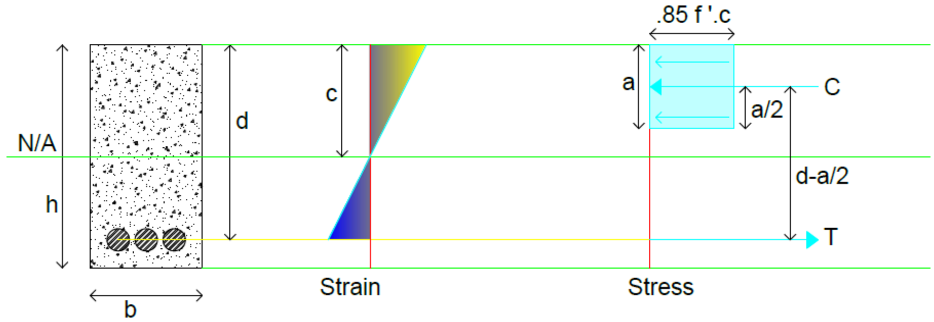
Singly Reinforced Beam Section



Assumptions: Steel only in tension
Steel Yields before the concrete reaches the maximum compression
Uses ACI 318 - 08 ; CODE: 10.2.7
Equivalent Concrete Stress Distribution

Variable Definitions

A_s = Area of Tension Reinforcement (steel)

A'_s = Area of Compression

b = Width of Compression Zone

h = Height

d = Distance from the extreme/top fiber in compression to the centroid of tension steel

f'_c = Compressive Strength of Concrete

C = Compressive Force

T = Tensile Force

a = Distance from the top fiber in compression to the bottom of the equivalent compressive stress distribution

c = Distance from the top fiber in compression to the neutral axis

β_1 = Constant from the ACI 318 - 08 manual that is used to calculate, c or a

f_y = Yielding Stress of Steel Rebar

E = Young's Modulus

ε_s = Steel Strain

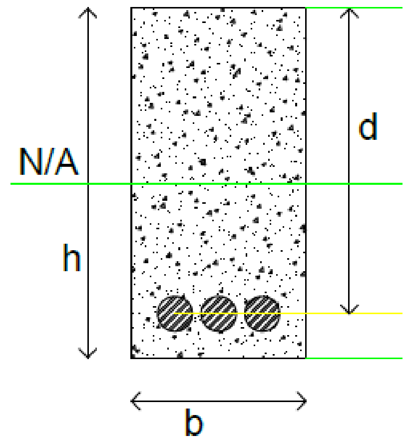
ε_y = Yielding Steel Strain

M_n = Nominal Moment

ε_{cu} = Ultimate Compressive Strain of Concrete

Given:

- Geometric structure of the beam



$h := 24 \cdot in$

$b := 14 \cdot in$

$d := 21 \cdot in$

- Properties of Concrete

$f'_c := 3000 \cdot \frac{lb}{in^2}$

- Properties of Steel

$Rebar_{number} := 9$

$Rebar_{amount} := 3$

$A_S := Rebar_{amount} \cdot max\left(if\left(Rebar_{number} < 4, .11, 0\right), if\left(3 < Rebar_{number} < 5, .2, 0\right), if\left(4 < Rebar_{number} <\right.\right.$

$A_S = 3 in^2$

$Rebar_{grade} := 60$

$f_y := Rebar_{grade} \cdot 1000 \cdot \frac{lb}{in^2}$

$f_y = 60000 \frac{lb}{in^2}$

Strategy

Step 1: Check that $A_s > A_{smin}$ (code) **NEEDS TO BE BUILT IN ONCE I KNOW THE CODE**
Step 2: Compute " a " based on the assumption that the steel is yielding before the concrete
Step 3: verify that the steel is yielding
Step 4: Calculate the nominal moment " M_n "

Step 2:

Computation of " a "

C is equal to T, and each is just the summation of the forces for the whole object.

C = T = .85 * f ' $_c$ * a * b = A_s * f_y

$$a := \frac{A_S \cdot f_y}{.85 \cdot f'_c \cdot b}$$

$$\frac{in^2 \cdot \frac{lb}{in^2}}{\left(\frac{lb}{in^2}\right) \cdot in} = 1\,in$$

$$a = 5.04202\,in$$

Computation of " β_1 " **(ACI 10.2.7.3)**

"For f '$_c$ between 2500 and 4000 psi, β_1 shall be taken as 0.85. For f '$_c$ above 4000 psi, β_1, shall be reduced linearly at a rate of .05 for each 1000 psi of strength in excess of 4000 psi, but β_1 shall not be taken less than 0.65."

$$\beta_1 := if\left[f'_c > 4000 \cdot \frac{lb}{in^2}, if\left[\left[.85 - .05 \cdot \frac{in^2}{lb}\left(\frac{f'_c - 4000\frac{lb}{in^2}}{1000}\right)\right] \geq .65, \left[.85 - .05 \cdot \frac{in^2}{lb}\left(\frac{f'_c - 4000\frac{lb}{in^2}}{1000}\right)\right], .65\right], .85\right]$$

$$\beta_1 = 0.85$$

If β_1 is less than .65, reexamine the calculation and enter manually.

Computation of " c " **(ACI 10.2.7.1)**

"Concrete stress of .85 *f '$_c$ shall be assumed uniformly distributed over an equivalent compression zone bounded by edges of the cross section and a straight line located parallel to the neutral axis at a distance a = c * β_1 from the fiber of maximum compressive strain. "

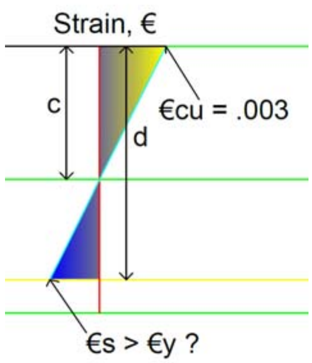
c = a / β_1

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

$$c = 5.93178\,in$$

Step 3:

The ultimate compressive strain of the concrete is a constant and known to be .0035. By calculating " c " in Step 2, and knowing the value of " d ", we are able to use simple triangular geometry to calculate ε_s. We can then check to see if ε_s is actually yielding by comparing it to ε_y ,the yielding strain of the steel that is derived by using the Young's modulus and the yielding stress.



E = Young's Modulus = σ/ε = stress / strain

*Using the young's modulus assumes elastic behavior and obey hooke's law.
*E is a property of the material and is constant.

E_{steel} = 29,000,000 psi (29,000 ksi)

ε_{cu} = ultimate compressive strain of concrete = .0035

Computation of " ε_y "

$E := 29000000 \frac{lb}{in^2}$ $\qquad$ $f_y = 60000 \frac{lb}{in^2}$

$\varepsilon_y = \sigma/E = f_y / E$

$$\varepsilon_y := \frac{f_y}{E}$$

$$\varepsilon_y = 0.00207$$

Computation of " ε_s " and comparison to " ε_y "

$$\varepsilon_{cu} := .003$$

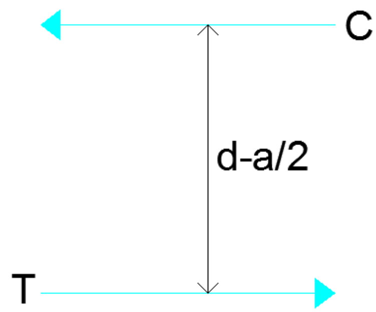
$$\varepsilon_s := \frac{(d - c)\cdot\varepsilon_{cu}}{c}$$

$$\varepsilon_s = 0.00762$$

***If " ε_s" is less than "ε_y" then reevaluation is required.**

$\varepsilon_s = 0.00762$ $\qquad$ $\varepsilon_y = 0.00207$

Step 4:



Calculation of the nominal moment is easily computed by multiplying either the compressive force, C, or tension force, T, by the moment arm. Either method is effective.

M_n = T (d-a/2)

The Tension force can be calculated by Knowing the tensile stress that is applied to the steel. Fundamentally, stress is a force divided by the area the force is applied to. The entire tension force is being applied through the cross sectional area of the steel rebar, which is a known quantity.

σ = F/A

Tensile Stress = Yielding Stress assumed at the beginning of the analysis.

$$f_y = 60000 \frac{lb}{in^2}$$

The Area of the Steel was calculated previously.

$$A_S = 3\,in^2$$

$$T := f_y \cdot A_S$$

$$T = 180000\,lb$$

$$M_n := T \cdot \left(d - \frac{a}{2}\right)$$

$$M_n = 3.32622 \times 10^6\,lb \cdot in$$

$6, .31, 0\Big), \text{if}\Big(5 < \text{Rebar}_{\text{number}} < 7, .44, 0\Big), \text{if}\Big(6 < \text{Rebar}_{\text{number}} < 8, .60, 0\Big), \text{if}\Big(7 < \text{Rebar}_{\text{number}} < 9, .79, 0\Big), \text{if}\Big(8 <$

$$: \text{Rebar}_{number} < 10, 1, 0), \text{if}\left(9 < \text{Rebar}_{number} < 11, 1.27, 0\right), \text{if}\left(10 < \text{Rebar}_{number} < 14, 1.41, 0\right), \text{if}\left(11 < \text{Rebar}_{nu}\right.$$

$\text{mber} < 18, 2.25, 0\Big), \text{if}\Big(14 < \text{Rebar}_{\text{number}}, 4, 0\Big)\Big)\cdot \text{in}^2$