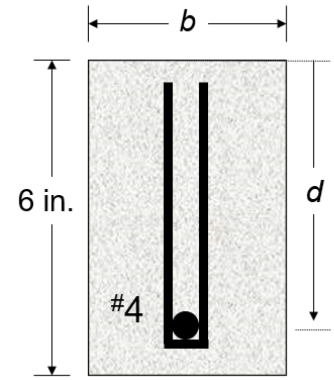
Example 1



Let's use the failure models to predict the ultimate strength-to-weight (SWR) of one of our reinforced concrete beams from the lab.

Consider a beam with the following characteristics:

- Concrete strength f'_c = 4,000 psi
- Steel strength f_y = 60,000 psi
- The tension reinforcement will be 1 #4 rebars
- The shear reinforcement will be #3 rebars installed vertically at 3 in. spacing
- Use a minimum cover of 0.75 in., a bar spacing of 0.75 in., and a width to accommodate the reinforcement

Consider the following mix for a yd^3 of concrete developed using the ACI mix design procedure.

Component	Amount (lb.)
water	315
cement	553
coarse aggregate	1,641
fine aggregate	1,431

Bar #	Diameter (in.)	As (in.^{2})
3	0.375	0.11
4	0.500	0.20
5	0.625	0.31
6	0.750	0.44

1.1 What is the minimum width *b* of the beam:

b =

1.2 What is the beam's minimum depth d (in.)?

d =

1.3 Compute A_s =

1.4 What is the value for a (depth of the Whitney compression block)?

$$a = \frac{A_s f_y}{0.85 f'_c\, b} =$$

1.5 What is the beam's moment capacity M (lb.-in.)?

$$M = A_s f_y \left(d - \frac{a}{2} \right) =$$

1.6 What is the predicted strength *P* (k) based on the tension model?

1.7 What is the predicted strength P (k) based on the shear model?

$$P_{shear} = 2\left(\frac{A_v f_y d}{s} + 2\sqrt{f'_c}bd\right) =$$

1.7a Which value for P controls the design? S =

1.8 What is the beta value for this design?

$$f'_c \le 4000\ psi \quad \Rightarrow \quad \beta_1 = 0.85$$

$$f'_c \ge 4000\ psi \quad \Rightarrow \quad \beta_1 = 0.85 - 0.05\left(\frac{f'_c - 4000}{1000}\right) \ge 0.65$$

1.9 What is the reinforcement ratio ρp for tension control (c/d = 0.375)

$$\rho = 0.85\beta_1 \frac{c}{d}\frac{f'_c}{f_y} =$$

1.10 What is the reinforcement ratio ρ for the RC beam

$$\rho = \frac{A_s}{bd} =$$

1.11 What is the estimated weight of the beam (lb.)?

$$W = \frac{bhL}{1728\text{in.}^3/\text{ft.}^3}\left(\frac{145\text{lb.}}{\text{ft.}^3}\right) + \frac{A_s L}{1728\ \text{in.}^3/\text{ft.}^3}\left(\frac{490\text{lb.} - 145\text{lb.}}{\text{ft.}^3}\right)$$

W =

1.12 What is the estimated SWR?

$$SWR = \frac{Ultimate\,Load(lb.)}{Beam\,Weight(lb.)} =$$

1.13 What is the estimated cost of this beam?

$$Cost\ of\ steel = \frac{A_s L}{1{,}728\,\text{in.}^3/\text{ft.}^3}\left(490\,\frac{\text{lb.}}{\text{ft.}^3}\right)\left(\frac{\$530}{ton}\right)\left(\frac{ton}{2{,}000\text{ lb.}}\right) =$$

$$Cost\ of\ cement = \frac{bhL}{1{,}728\,\text{in.}^3/\text{ft.}^3}\left(\frac{W_{cement}}{27\ ft.^3}\right)\left(\frac{\$130}{\text{ton}}\right)\left(\frac{\text{ton}}{2{,}000\text{ lb.}}\right) =$$

$$Cost\ of\ coarse\ aggregate = \frac{bhL}{1{,}728\,\text{in.}^3/\text{ft.}^3}\left(\frac{W_{CA}}{27\ ft.^3}\right)\left(\frac{\$18}{\text{ton}}\right)\left(\frac{\text{ton}}{2{,}000\text{ lb.}}\right) =$$

$$Cost\ of\ fine\ aggregate = \frac{bhL}{1{,}728\,\text{in.}^3/\text{ft.}^3}\left(\frac{W_{FA}}{27\ ft.^3}\right)\left(\frac{\$10}{\text{ton}}\right)\left(\frac{\text{ton}}{2{,}000\text{ lb.}}\right) =$$

1.14 What is the cost-adjusted *SWR* of this beam?

If the cost > \$1.50, then: $Cost\,Factor = \frac{\$1.50}{Cost}$

$$SWR_{Adjusted} = SWR \times Cost\ Factor =$$