Example 3 - TopHat

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 #6 rebars
- The shear reinforcement will be #3 rebars, U-shaped, three in. spacing
- Use a minimum cover of 0.75 in. and width to accommodate the reinforcement

Consider the following mix for a yd³ 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

3.1 What is the minimum width *b* of the beam?

b =

d =

3.3 Compute $A_s =$

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

$$M = A_s f_y \left(d - 0.59 \frac{A_s f_y}{f'_c b} \right) =$$

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

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

$$P_{shear} = 2\left(rac{A_v f_v d}{s} + 2\sqrt{f'_c}bd
ight) =$$



3.6a Which value for P controls the design? S =

3.7 What is the beta value for this design?

$$f'_{c} \leq 4000 \ psi \implies \beta_{1} = 0.85$$

$$f'_{c} \ge 4000 \ psi \implies \beta_{1} = 0.85 - 0.05 \left(\frac{f'_{c} - 4000}{1000} \right) \ge 0.65$$

3.8 What is the reinforcement ratio ρ for tension control (*c*/*d* = 0.375)

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

3.9 What is the reinforcement ratio ρ for compression control (*c/d* = 0.6)

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

3.10 What is the reinforcement ratio ρ for the RC beam

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

3.11 What is the stress in the steel f_y ?

$$a = \frac{A_s f_y}{0.85 f_c' b} =$$

$$c = \frac{a}{\beta_1} =$$

$$f_{steel} = 87,000 \, psi \left(rac{d-c}{c}
ight) =$$

3.12 What is the predicted strength (k) due to compression failure?

$$P_{compression} = \frac{A_s}{4} \left(\frac{d-c}{c} \right) \left(d - \frac{a}{2} \right)$$
87,000 *psi* =

3.13 What is the predicted strength (lb) of the beam?

3.14 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 =

3.15 What is the estimated SWR?

 $SWR = \frac{UltimateLoad(lb.)}{BeamWeight(lb.)} =$

3.16 What is the estimated cost of this beam?

3.17 What is the cost-adjusted SWR of this beam?

If the cost is > \$2, then: $Cost Factor = \frac{$2}{Cost}$

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