Birzeit University - Faculty of Engineering
Department of Civil Engineering
Structural Steel Design – ENCE 437, Final Exam

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1st Semester 2020/21

Question 1 (30 marks)

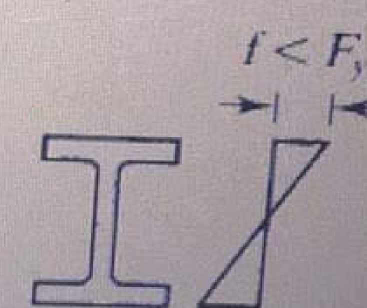
Comment on / Explain the following (no more than 4 lines of text and sketches).

(a) For evaluating available column strength ($\Phi_c P_n = \mathbf{F_{cr}} A_g$), $\mathbf{F_{cr}}$ is used instead of $\mathbf{F_y}$.

(b) List potential measures which may be implemented to improve the strength of an existing column / compression member.

(c) What is equivalent length of column? Give example.

(d) Upon examination of a failed beam, the stress distribution was found to be as shown in the figure. Explain this situation.



(e) Explain the purpose of the crossed elements used in the framing of the steel

found to be as shown in the figure. Explain this situation.

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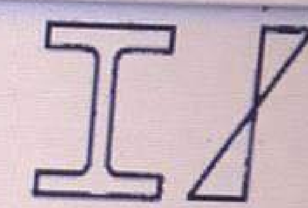

(e) Explain the purpose of the crossed elements used in the framing of the steel bridge shown in the figure.

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(f) What is the justification for the enlarged shape at G of the crane arm AB.

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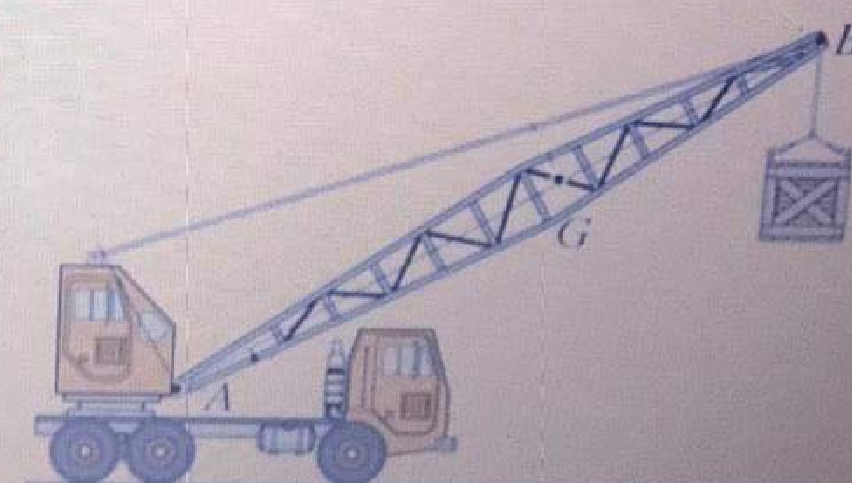


Question 2 (35 points)

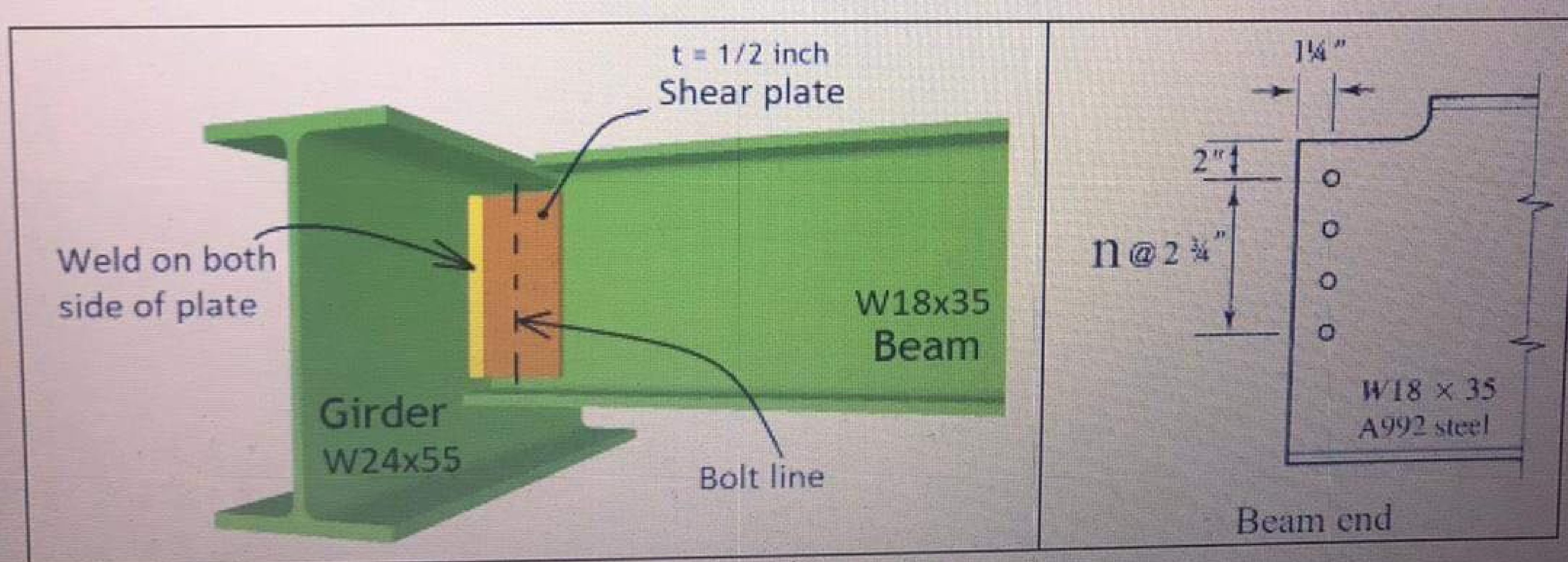
(a) Discuss the limit states (potential modes of failure) for
- Beam end
- Shear plate

Use sketches where appropriate.

(b) Design the bolted shear connection (coped end of W18x35 beam).
Use $\frac{7}{8}$ in.-diam. A325-N bolts.

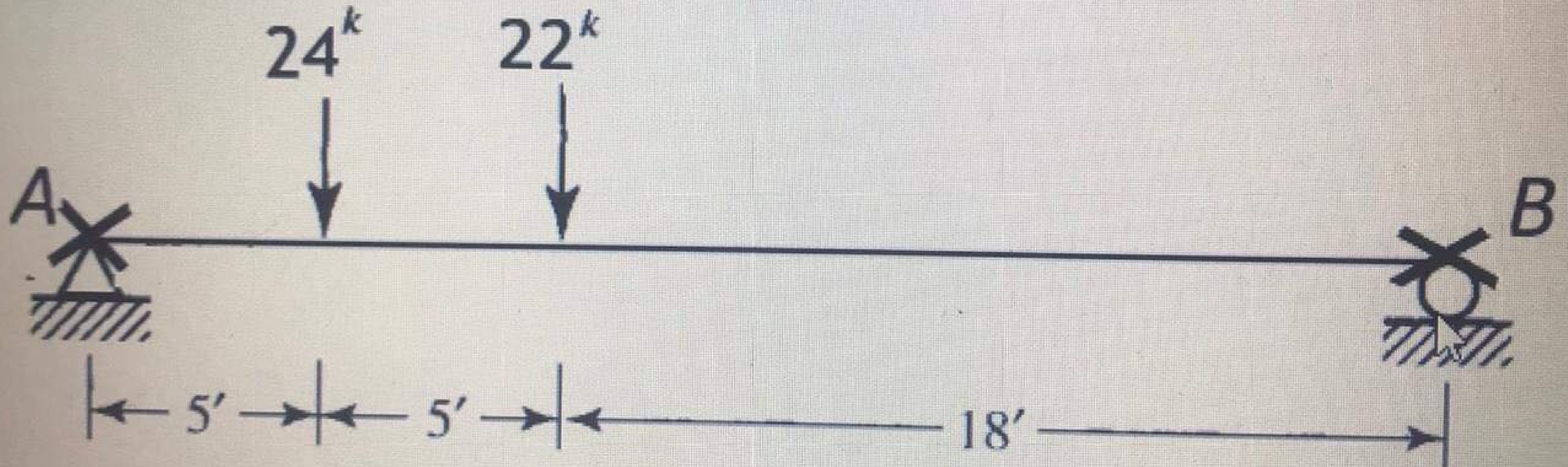
(c) Design the welded connection of the shear plate to web of girder.
Use weld size w= E70 electrode.

Beam end reaction at the connection due to factored loads is **110 kips**.



Question 3 (35 points)

The beam shown below has lateral support at ends *A* and *B* only. The concentrated loads are service live loads. Use LRFD beam equations to select a W12 or W14 shape of A572- Gr 50 steel.



(a): Because most Columns generally fail by instability rather than by compressive yielding, Thus, to account for instability (buckling), The critical buckling stress (F_{cr}) should be used instead of (F_y).

(b): By adding lateral bracings at shorter intervals of the column's span, if possible, also by improving the fixation of the boundary Conditions (adding more fixation to ends ⇒ k is less), in addition, if the section is hollow (tubes, pipes) we can cast concrete inside them (Composite sections).

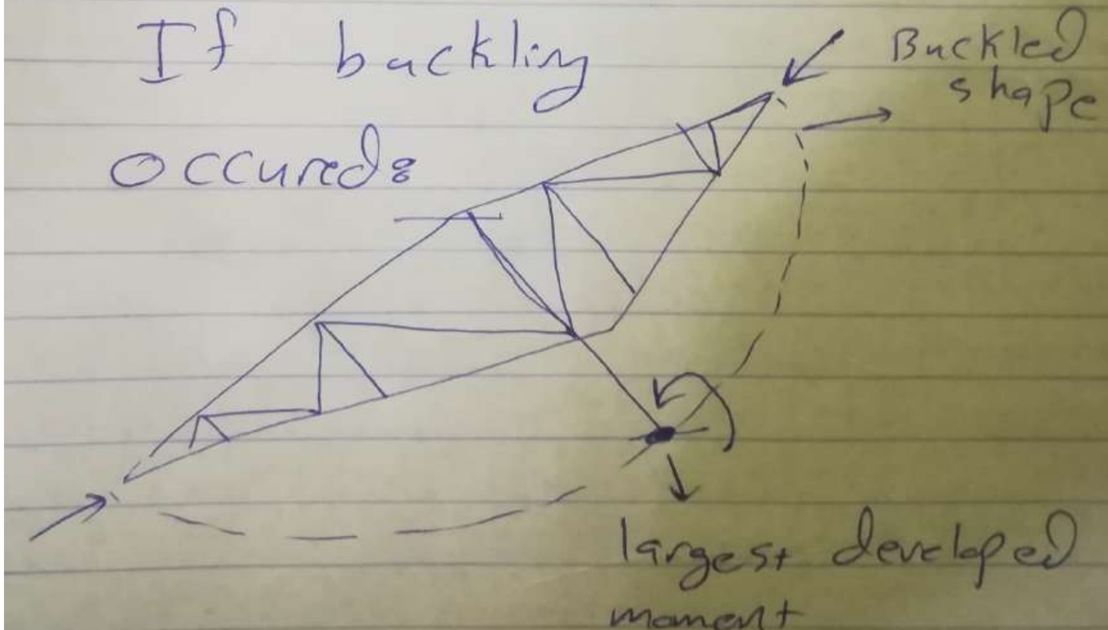
(C): It is the Portion of the actual length of the column at which buckling occurs, and it stands for the equivalent length of the column to the pinned_pinned end conditions for example if a column is fixed_fixed and has a length (L), then its effective length is (0.5 L), meaning that buckling happens at half length only.

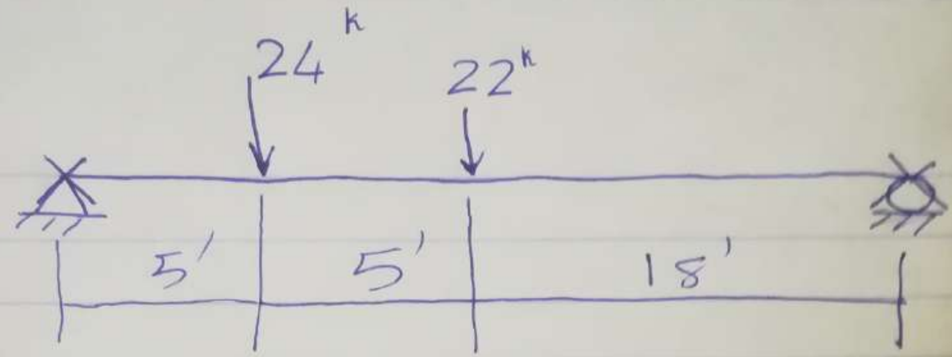
(d): It is obvious that the developed stresses due to bending are not sufficent to bring the section material to yielding, thus, the section has failed well before reaching its full capacity against bending. It is predicted that the beam has failed either by instability or by shear failure.

(e): The beams in the bridge have relatively long spans, thus, they are highly flexible and might fail by instability or (lateral torsional buckling) LTB by their own weight or by the construction load, so, we increase the stability of the beam by adding lateral X- bracings to prevent the beam, especially the compression flange from failing by (LTB).

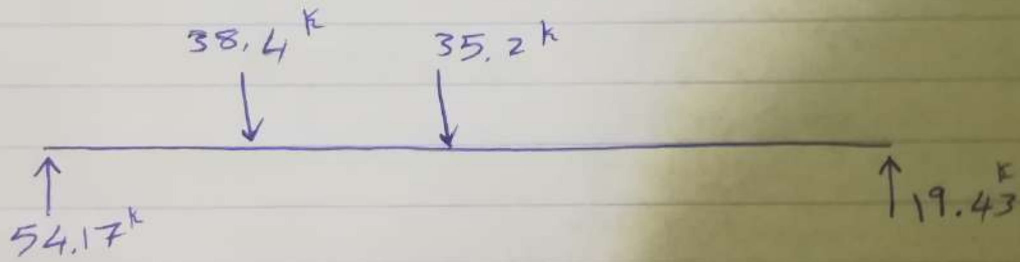
(f): The crane arm is a compression member (2-force member), and might fail by buckling, as a result, for potential failure, the resulted moments would be maximized at the mid of the cranes span, hence a larger section (larger I) is provided at the ~~region~~ region to resist the large developed moments.

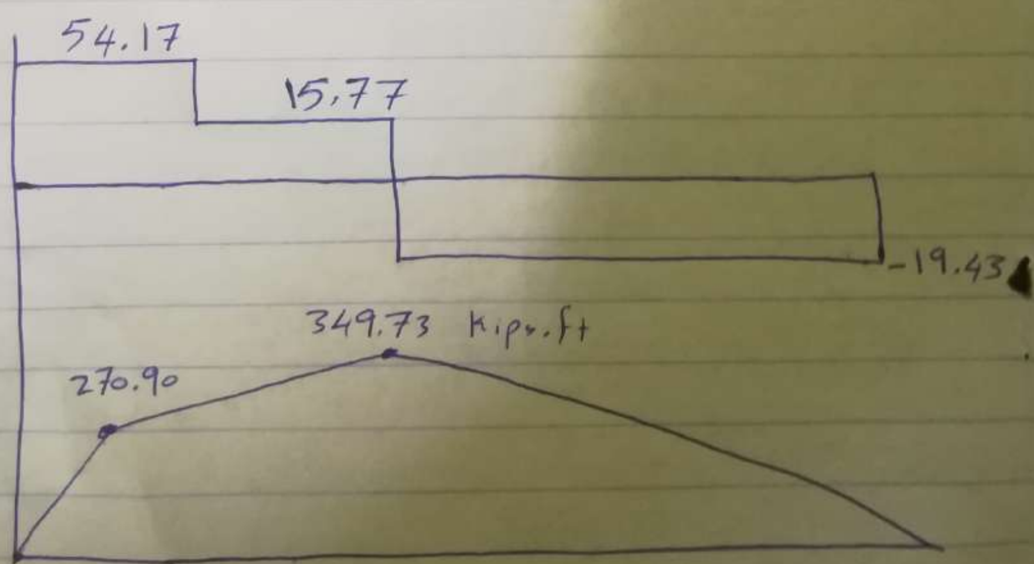
If buckling occured:





Factored Loads: 1.6 (24) = 38.4 kips
1.6 (22) = 35.2 kips





$M_u = 349.73$ kips.ft

Assume the section is compact & give full capacity, then:

$$\phi M_n \geq M_u \Rightarrow 0.9 F_y Z_x \geq M_u$$

$$\Rightarrow Z_x \geq \frac{M_u}{0.9 F_y} \Rightarrow Z_x \geq \frac{(349.73)(12)}{0.9(50)} = 93.3 \text{ in}^3$$

From the Z_x - tables (Table 3-2):

The lightest shape with $Z_x > 93.3$ is:

W 14 X 61

Properities: $\frac{b_f}{2t_f} = 7.75$ $\quad h_o = 13.3$ in

$S_x = 92.1$ in^3 $\quad J = 2.19$ in^4

$Z_x = 102$ in^3

$r_{ts} = 2.78$ in

$$\lambda_f = \frac{b_f}{2t_f} = 7.75$$

$$\lambda_p = 0.38\sqrt{\frac{29000}{50}} = 9.15$$

$\lambda_f < \lambda_p \Rightarrow$ Section is Compact

$L_b = 28'$ (unbraced length)

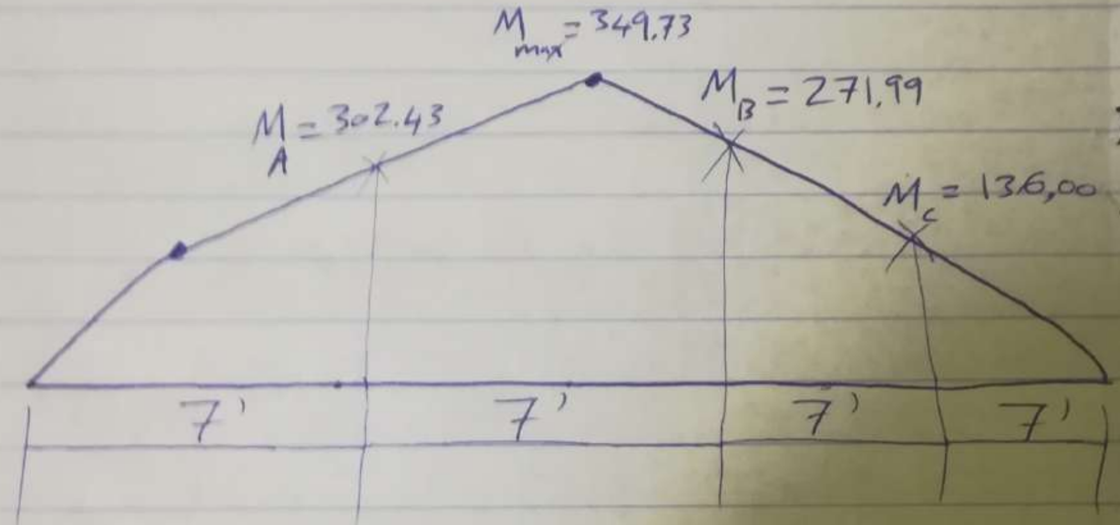
$L_p = 8.65'$ (Z_x tables)

$L_r = 27.5'$ (Z_x tables)

$L_b > L_r \Rightarrow$ Elastic LTB

$$\phi M_n = 0.9 F_{cr} S_x \leq 0.9 F_y Z_x$$

To calculate (F_{cr}) we need C_b



$$C_b = \frac{12.5(349.73)}{2.5(349.73) + 3(302.43) + 4(271.99) + 3(136)}$$

$$C_b = 1.33$$

$$F_{cr} = \frac{1.33\pi^2(29000)}{\left(\frac{(28)(12)}{2.78}\right)^2}\sqrt{1 + 0.078\left(\frac{(2.19)(1)}{(92.1)(13.3)}\right)\left(\frac{(28)(12)}{2.78}\right)^2}$$

$$= 45.4 \text{ ksi}$$

Controls

$$\phi M_n = \min \begin{cases} 0.9(45.4)(92.1) = 3763 \text{ kips.in} \uparrow \\ 0.9(50)(102) = 4590 \text{ kips.in} \end{cases}$$

$\Rightarrow \phi M_n = 3763$ kips.in $= 313.6$ kips.ft

$\phi M_n < M_u \Rightarrow$ Section is not adequate

Try W14 X 68 [Next lightest shape]

Properties: $\frac{b_f}{2t_f} = 6.97$

$S_x = 103$ in^3 $\qquad J = 3.01$ in^4

$Z_x = 115$ in^3

$r_{ts} = 2.80$ in

$h_o = 13.3$ in

$$\lambda = \frac{b_f}{2t_f} = 6,97 < \lambda_p \Rightarrow \text{Compact}$$

$$L_p = 8.69' \quad , \quad L_r = 29.3'$$

$$L_p < L_b < L_r$$

$\therefore$ Inelastic LTB

$$\phi M_n = \min \begin{cases} 0.9 C_b \left[M_p - (M_p - 0.7 F_y S_x) \left(\dfrac{L_b - L_p}{L_r - L_p} \right) \right] \\ \\ \phi M_p = 0.9 F_y Z_x \end{cases}$$

$$\phi M_n = \min \begin{cases} 0.9(1.33)\left[(50)(115) - ((50)(115) - 0.7(50)(63))\left(\dfrac{28 - 8.69}{29.3 - 8.69}\right)\right] \\ = 4477 \text{ kips}\cdot\text{in} \quad (\text{Controls}) \\ \\ 0.9(50)(115) = 5175 \text{ kips}\cdot\text{in} \end{cases}$$

$\phi M_n = 4477$ kips.in $= 373$ kips.ft

$\phi M_n > M_u$ (Section is adequate for bending)

Now, check for shear:

$$\frac{h}{t_w} = 27.5 < 2.24\sqrt{\frac{29000}{50}} = 53.9$$

$\Rightarrow$ Shear yielding

$\Rightarrow \phi_v = 1$
$C_v = 1$

$$\phi V_n = \phi\, 0.6 F_y (d\, t_w)(C_v)$$

$$= 1(0.6)(50)(14)(0.415)(1) = 174 \text{ kips}$$

$\phi V_n > V_u \Rightarrow$ adequate for shear