Flexural Design Example

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Computation - Cover Sheet

Structures Calculations

Project: Your Project Name
Subject: Project Subject
Task: Task of Project

Project Number: 0

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Preliminary Calculation: **Final Calculation:**

Description:

Calculates the flexural capacity of a doubly-symmetric steel member

Design Methodology:

Allowable Stress Design: Load Factor Design: Load & Resistance Factor Design: N/A

Combination of Methodologies (describe)

Calculates the flexural capacity of a doubly-symmetric steel member

Codes/References:

AASHTO
Edition: 9th
Interims Through:
Applicable Sections: 6

AREMA
Chapter:
Last Update:
Applicable Sections: 6

Other
Title:
Year/Edition:
Applicable Sections: 6

Original Designer:

Name: Cole Miller Initials: CAM Date: 2024-10-26

Checker:

Name: Cole Miller Initials: CAM Date: 2024-10-26

Check Method:

For Hand Calculations: Backchecked original calculations: Independent calculations:

For Computer Calculations: Checked input & output: Reran same software: Ran different software:

Does this calculation supersede a previous calculation? Yes: No:

Checker's Comments:

No Changes: Minor Corrections: original design satisfactory:

Revise desgin as shown on Sheets: Calculates the flexural of Calculates the flexural

Other comments/conclusions:

Calculates the flexural capacity of a doubly-symmetric steel member

Flexural Example Problem

Flexural Example Problem

Determine the LRFD flexural design strength for a W10x12 beam with an unbraced length of 10 ft.

Section Properties of W10X12

$h = 8.85$ inch $\quad t_f = 0.21$ inch $\quad b_f = 3.96$ inch $\quad t_w = 0.19$ inch

$E = 29000$ ksi $\quad F_y = 50$ ksi $\quad S_x = 10.9\ \text{inch}^3 \quad Z_x = 12.6\ \text{inch}^3$

$L_b = 10$ ft

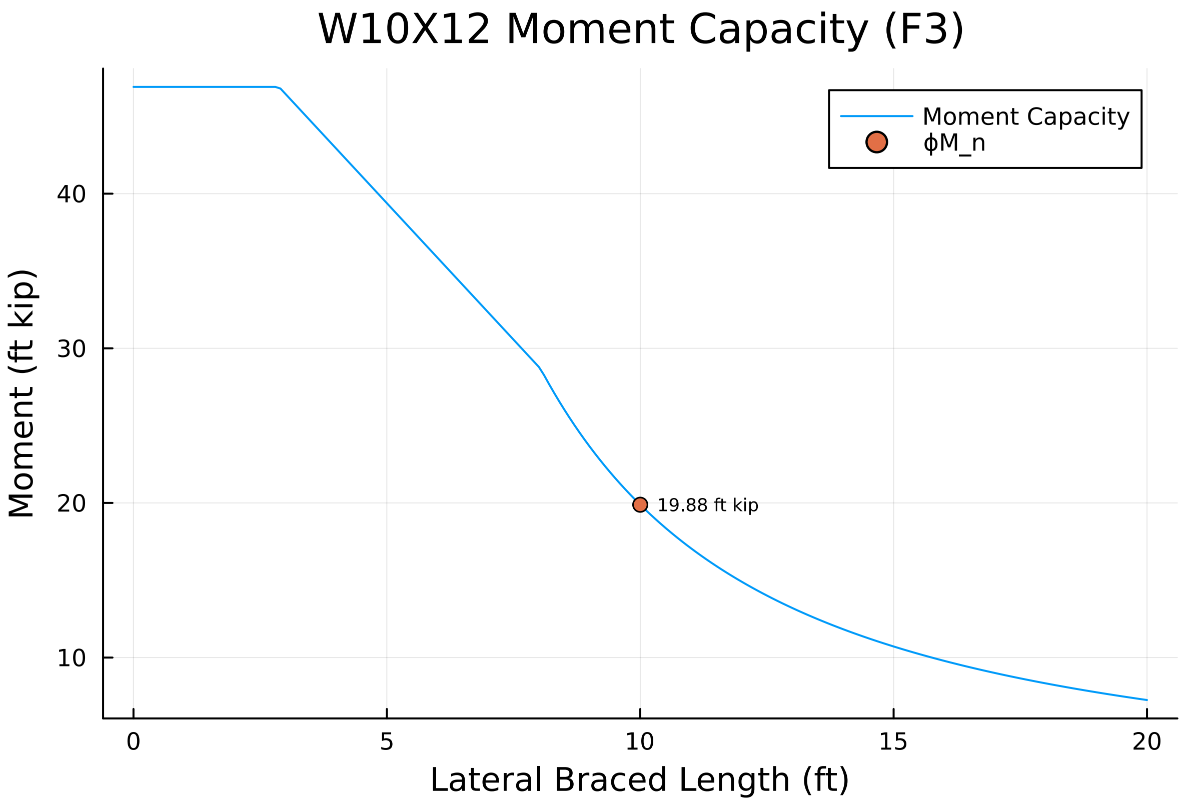

Figure 1: W-Shape: Flexural Strength

Determine if Section is Compact

Determine the limiting ratios (AISC Table B4.1b)

Check Flange

$$b = \frac{b_f}{2} = \frac{3.96\text{ inch}}{2} = 1.98\text{ inch}$$

$$t = t_f = 0.21\text{ inch}$$

$$\lambda = \frac{b}{t} = \frac{1.98\text{ inch}}{0.21\text{ inch}} = 9.43$$

$$\lambda_p = 0.38 \cdot \sqrt{\frac{E}{F_y}} = 0.38 \cdot \sqrt{\frac{29000\text{ ksi}}{50\text{ ksi}}} = 9.15$$

$$\lambda_r = 1 \cdot \sqrt{\frac{E}{F_y}} = 1 \cdot \sqrt{\frac{29000\text{ ksi}}{50\text{ ksi}}} = 24.08$$

$$class = \begin{cases} compact & \text{if } \lambda \le \lambda_p \\ noncompact & \text{if } \lambda_p < \lambda \le \lambda_r \\ slender & \text{otherwise} \end{cases} = \begin{cases} compact & \text{if } 9.43 \le 9.15 \\ noncompact & \text{if } 9.15 < 9.43 \le 24.08 \\ slender & \text{otherwise} \end{cases} = noncompact$$

Flange is noncompact

Check Web

$$h = h = 8.85\text{ inch}$$

$$t_w = t_w = 0.19\text{ inch}$$

$$\lambda = \frac{h}{t_w} = \frac{8.85\text{ inch}}{0.19\text{ inch}} = 46.6$$

$$\lambda_p = 3.76 \cdot \sqrt{\frac{E}{F_y}} = 3.76 \cdot \sqrt{\frac{29000\text{ ksi}}{50\text{ ksi}}} = 90.55$$

$$\lambda_r = 5.7 \cdot \sqrt{\frac{E}{F_y}} = 5.7 \cdot \sqrt{\frac{29000\text{ ksi}}{50\text{ ksi}}} = 137.27$$

$$class = \begin{cases} compact & \text{if } \lambda \le \lambda_p \\ noncompact & \text{if } \lambda_p < \lambda \le \lambda_r \\ slender & \text{otherwise} \end{cases} = \begin{cases} compact & \text{if } 46.6 \le 90.55 \\ noncompact & \text{if } 90.55 < 46.6 \le 137.27 \\ slender & \text{otherwise} \end{cases} = compact$$

Web is compact

W-Shape is classified as F3

Determine Flexural Capacity based on Chapter F, Section 3

Calculate Miscellaneous Variables

$$c = 1$$

$$M_p = F_y \cdot Z_x$$

$$= 50\ \text{ksi} \cdot 12.6\ \text{inch}^3$$

$$= 52.5\ \text{ft kip}$$

$$L_p = 1.76 \cdot r_y \cdot \sqrt{\frac{E}{F_y}}$$

$$= 1.76 \cdot 0.78\ \text{inch} \cdot \sqrt{\frac{29000\ \text{ksi}}{50\ \text{ksi}}}$$

$$= 2.77\ \text{ft}$$

$$L_r = 1.95 \cdot r_{ts} \cdot \frac{E}{0.7 \cdot F_y} \cdot \sqrt{\frac{J \cdot c}{S_x \cdot h_0} + \sqrt{\left(\frac{J \cdot c}{S_x \cdot h_0}\right)^2 + 6.76 \cdot \left(\frac{0.7 \cdot F_y}{E}\right)^2}}$$

$$= 1.95 \cdot 0.98\ \text{inch} \cdot \frac{29000\ \text{ksi}}{0.7 \cdot 50\ \text{ksi}} \cdot \sqrt{\frac{0.05\ \text{inch}^4 \cdot 1}{10.9\ \text{inch}^3 \cdot 9.66\ \text{inch}} + \sqrt{\left(\frac{0.05\ \text{inch}^4 \cdot 1}{10.9\ \text{inch}^3 \cdot 9.66\ \text{inch}}\right)^2 + 6.76 \cdot \left(\frac{0.7 \cdot 50\ \text{ksi}}{29000\ \text{ksi}}\right)^2}}$$

$$= 8.05\ \text{ft}$$

$$F_{cr} = \frac{C_b \cdot \pi^2 \cdot E}{\left(\frac{L_b}{r_{ts}}\right)^2} \cdot \sqrt{1 + 0.08 \cdot \frac{J \cdot c}{S_x \cdot h_0} \cdot \left(\frac{L_b}{r_{ts}}\right)^2}$$

$$= \frac{1 \cdot 3.14^2 \cdot 29000\ \text{ksi}}{\left(\frac{10\ \text{ft}}{0.98\ \text{inch}}\right)^2} \cdot \sqrt{1 + 0.08 \cdot \frac{0.05\ \text{inch}^4 \cdot 1}{10.9\ \text{inch}^3 \cdot 9.66\ \text{inch}} \cdot \left(\frac{10\ \text{ft}}{0.98\ \text{inch}}\right)^2}$$

$$= 24.32\ \text{ksi}$$

$$k_c = \frac{4}{\sqrt{\frac{h}{t_w}}}$$

$$= \frac{4}{\sqrt{\frac{8.85\ \text{inch}}{0.19\ \text{inch}}}}$$

$$= 0.59$$

$$k_c = \max\left(\min\left(k_c, 0.76\right), 0.35\right)$$

$$= \max\left(\min\left(0.59, 0.76\right), 0.35\right)$$

$$= 0.59$$

1. Lateral Torsional Buckling

$$M_{nLTB} = \begin{cases} M_p & \text{if } L_b \leq L_p \\ C_b \cdot \left(M_p - \left(M_p - 0.7 \cdot F_y \cdot S_x\right) \cdot \frac{L_b - L_p}{L_r - L_p}\right) & \text{if } L_p < L_b \leq L_r \\ F_{cr} \cdot S_x & \text{otherwise} \end{cases}$$

$$= \begin{cases} 52.5\ \text{ft kip} & \text{if } 10\ \text{ft} \leq 2.77\ \text{ft} \\ 1 \cdot \left(52.5\ \text{ft kip} - \left(52.5\ \text{ft kip} - 0.7 \cdot 50\ \text{ksi} \cdot 10.9\ \text{inch}^3\right) \cdot \frac{10\ \text{ft} - 2.77\ \text{ft}}{8.05\ \text{ft} - 2.77\ \text{ft}}\right) & \text{if } 2.77\ \text{ft} < 10\ \text{ft} \leq 8.05\ \text{ft} \\ 24.32\ \text{ksi} \cdot 10.9\ \text{inch}^3 & \text{otherwise} \end{cases}$$

$$= 22.09\ \text{ft kip}$$

2. Compression Flange Local Buckling

$$M_{nCFLB} = \begin{cases} M_p - \left(M_p - 0.7 \cdot F_y \cdot S_x\right) \cdot \frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}} & \text{if } \lambda_{fclass} = noncompact \\ \frac{0.9 \cdot E \cdot k_c \cdot S_x}{\lambda_f^2} & \text{if } \lambda_{fclass} = slender \\ M_p & \text{otherwise} \end{cases}$$

$$= \begin{cases} 52.5\ \text{ft kip} - \left(52.5\ \text{ft kip} - 0.7 \cdot 50\ \text{ksi} \cdot 10.9\ \text{inch}^3\right) \cdot \frac{9.43 - 9.15}{24.08 - 9.15} & \text{if } noncompact = noncompact \\ \frac{0.9 \cdot 29000\ \text{ksi} \cdot 0.59 \cdot 10.9\ \text{inch}^3}{9.43^2} & \text{if } noncompact = slender \\ 52.5\ \text{ft kip} & \text{otherwise} \end{cases}$$

$$= 52.12\ \text{ft kip}$$

Flexure Capacity

$$\phi M_n = \phi_b \cdot \min\left(M_{n1}, M_{n2}\right) = 0.9 \cdot \min\left(22.09\ \text{ft kip}, 52.12\ \text{ft kip}\right) = 19.88\ \text{ft kip}$$