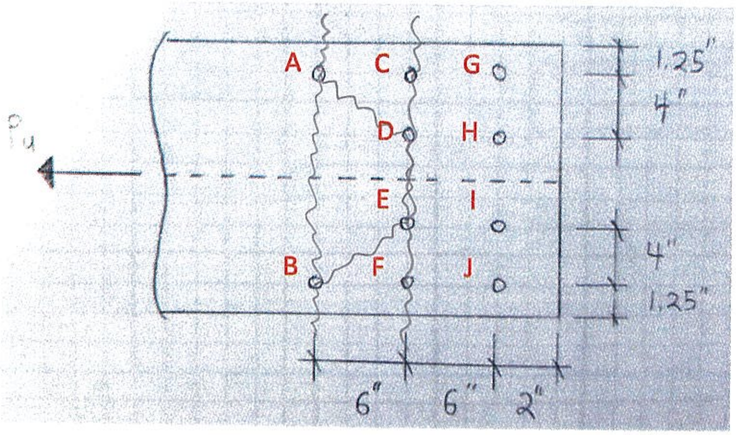
Problem 3: ________ / 10

Problem 4: ________ / 10

Problem 5: ________ / 10

TOTAL: ________ / 50

Problem 1: The flange of a **WT12X114.5** tension member is bolted to an A36 gusset plate using 1 in. diameter bolts. The WT-section is A992 steel material. Determine the Net Section Rupture (NSR) capacity of the WT12X114.5 tension member. **Consider the critical sections defined by lines AB, ADEB, and CDEF. You do not need to consider any other limit states or serviceability criteria.**



$$\underline{\text{WT12x114.5}}: \quad A_g = 33.6 \text{ in}^2, \quad \bar{y} = 2.96'', \quad t_f = 1.73'' \quad \Big\} \text{ 1-60}$$

$$\underline{\text{A992}}: \quad f_y = 50 \text{ ksi}, \quad f_u = 65 \text{ ksi} \quad \Big\} \text{ 2-48}$$

$$\underline{\text{AB:}} \quad A_n = 33.6 \text{ in}^2 - (2 \text{ holes})\left(1'' + \underset{\substack{\uparrow \\ \text{tolerance}}}{\tfrac{1}{8}''} + \underset{\substack{\uparrow \\ \text{damage}}}{\tfrac{1}{16}''}\right)(1.73'') = \underline{\underline{29.5 \text{ in}^2}} \leftarrow \text{CONTROLS}$$

$$\underline{\text{ADEB}}: \quad A_n = 33.6 \text{ in}^2 - (4 \text{ holes})\left(1'' + \tfrac{1}{8}'' + \tfrac{1}{16}''\right)(1.73'') + \left(\frac{(6'')^2}{4(4'')}\right)(1.73'')(2 \text{ staggers})$$

$$= \underline{\underline{33.17 \text{ in}^2}}$$

$$\underline{\text{CDEF}}: \quad A_n = \left(\frac{10}{8}\right)\left[33.6 \text{ in}^2 - (4 \text{ holes})\left(1'' + \tfrac{1}{8}'' + \tfrac{1}{16}''\right)(1.73'')\right] = \underline{\underline{31.73 \text{ in}^2}}$$

$$\underline{\text{NSR}}: \quad U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{2.96 \text{ in}}{12''} = 0.7533$$

$$A_e = U A_n = 0.7533(29.5 \text{ in}^2) = 22.22 \text{ in}^2$$

$$\phi_t P_n = \phi_t A_e f_u = 0.75(22.22 \text{ in}^2)(65 \text{ ksi}) = \boxed{1083 \text{ k}}$$

Problem 2: W-Sections are used to diagonally brace (red arrow) a 10-ft wide horizontal canopy, as shown. The W-Section braces are spaced 60 ft apart. The horizontal canopy must carry a uniform pressure load consisting of the following:

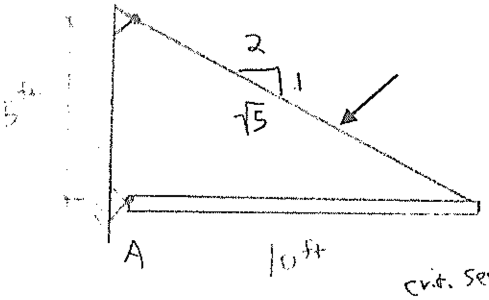
DL = 1,000 lb/ft^2
LL = 800 lb/ft^2

C1: $1.4D = 1.4(1000) = 1400 \text{ lb/ft}^2$

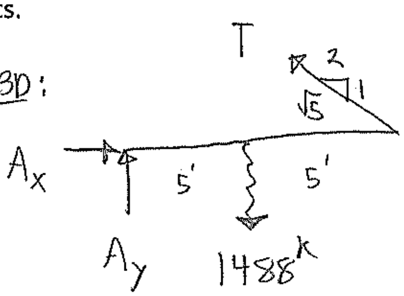
C2: $1.2D + 1.6L = 1.2(1000) + 1.6(800) = 2480 \text{ lb/ft}^2$ ← controls

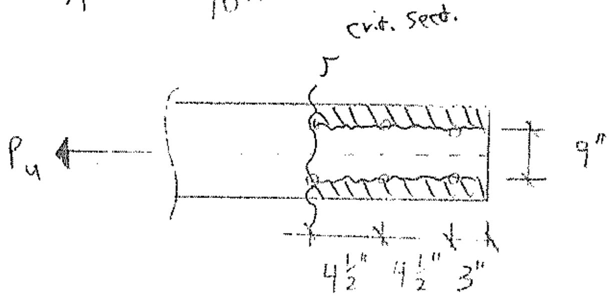
$$R = (10^{ft})(60^{ft})(2480 \text{ lb/ft}^2)\left(\frac{1}{1000}\right) = 1488^{k}$$

The W-section is connected to the canopy through the flanges using 7/8 in. diameter bolts, as shown. Select the lightest W12X____ section that is required to safely carry the canopy loads. Be sure to verify the capacity of the member checking all limit states and any serviceability requirements.



FBD:





$$\overset{+}{\curvearrowleft}\sum M_A = T\left(\frac{1}{\sqrt{5}}\right)(10') - 1488^k(5') = 0$$

$$P_u = T = 1664^{k}$$

Assume A992 Steel: $f_y = 50$ ksi, $f_u = 65$ ksi

GSY: $$(A_g)_{req'd} = \frac{P_u}{\phi f_y} = \frac{1664^k}{0.9(50^{ksi})} = 36.98 \text{ in}^2$$

Try W12X136: $A_g = 39.9 \geq (A_g)_{req'd} = 37 \text{ in}^2$ ∴ GSY ok

NSR: $\phi P_n = \phi A_e f_u$

$$A_n = 39.9 \text{ in}^2 - (2 \text{ holes})(2 \text{ flanges})\left(\frac{7}{8}'' + \underset{\text{tol.}}{\underset{\uparrow}{\frac{1}{16}''}} + \underset{\text{damage}}{\underset{\uparrow}{\frac{1}{16}''}}\right)\overset{t_f}{\overset{\downarrow}{(1.25'')}} = 34.9 \text{ in}^2$$

$$U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{1.35''}{9''} = 0.85$$ "CASE 2"

$\bar{x} = 1.35''$ (ie $\bar{y}$ for WT6X68)

$U = 0.90$ "CASE 7"

$b_f = 12.4'' \geq \frac{2}{3}d = 8.13$

$\phi P_n = 0.75\,(0.9)(34.9\ in^2)(65\ ksi) = 1531^K \leq P_u = 1664^k$

$\underline{X}$

Try W12X152: $A_g = 44.7\ in^2$ ∴ $\underline{GSY}$ ok

$\underline{NSR}$: $A_n = 44.7\ in^2 - (2)(2)(1")(1.4") = 39.1\ in^2$

$U = 1 - \frac{1.43"}{9"} = 0.84$

$U = 0.9$

$\phi P_n = 0.75(0.9)(39.1\ in^2)(65\ ksi) = 1715^K > P_u = 1664^k\ \underline{\checkmark}$

$\underline{BSR}$: $A_{gv} = (2\ \text{lines})(2\ \text{flanges})(1.40")(12") = 67.2\ in^2$

$A_{nv} = (2)(2)(1.40")\left[12" - 3.5\ \text{holes}\ (1")\right] = 53.2\ in^2$

$A_{nt} = (2\ \text{flanges})(1.40")\left[12.4" - 9" - 1\ \text{hole}\ (1")\right] = 6.72\ in^2$

$\phi R_n = \phi\left[0.6F_uA_{nv} + U_{bs}F_uA_{nt}\right] \leq \phi\left[0.6F_yA_{gv} + U_{bs}F_uA_{nt}\right]$

$\phi R_n = 1883.7^K < \underset{\substack{\uparrow \\ \text{controls}}}{1839.6^k}$

$\phi R_n = 1840^k > P_u = 1664^k\ \underline{\checkmark}$

NSR CONTROLS → $\phi P_n = 1715^k > P_u = 1664^K$

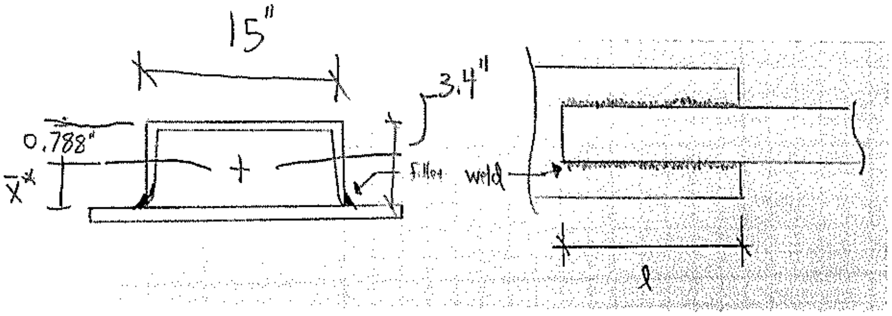
SERVICEABILITY: $l = \sqrt{5^2 + 10^2} = 11.2\ ft$

$r_{min} = 3.19\ in$

$\frac{l}{r_{min}} = \frac{11.2'(12)}{3.19"} = 42.1 < 300\ \underline{\checkmark}$

$\boxed{\text{USE W12X152, 11.2 ft LONG, A992 STEEL}}$

Problem 3: A channel section is to be welded to a gusset plate as shown. The channel is required to carry an axial dead load of 60 kips and live load of 145 kips. **(A) Select the lightest and shortest depth channel section required to carry the factored load and (B) Determine the minimum length of weld, l, that is required for the Net Section Rupture (NSR) design capacity to match the Gross Section Yielding (GSY) design capacity.** Round the required length to the next largest in.



$P_u = 1.2(60^k) + 1.6(145^k) = 304^k$

A36: $f_y = 36^{ksi}$
$f_u = 58^{ksi}$

A) $(A_g)_{req'd} = \dfrac{P_u}{\phi f_y} = \dfrac{304^k}{0.9(36\ ksi)} = 9.38\ in^2$

TRY C15X33.9 $\rightarrow A_g = 10.0\ in^2 \geq (A_g)_{req'd} = 9.38 \therefore$ GSY OK

$\phi_t P_n = \phi_t A_g f_y = 0.9(10.0\ in^2)(36\ ksi) = \underline{\underline{324^k}}$

B) $A_e = A_g U$

$U = \dfrac{3l^2}{3l^2 + w^2}\left(1 - \dfrac{\bar{x}}{l}\right)$ "CASE 4"

$\bar{x}^* = 3.4'' - 0.788'' = 3.612''$

$\overset{P_u}{\cancel{\phi_t P_n}} = \phi_t A_e f_u$

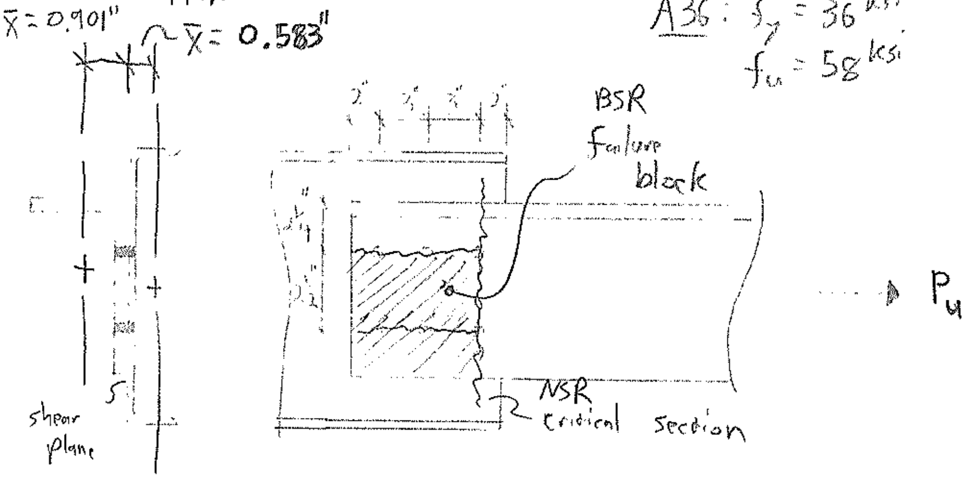
$324^k = 0.75(58\ ksi)(10.0\ in^2)\left(\dfrac{3l^2}{3l^2 + (15)^2}\right)\left(1 - \dfrac{3.612''}{l}\right)$

$\boxed{\text{SOLVE FOR, } l = 21''}$

Problem 4: A C9X20 channel is bolted to a L5 X 3-1/2 X 1/2 angle, as shown. The channel is A36 steel and the angle is A529 Gr. 55 steel. The bolt holes are 3/4 in. diameter. It cannot be said which member, the channel or the angle, controls the design tensile capacity. Therefore, determine the controlling design tensile capacity by considering all limit states that apply.

A36: $f_y = 36^{ksi}$
$f_u = 58^{ksi}$

A529 Gr 55: $f_y = 55$ ksi
$f_u = 70$ ksi



L5X3½ X½: $A_g = 4.00 \text{ in}^2$

GSY: $\phi P_n = 0.9(4.00 \text{ in}^2)(55 \text{ ksi}) = \underline{198^k}$

NSR: $A_n = 4.00 \text{ in}^2 - (2 \text{ holes})\left(\frac{3}{4}'' + \underset{\text{damage}}{\frac{1}{16}''}\right)\left(\frac{1}{2}''\right) = 3.1875 \text{ in}^2$

$U = 1 - \frac{\bar{x}}{l} = 1 - \frac{0.901''}{6''} = 0.85$ "CASE 2"

-or-

$U = 0.6$ "CASE 8"

$\phi P_n = 0.75(0.85)(3.1875 \text{ in}^2)(70 \text{ ksi}) = \underline{142.2^k}$

BSR: $A_{gv} = (8'')(\frac{1}{2}'') = 4 \text{ in}^2$

$A_{nv} = 4 \text{ in}^2 - (2.5 \text{ holes})\left(\frac{3}{4}'' + \frac{1}{16}''\right)\left(\frac{1}{2}''\right) = 2.984 \text{ in}^2$

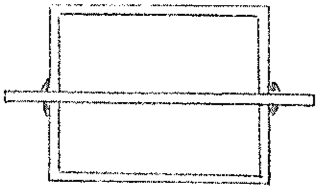
$A_{nt} = \left[5'' - 1.5''\left(\frac{3}{4}'' + \frac{1}{16}''\right)\right]\left(\frac{1}{2}''\right) = 1.891 \text{ in}^2$

$\phi R_n = \phi[0.6 f_u A_{nv} + U_{bs} f_u A_{nt}] \leq \phi[0.6 f_y A_{gv} + U_{bs} f_u A_{nt}]$

$= \underset{\text{controls}}{193.3^k} \leq 198.3^k$

$\phi R_n = 193.3^k$

Problem 5: Determine the maximum tensile load, Pu, that can be applied to a HSS6X4X1/4 that is connected to a concentric gusset plate, as shown, with dimensions 8 in. by 3/8 in. thick. 12" long



HSS 6X4X1/4: $A_g = 4.3 \text{ in}^2$

$t = 0.233 \text{ in}$

GSY: $\phi P_n = 0.9(4.3 \text{ in}^2)(50 \text{ ksi}) = 193.5^{k}$

$\uparrow$ A500 Gr C, p 2-48

NSR: $\phi P_n = 0.75 A_e f_u$

$\ell = 12'' \geq H = 6''$, $U = 1 - \frac{\bar{x}}{\ell} = 1 - \frac{1.6}{12''} = 0.867$

$$\bar{x} = \frac{B^2 + 2BH}{4(B+H)} = \frac{4^2 + 2(4)(6)}{4(4+6)} = 1.6$$

$$A_n = A_g - \sum A_{slot} = 4.3 \text{ in}^2 - (2)(0.233 \text{ in})(\tfrac{3}{8} \text{ in}) = 4.125 \text{ in}^2$$

$\phi P_n = 0.75(4.125 \text{ in}^2)(0.867)(62 \text{ ksi}) = 166.3 \text{ k}$

$\uparrow$ A500 Gr C, p2-48

GSY, gusset: $\phi P_n = 0.9(8'')(\tfrac{3}{8}'')(36 \text{ ksi}) = \underline{\underline{97.2}}^{k}$

$\uparrow$ A36, p2-50

$\boxed{\text{GUSSET CONTROLS, } \phi P_n = 97.2^{k}}$