

# Architecture 324: Structures II

## LRFD Steel Beam Design

Problem: Design Beam B1 (Select Lightest W-Section) [ANSWER KEY]

**Given Data:** Span A (L): 29 FT    Span B (Trib. Width): 20 FT  
**Floor DL:** 19 PSF    **Floor LL:** 100 PSF     $F_y$ : 50 KSI  
**Assumptions:** Fully braced ( $L_b < L_p$ ), Neglect beam self-weight for preliminary selection.

### Part 1: Load Calculations (Neglecting Self-Weight)

#### Q1 Unfactored Floor Dead Load ( $w_{DL}$ )

$$w_{DL} = \text{Floor DL} \times \text{Trib. Width}$$

1. **Calculate:** 19 PSF  $\times$  20 FT

**Final  $w_{DL}$ :** **380** PLF

#### Q2 Unfactored Floor Live Load ( $w_{LL}$ )

$$w_{LL} = \text{Floor LL} \times \text{Trib. Width}$$

1. **Calculate:** 100 PSF  $\times$  20 FT

**Final  $w_{LL}$ :** **2000** PLF

#### Q3 Total Factored Design Load ( $w_u$ )

$$w_u = 1.2(w_{DL}) + 1.6(w_{LL})$$

1. **Dead:**  $1.2 \times 380 = 456$  PLF

2. **Live:**  $1.6 \times 2000 = 3200$  PLF

3. **Sum:**  $456 + 3200 = 3656$  PLF

4. **Convert to KLF:**  $3656 \div 1000$

**Final  $w_u$ :** **3.656** KLF

#### Q4 Factored Design Moment ( $M_u$ )

$$M_u = \frac{w_u L^2}{8}$$

1. **Calculate:**  $(3.656 \times (29)^2) \div 8$

**Final  $M_u$ :** **384.34** K-FT

### Part 2: Preliminary Section Selection

#### Q5 Nominal Bending Moment ( $M_n$ )

$$M_n = \frac{M_u}{\phi_b} \quad (\phi_b = 0.9)$$

1. **Convert  $M_u$ :**  $384.34 \text{ K-FT} \times 12 = 4612.08 \text{ K-IN}$

2. **Divide:**  $4612.08 \div 0.9$

**Final  $M_n$ :** **5124.5** K-IN

#### Q6 Required Plastic Modulus ( $Z_x^*$ )

$$Z_x = \frac{M_n}{F_y}$$

1. **Calculate:**  $5124.5 \div 50$

**Final  $Z_x^*$ :** **102.49** IN<sup>3</sup>

### Part 3: Select Lightest Section

#### Q7 Select W-Section

Lookup AISC Table (Z-Table). Find first section with  $Z_x \geq 102.5$ .

1. **Options:** W21 $\times$ 48 ( $Z_x = 107$ ), W18 $\times$ 50 ( $Z_x = 101$ , Fail), W16 $\times$ 57.

2. **Selection:** Lightest passing is W21 $\times$ 48.

**Chosen Section:** **W21 $\times$ 48**    (**Depth:** **21** IN)

#### Q8 Section Weight

**Weight:** **48** PLF

#### Q9 Section Properties ( $Z_x$ )

Actual  $Z_x$  from AISC Table 1-1. **Actual  $Z_x$ :** **107** IN<sup>3</sup>

### Part 4: Verification (Including Self-Weight)

#### Q10 Revised Dead Load ( $w_{DL,new}$ )

$$w_{DL,new} = w_{DL, floor} + w_{SW}$$

1. **Sum:**  $380 + 48$

**Final  $w_{DL}$ :** **428** PLF

#### Q11 Revised Factored Load ( $w_{u,new}$ )

$$w_u = 1.2(w_{DL,new}) + 1.6(w_{LL})$$

1. **Sum (PLF):**  $1.2(428) + 1.6(2000) = 513.6 + 3200 = 3713.6$

2. **Convert to KLF:**  $3713.6 \div 1000$

**Final  $w_u$ :** **3.714** KLF

#### Q12 Revised Moment ( $M_u$ in K-FT)

$$M_u = \frac{w_u L^2}{8}$$

1. **Calc:**  $(3.714 \times 29^2) \div 8$

**Final  $M_u$ :** **390.39** K-FT

#### Q13 Revised Moment ( $M_u$ in K-IN)

$$M_u \text{ (K-IN)} = M_u \text{ (K-FT)} \times 12$$

**Final  $M_u$ :** **4684.7** K-IN

#### Q14 Design Strength Check ( $\phi M_n$ )

$$\phi M_n = 0.9 \times F_y \times Z_{x, actual}$$

1. **Calc:**  $0.9 \times 50 \times 107$

2. **Check:**  $4815 > 4684.7$  (**OK**)

**Final  $\phi M_n$ :** **4815** K-IN