Reinforced Concrete Calculator User Manual

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General Note

These calculators guide your workflow and flag common issues, but it assumes the user has been introduced to the basics of reinforced concrete analysis and design. It automates routine calculations and highlights when inputs or outcomes are likely noncompliant and suggests direction. It is intended for users who are taking a Reinforced Concrete analysis and design course and can select appropriate inputs and interpret results. The tools work through simplified cases, and this limits its application for more complicated problems. Always verify outputs against ACI codes, perform complementary checks, and use engineering judgment.

If an unexpected output is presented, calculate a solution by hand to check. The calculators have been tested, but it is possible that extreme inputs will not produce accurate results.

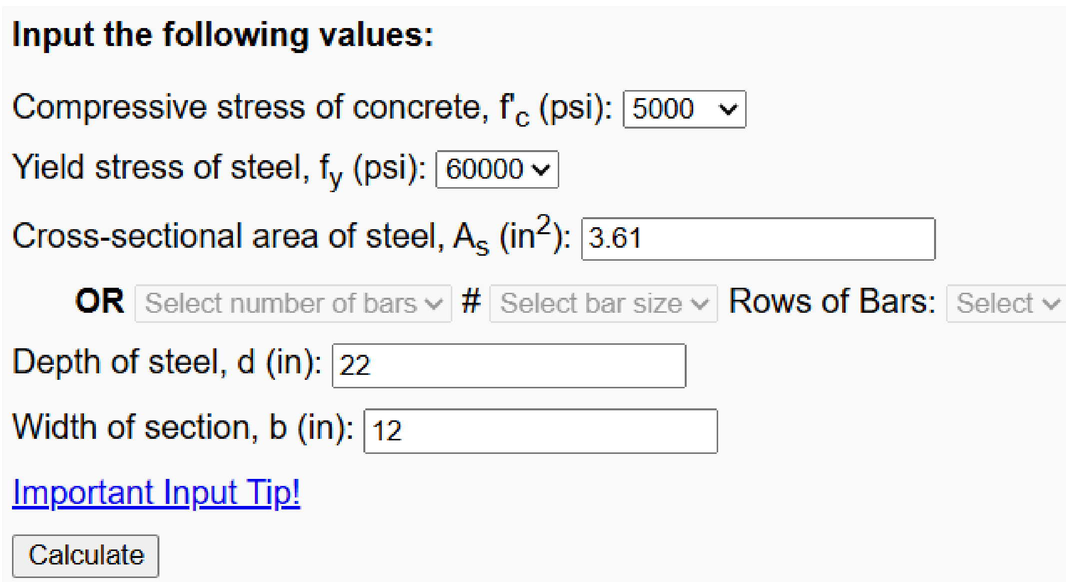
Singly Reinforced Beam (SRB) Analysis

Purpose

This tool analyzes a rectangular, singly reinforced concrete beam at failure. It computes the Whitney stress block depth a, neutral axis depth c, steel tensile strain ε_t, strength reduction factor φ, nominal moment capacity M_n, design capacity φM_n, and reinforcement ratio ρ. It also sketches a stress/strain diagram.

How to Use the Calculator

Example Inputs



Step A – Select Material Strengths

- **Concrete compressive strength, f'c (psi):** choose from 3000, 4000, or 5000.
- **Steel yield strength, fy (psi):** choose from 40000, 50000, or 60000.

Step B – Enter Steel Area or Pick Bars

- **Option 1 (Direct):** Enter *As* (in²) in the *Cross-sectional area of steel* field.
- **Option 2 (Bar Selection):** Choose number of bars, bar size (#3–#18), and number of rows (1–3).

The calculator checks internal bar tables for valid layouts and minimum beam width (*bmin*). Incompatible configurations are disabled automatically.

Step C – Enter Geometry

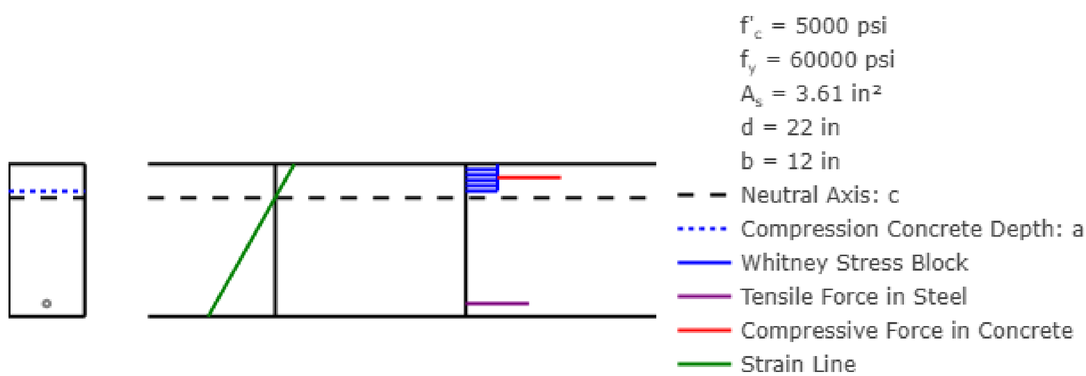
- **Depth to steel, d (in):** Measured to centroid of tension steel.
- **Beam width, b (in):** Rectangular section width.

Step D – Calculate and Review Results

Click Calculate to generate outputs. Results, warnings, and the stress/strain diagram appear below. Use Copy Graph or Download Graph to export.

Results:

The cross-sectional area exceeds the minimum.
$a = 4.25$ in
$\beta_1 = 0.80$
$c = 5.31$ in
$\varepsilon_t = 0.0094$
$\Phi = 0.90$, Ductile Section
Maximum internal moment: $M_n = 358.77$ k·ft
Usable/design capacity: $\Phi M_n = 322.89$ k·ft
Steel reinforcing ratio: $\rho = 0.0137$



Understanding Warnings and Errors

The calculator is designed to be explicit if something is off. Some messages are about incorrect inputs, while others have to do with the beam analysis. Here are the messages you may see and how to address them:

1. **Pop-up: Please enter all values.**
   - Trigger: Any required input is missing.
   - Fix: Complete all necessary fields.
2. **Please select the number of rows.**
   - Trigger: You chose bars but left Rows blank.
   - Fix: Choose Rows = 1, 2, or 3.
3. **Selected configuration X in Y row(s) is not available. Please try a different layout.**
   - Trigger: That exact combo isn't in the internal bar layout table. You may have tried to do a configuration in which rows do not have an equal number of bars.
   - Example: 5#18 bars in 2 rows.
   - Fix: Try a new combo. Rows need to have an equal number of bars for this program.
4. **Selected configuration X requires a minimum beam width of Z in. Increase b or choose different bar configuration.**
   - Trigger: The chose bar layout violates the minimum width b_{min} for spacing/cover.
   - Example: 8#8 bars in 2 rows needs b_{min} = 11.3 in. If b = 10 in, this error appears.
   - Fix: Increase b to at least b_{min} or use a different layout.
5. **The cross-section area of the steel does NOT exceed the minimum. These section parameters cannot be used.**
   - Trigger: The selected A_s is less than the minimum steel required for the section.
   - Fix: Increase A_s (or adjust b, d, f_y as appropriate)
   - Note: Results still print for insight, but the red message indicates the section is not acceptable.
6. **Strain/ductility compliance**
   - If $\varepsilon_t \geq 0.005$ → **Ductile Section**, $\phi = 0.9$
   - If $0.004 \leq \varepsilon_t < 0.005$ → Transition Zone
   - If $\varepsilon_t < 0.004$ → error message:
     Tension strain in steel is less than 0.004 and therefore is not ACI compliant. These section parameters cannot be used.

- Fix: Increase tension steel depth d, reduced compression block (e.g. smaller A_s or b), or adjust materials to achieve $\varepsilon_t \geq 0.004$ (preferably $\varepsilon_t \geq 0.005$).

Singly Reinforced Beam (SRB) Analysis

Given:

$f'_c := 5000$ psi $\quad A_s := 3.61 \quad in^2 \quad d := 22 \quad in$

$f_y := 60000$ psi $\quad b := 12 \quad in$

Solution

$$\beta_1 := \begin{array}{l} \text{if } f'_c \le 4000 \\ \quad 0.85 \\ \text{else if } 4000 < f'_c < 8000 \\ \quad 0.85 - \left(\dfrac{f'_c - 4000}{1000}\right) \cdot 0.05 \\ \text{else if } f'_c \ge 8000 \\ \quad 0.65 \end{array} \qquad \beta_1 = 0.8$$

$A_{s,min}$ check:

$$A_{s\_min} := \max\left(\frac{3\sqrt{f'_c} \cdot b \cdot d}{f_y}, \frac{200 \cdot b \cdot d}{f_y}\right) = 0.933$$

$$A_{s\_min}check := \begin{array}{l} \text{if } A_s \ge A_{s\_min} \\ \quad \text{"Good"} \\ \text{else} \\ \quad \text{"No Good"} \end{array} = \text{"Good"}$$

$$A_s \cdot f_y = 0.85 \cdot f'_c \cdot A_c = 0.85 \cdot f'_c \cdot (a \cdot b)$$

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b} = 4.247 \quad in \qquad c := \frac{a}{\beta_1} = 5.309 \quad in$$

$$\varepsilon_t := \frac{d - c}{c}(0.003) = 0.0094 \qquad 0.0094 \ge 0.005$$ so ductile section, $\phi := 0.9$

$$M_N = T \cdot arm \qquad M_N := A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right) \cdot \frac{1}{12 \cdot 1000} = 358.77 \quad k \cdot ft$$

$$\phi \cdot M_N = 322.89 \quad k \cdot ft \qquad \rho := \frac{A_s}{b \cdot d} = 0.0137$$

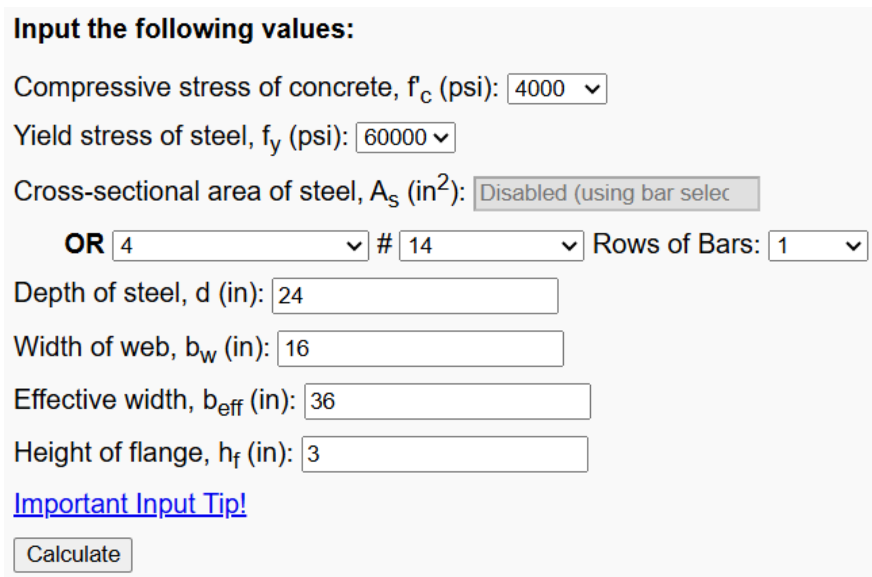
Singly Reinforced T-Beam Analysis

Purpose

This tool analyzes a T-section, singly-reinforced concrete beam at failure. The program determines beam case and follows the appropriate calculation procedure. It computes the Whitney stress block depth a, neutral axis depth c, steel tensile strain ε_t, strength reduction factor φ, nominal moment capacity M_n, design capacity φM_n, and reinforcement ratio ρ. It also sketches a stress/strain diagram.

How to Use the Calculator

Example Inputs



Step A – Select material strengths

- **Concrete compressive strength, f'_c (psi):** dropdown (3000, 4000, 5000)
- **Steel yield strength, f_y (psi):** dropdown (40000, 50000, 60000)

Step B – Enter steel area or pick bars

- **Option 1 (direct):** enter A_s in in^2 in the “Cross-sectional area of steel” field.
- **Option 2 (bar selection):** choose number of bars, bar size #3 – #18, and rows (1 – 3).
  - The calculator disables the unused path automatically to prevent conflicts.
  - It checks a built-in bar table for availability and minimum beam width b_{min} for the chosen layout.

Step C – Enter geometry

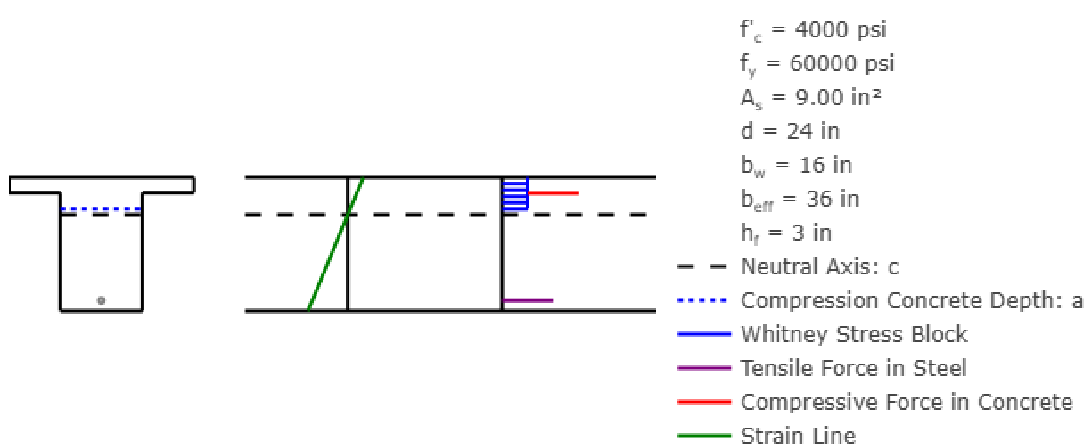
- **Depth to steel, d (in)**, measured to the centroid of the tension steel
- **Width of web, b_w (in)**
- **Effective flange width, b_{eff} (in)**
- **Height of flange, h_f (in)**

Step D – Calculate and view results

- Click Calculate.
- The tool prints **Results** and any **Warnings/Errors**.
- The diagram is generated below. Use Copy Graph or Download Graph to export the image.

Results:

The cross-sectional area exceeds the minimum.
a = 6.18 in
β_1 = 0.85
c = 7.27 in
ε_t = 0.0069
Φ = 0.90, Ductile Section
Maximum internal moment: M_n = 968.03 k·ft
Usable/design capacity: ΦM_n = 871.23 k·ft



Understanding Warnings and Errors

The calculator is designed to be explicit if something is off. Some messages are about incorrect inputs, while others have to do with the beam analysis. Here are the messages you may see and how to address them:

1. **Pop-up: Please enter all values.**

- Trigger: Any required input is missing.
- Fix: Complete all necessary fields.

2. **Please select the number of rows.**
   - Trigger: You chose bars but left Rows blank.
   - Fix: Choose Rows = 1, 2, or 3.
3. **Selected configuration X in Y row(s) is not available. Please try a different layout.**
   - Trigger: That exact combo isn't in the internal bar layout table. You may have tried to do a configuration in which rows do not have an equal number of bars.
   - Example: 5#18 bars in 2 rows.
   - Fix: Try a new combo. Rows need to have an equal number of bars for this program.
4. **Selected configuration X requires a minimum beam width of Z in. Increase b or choose different bar configuration.**
   - Trigger: The chose bar layout violates the minimum width b_{min} for spacing/cover.
   - Example: 8#8 bars in 2 rows needs b_{min} = 11.3 in. If b = 10 in, this error appears.
   - Fix: Increase b to at least b_{min} or use a different layout.
5. **The cross-section area of the steel does NOT exceed the minimum. These section parameters cannot be used.**
   - Trigger: The selected A_s is less than the minimum steel required for the section.
   - Fix: Increase A_s (or adjust b, d, f_y as appropriate)
   - Note: Results still print for insight, but the red message indicates the section is not acceptable.
6. **Strain/ductility compliance**
   - If $\varepsilon_t \geq 0.005$ → **Ductile Section**, $\phi = 0.9$
   - If $0.004 \leq \varepsilon_t < 0.005$ → **Transition Zone**
   - If $\varepsilon_t < 0.004$ → error message:
     Tension strain in steel is less than 0.004 and therefore is not ACI compliant. These section parameters cannot be used.
   - Fix: Increase tension steel depth d, reduced compression block (e.g. smaller A_s or b), or adjust materials to achieve $\varepsilon_t \geq 0.004$ (preferably $\varepsilon_t \geq 0.005$).

Singly Reinforced T-Beam Analysis

Given:

$f'_c := 4000$ psi $\quad A_s = 4\ \#14\ bars \quad d := 24\ \ in \quad b_{eff} := 36\ \ in$

$f_y := 60000$ psi $\quad b_w := 16\ \ in \quad h_f := 3\ \ in$

Solution

$$\beta_1 := \begin{array}{|l} \text{if } f'_c \le 4000 \\ \quad \| \ 0.85 \\ \text{else if } 4000 < f'_c < 8000 \\ \quad \| \ 0.85 - \left(\dfrac{f'_c - 4000}{1000}\right) \cdot 0.05 \\ \text{else if } f'_c \ge 8000 \\ \quad \| \ 0.65 \end{array}$$

$\beta_1 = 0.85$

$4\ \#14\ \ bars \qquad A_s := 9.0 \quad in^2$

$A_{s,min}$ check:

$$A_{s\_min} := \max\left(\frac{3\sqrt{f'_c} \cdot b_w \cdot d}{f_y}, \frac{200 \cdot b_w \cdot d}{f_y}\right) = 1.28$$

$$A_{s\_min}check := \begin{array}{|l} \text{if } A_s \ge A_{s\_min} \\ \quad \| \ \text{“Good”} \\ \text{else} \\ \quad \| \ \text{“No Good”} \end{array} = \text{“Good”}$$

$A_f := h_f \cdot b_{eff} = 108 \quad in^2$

$A_c := \dfrac{A_s \cdot f_y}{0.85 \cdot f'_c} = 158.824 \quad in^2 \qquad A_c > A_f$ so Whitney Stress block goes into web

$a := h_f + \dfrac{A_c - A_f}{b_w} = 6.176 \quad in$

$c := \dfrac{a}{\beta_1} = 7.266 \quad in$

$\varepsilon_t := \dfrac{d - c}{c}(0.003) = 0.0069 \qquad 0.0069 \ge 0.005$ so ductile section, $\phi := 0.9$

$$y_c := \frac{A_f \cdot \left(\frac{h_f}{2}\right) + \left(\left(a - h_f\right) \cdot b_w\right) \cdot \left(h_f + \frac{a - h_f}{2}\right)}{A_c} = 2.488 \quad in$$

$$M_N = T \cdot arm \qquad M_N := A_s \cdot f_y \cdot \left(d - y_c\right) \cdot \frac{1}{12 \cdot 1000} = 968.03 \quad k \cdot ft$$

$$\phi \cdot M_N = 871.23 \quad k \cdot ft$$

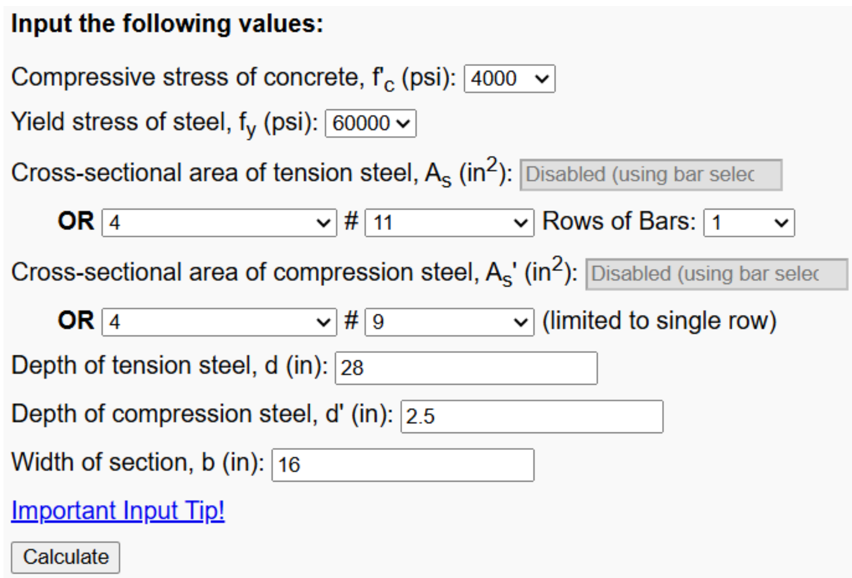
Doubly Reinforced Beam (DRB) Analysis

Purpose

This tool analyzes a rectangular, doubly reinforced concrete beam at failure. It computes the Whitney stress block depth a, neutral axis depth c, steel tensile strain ε_t, strength reduction factor φ, nominal moment capacity M_n, design capacity φM_n, and reinforcement ratio ρ. It also sketches a stress/strain diagram.

How to Use the Calculator

Example Inputs



Step A – Select material strengths

- **Concrete compressive strength, f'_c (psi):** dropdown (3000, 4000, 5000)
- **Steel yield strength, f_y (psi):** dropdown (40000, 50000, 60000)

Step B – Enter steel area or pick bars for tension and compression steel

- **Option 1 (direct):** enter A_s/ A_s' in in^2 in the “Cross-sectional area of steel” field.
- **Option 2 (bar selection):** choose number of bars, bar size #3 – #18, and for tension steel also pick rows (1 – 3).
    - The calculator disables the unused path automatically to prevent conflicts.
    - It checks a built-in bar table for availability and minimum beam width b_{min} for the chosen layout.

Step C – Enter geometry

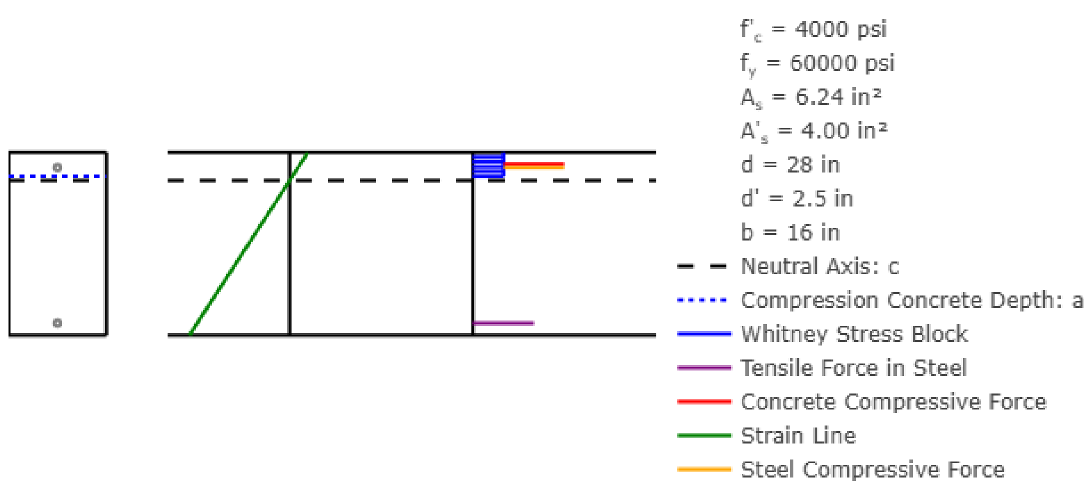
- **Depth to tension steel, d (in):** measured to the centroid of the tension steel
- **Depth to compression steel, d' (in):** measured to the centroid of the compression steel
- **Beam width, b (in):** rectangular section width

Step D – Calculate and view results

- Click Calculate.
- The tool prints **Results** and any **Warnings/Errors**.
- The diagram is generated below. Use Copy Graph or Download Graph to export the image.

Results:

β_1 = 0.85
c = 4.63 in
a = 3.94 in
ε_s' = 0.001381
ε_t = 0.0151
Φ = 0.90, Ductile Section
Maximum internal moment: M_n = 805.08 k·ft
Usable/design capacity: ΦM_n = 724.57 k·ft



Understanding Warnings and Errors

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1. **Pop-up: Please enter all values.**
   - Trigger: Any required input is missing.

- Fix: Complete all necessary fields.

2. **Please select the number of rows.**
   - Trigger: You chose bars but left <u>Rows</u> blank.
   - Fix: Choose <u>Rows</u> = 1, 2, or 3.
3. **Selected tension configuration X in Y row(s) is not available. Please try a different layout.**
   - Trigger: That exact combo isn't in the internal bar layout table. You may have tried to do a configuration in which rows do not have an equal number of bars.
   - Example: 5#18 bars in 2 rows.
   - Fix: Try a new combo. Rows need to have an equal number of bars for this program.
4. **Selected [tension/compression] configuration X requires a minimum beam width of Z in. Increase b or choose different bar configuration.**
   - Trigger: The chose bar layout violates the minimum width b_{min} for spacing/cover.
   - Example: 8#8 bars in 2 rows needs b_{min} = 11.3 in. If b = 10 in, this error appears.
   - Fix: Increase b to at least b_{min} or use a different layout.
5. **Strain/ductility compliance**
   - If $\varepsilon_t \geq 0.005$ → **Ductile Section**, $\phi = 0.9$
   - If $0.004 \leq \varepsilon_t < 0.005$ → **Transition Zone**
   - If $\varepsilon_t < 0.004$ → error message:
     Tension strain in steel is less than 0.004 and therefore is not ACI compliant. These section parameters cannot be used.
   - Fix: Increase tension steel depth d, reduced compression block (e.g. smaller A_s or b), or adjust materials to achieve $\varepsilon_t \geq 0.004$ (preferably $\varepsilon_t \geq$ 0.005).

Doubly Reinforced Beam (DRB) Analysis

Given:

$f'_c := 4000$ psi $\quad A_s = 4\ \#11\ bars \quad d := 28\ in \quad d' := 2.5\ in$

$f_y := 60000$ psi $\quad A_s' = 4\ \#9\ bars \quad b := 16\ in \quad E_s := 29000000\ psi$

Solution

$$\beta_1 := \begin{cases} 0.85 & \text{if } f'_c \le 4000 \\ 0.85 - \left(\dfrac{f'_c - 4000}{1000}\right) \cdot 0.05 & \text{else if } 4000 < f'_c < 8000 \\ 0.65 & \text{else if } f'_c \ge 8000 \end{cases} \qquad \beta_1 = 0.85$$

$4\ \#11\ bars \quad A_s := 6.25\ in^2$

$4\ \#9\ bars \quad A_s' := 4.00\ in^2$

assume $\quad f'_s = f_y$

$T = C_c$

$$a := \frac{f_y \cdot (A_s - A_s')}{0.85 \cdot f'_c \cdot b} = 2.482\ in \qquad c := \frac{a}{\beta_1} = 2.92\ in$$

$$\varepsilon'_s := \frac{c - d'}{c}(0.003) = 0.00043 \qquad 0.00043 < 0.00207$$

INVALID ASSUMPTION

$T = C_c + C_s'$

$$A_s \cdot f_y = 0.85 \cdot f'_c \cdot (c \cdot \beta_1) \cdot b + A_s' \cdot E_s \cdot \left(\frac{c - d'}{c} \cdot (0.003)\right)$$

$$c \cdot A_s \cdot f_y = 0.85 \cdot f'_c \cdot (c^2 \cdot \beta_1) \cdot b + A_s' \cdot E_s \cdot 0.003\ (c - d')$$

$$0.85 \cdot f'_c \cdot \beta_1 \cdot b \cdot c^2 + (A_s' \cdot E_s \cdot 0.003 - A_s \cdot f_y) \cdot c - 0.003\ A_s' \cdot E_s \cdot d' = 0$$

$$46.24\ c^2 - 27\ c - 870 = 0$$

$$c = -4.055\ ,\quad 4.6394\ in$$

$$c_2 := 4.6394\ in$$

$$a_2 := c_2 \cdot \beta_1 = 3.943\ in$$

Doubly Reinforced Beam (DRB) Analysis

$$\varepsilon'_{s2} := \frac{c_2 - d'}{c_2} (0.003) = 0.00138$$

$$f'_s := E_s \cdot \varepsilon'_{s2} = 40118.938 \quad psi$$

$$\varepsilon_t := \frac{d - c_2}{c_2} (0.003) = 0.0151 \qquad 0.0151 \geq 0.005 \quad \text{so ductile section,} \quad \phi := 0.9$$

$$M_N := \left(\left(0.85 \cdot f'_c \cdot a_2 \cdot b \cdot \left(d - \frac{a_2}{2} \right) \right) + \left(A_s' \cdot f'_s \cdot \left(d - d' \right) \right) \right) \cdot \frac{1}{12 \cdot 1000} = 806.322 \quad k \cdot ft$$

$$\phi \cdot M_N = 725.69 \quad k \cdot ft$$

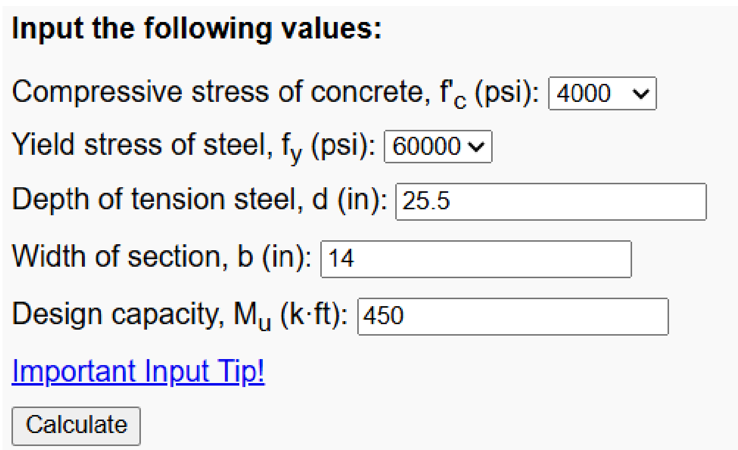
Singly Reinforced Beam (SRB) Design

Purpose

This calculator helps the user in designing a singly reinforced rectangular beam to meet a required factored moment, M_u. It computes the required steel area, suggests bar options that meet this requirement and fit within the given width, and analyzes the user's choice to confirm it complies.

How to Use the Calculator

Example Inputs



Step A – Select material strengths

- **Concrete compressive strength, f'_c (psi):** dropdown (3000, 4000)
- **Steel yield strength, f_y (psi):** dropdown (40000, 50000, 60000)

Step B – Enter geometry and required design capacity

- **Depth to steel, d (in):** measured to the centroid of the tension steel
- **Beam width, b (in):** rectangular section width
- **Design capacity, M_u (k·ft):** required design moment

Step C – Compute Required Steel and Ductile Solution Check

- Click Calculate and the tool computes $A_{s,req}$
- It will say if you should not continue with the design if no ductile solution exists for your inputs.

Design:

$A_{s,req}$ = 4.40 in

Bar Options:

Bar Selection	Area (in²)	Rows	b_{min} (in)
2#14 bars	4.50	1 row	8.9
3#11 bars	4.68	1 row	10.9
6#8 bars	4.71	2 rows	9.3
6#8 bars	4.71	3 rows	7.3
8#7 bars	4.81	2 rows	10.9
4#10 bars	5.06	1 row	12.9
4#10 bars	5.06	2 rows	7.8

Step D – Review Bar Options, Pick, and Analyze

- A filtered table of steel reinforcing options lists viable options for the design. Need more to choose from? Use the link to Tables 3 & 4.
- Enter the area of steel for your chosen bar set and click Analyze. It will tell you if your design meets the minimum design capacity.

Choose an option and ANALYZE

Area of steel for chosen bar selection, A_s (in^2):

4.50

Analyze

The cross-sectional area exceeds the minimum.
a = 5.67 in
c = 6.67 in
ε_t = 0.0085
Φ = 0.90, Ductile Section
Maximum internal moment: M_n = 509.94 k·ft
ΦM_n = 458.94 k·ft > 450.00 k·ft = M_u
Minimum design capacity met!

Understanding Warnings and Errors

The calculator is designed to be explicit if something is off. Some messages are about incorrect inputs, while others have to do with the beam design. Here are the messages you may see and how to address them:

1. **Pop-up: Please enter all values.**
    - Trigger: Any required input is missing.
    - Fix: Complete all necessary fields.
2. **With current b, d, and Mu there is no ductile solution. Do not continue with Bar Options. Try [increasing/decreasing] b or d and recalculate.**
    - Trigger: The input values put the design outside of the ductile range.
    - Fix: Follow the advice given for increasing or decreasing the geometry. Consider adjusting the required design capacity.
3. **Bar option table shows nothing**
    - Trigger: No option in the internal table meets the steel requirements within the allowable width.
    - Fix: Increase b or consult Tables 3 & 4 for alternative options.
4. **The cross-sectional area of the steel does NOT exceed the minimum. These section parameters cannot be used.**
    - Trigger: The area of steel you input is less than the minimum required. It is likely you did not choose from the table.
    - Fix: Enter an area that meets the minimum required. Choose from the table or from Tables 3 & 4.
5. **Tension strain in steel is less than 0.004 and therefore is not ACI compliant. These section parameters cannot be used. K**
    - Trigger: The most likely issue is the chosen area of steel is too large.
    - Fix: Choose an option that is less but still meets the minimum requirement.

Singly Reinforced Beam (SRB) Design

Given:

$f'_c := 4000$ psi $\quad d := 25.5\ in \quad M_u := 450\ k \cdot ft$

$f_y := 60000$ psi $\quad b := 14\ in \quad \phi := 0.90$

Solution

$$R_{N.} := \frac{M_u}{\phi \cdot b \cdot d^2} \cdot 12000 = 659.087 \quad psi$$

using ACI Table A.13 to find ρ_{req}

$\rho_{req} := 0.0124 \qquad (R_N = 662.3\ psi)$

$A_{s\_req} := \rho_{req} \cdot b \cdot d = 4.427 \quad in^2$

using ACI Table A.4 for bar size options

$2\ \#14 \qquad A_s := 4.50\ in^2 \qquad b_{min} := 8.9\ in \qquad b_{min}$ fits in $b = 14\ in$

Analyze:

$$\beta_1 := \begin{array}{l} \text{if } f'_c \le 4000 \\ \quad 0.85 \\ \text{else if } 4000 < f'_c < 8000 \\ \quad 0.85 - \left(\dfrac{f'_c - 4000}{1000}\right) \cdot 0.05 \\ \text{else if } f'_c \ge 8000 \\ \quad 0.65 \end{array}$$

$\beta_1 = 0.85$

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b} = 5.672 \quad in$$

$$c := \frac{a}{\beta_1} = 6.673 \quad in$$

$\varepsilon_t := \dfrac{d - c}{c}(0.003) = 0.0085 \qquad 0.0085 \ge 0.005 \qquad$ so it is ductile

$M_N = T \cdot arm \qquad M_N := A_s \cdot f_y \cdot \left(d - \dfrac{a}{2}\right) \cdot \dfrac{1}{12 \cdot 1000} = 509.937 \quad k \cdot ft$

$\phi \cdot M_N = 458.94 \quad k \cdot ft \qquad 458.94 > 450 \qquad$ so minimum design capacity met

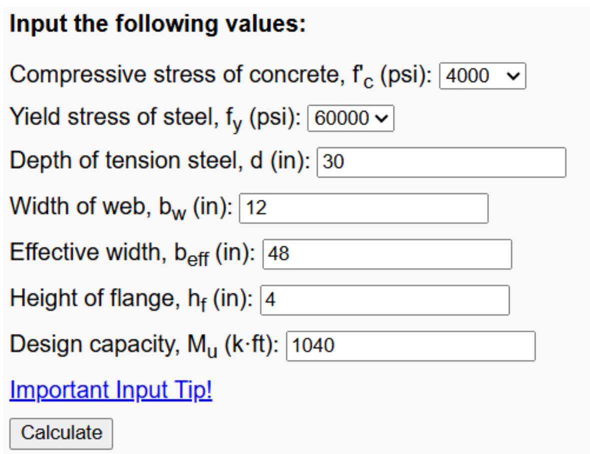
Singly Reinforced T-Beam Design

Purpose

This calculator helps the user in designing a singly reinforced T-beam to meet a required factored moment, M_u. It computes the required steel area, checks ductility for the inputs, lists bar options that meet required steel area and fit within the provided web width, and analyzes the user's chosen bar set to confirm ACI compliance and adequate design strength.

How to Use the Calculator

Example Inputs


Input the following values:

Compressive stress of concrete, f'_c (psi): 4000

Yield stress of steel, f_y (psi): 60000

Depth of tension steel, d (in): 30

Width of web, b_w (in): 12

Effective width, b_{eff} (in): 48

Height of flange, h_f (in): 4

Design capacity, M_u (k·ft): 1040

Important Input Tip!

Calculate

Step A – Select material strengths

- **Concrete compressive strength, f'_c (psi):** dropdown (3000, 4000)
- **Steel yield strength, f_y (psi):** dropdown (40000, 50000, 60000)

Step B – Enter geometry and required design capacity

- **Depth to tension steel, d (in):** measured to the centroid of the tension steel
- **Width of web, b_w (in)**
- **Effective flange width, b_{eff} (in)**
- **Height of flange, h_f (in)**
- **Design capacity, M_u (k·ft):** required design moment

Step C – Compute Required Steel and Ductile Solution Check

- Click Calculate and the tool computes $A_{s,req}$
- It will say if you should not continue with the design if no ductile solution exists for your inputs.

Design:

$A_{s,req}$ = 8.11 in

Bar Options:

Bar Selection	Area (in²)	Rows	b_{min} (in)
9#9 bars	9.00	3 rows	9.8
4#14 bars	9.00	2 rows	8.9
6#11 bars	9.37	2 rows	10.9
6#11 bars	9.37	3 rows	8.1
9#10 bars	10.12	3 rows	10.4

Step D – Review Bar Options, Pick, and Analyze

- A filtered table of steel reinforcing options lists viable options for the design. Need more to choose from? Use the link to Tables 3 & 4.
- Enter the area of steel for your chosen bar set and click Analyze. It will tell you if your design meets the minimum design capacity.

Choose an option and ANALYZE

Area of steel for chosen bar selection, A_s (in^2):

9.00

Analyze

The cross-sectional area exceeds the minimum.
a = 3.31 in
c = 3.89 in
ε_t = 0.0201
Φ = 0.90, Ductile Section
Maximum internal moment: M_n = 1275.55 k·ft
ΦM_n = 1148.00 k·ft > 1040.00 k·ft = M_u
Minimum design capacity met!

Understanding Warnings and Errors

The calculator is designed to be explicit if something is off. Some messages are about incorrect inputs, while others have to do with the beam design. Here are the messages you may see and how to address them:

1. **Pop-up: Please enter all values.**
   - Trigger: Any required input is missing.

- Fix: Complete all necessary fields.

2. **With current b_{eff}, b_w, d, h_f, and Mu there is no ductile solution. Do not continue with Bar Options. Try [increasing/decreasing] b or d and recalculate.**
   - Trigger: The input values put the design outside of the ductile range.
   - Fix: Follow the advice given for increasing or decreasing the geometry. Consider adjusting the required design capacity.
3. **Bar option table shows nothing**
   - Trigger: No option in the internal table meets the steel requirements within the allowable width.
   - Fix: Increase b or consult Tables 3 & 4 for alternative options.
4. **The cross-sectional area of the steel does NOT exceed the minimum. These section parameters cannot be used.**
   - Trigger: The area of steel you input is less than the minimum required. It is likely you did not choose from the table.
   - Fix: Enter an area that meets the minimum required. Choose from the table or from Tables 3 & 4.
5. **Tension strain in steel is less than 0.004 and therefore is not ACI compliant. These section parameters cannot be used.**
   - Trigger: The most likely issue is the chosen area of steel is too large.
   - Fix: Choose an option that is less but still meets the minimum requirement.

Given:

$f'_c := 4000$ psi $\quad d := 30$ in $\quad b_{eff} := 48\ in$ $\quad M_u := 1040\ k \cdot ft$

$f_y := 60000$ psi $\quad b_w := 12$ in $\quad h_f := 4$ in $\quad \phi := 0.90$

Solution

determine if case 1 or case 2

$$\phi M_N := \phi \cdot \left(0.85 \cdot f'_c \cdot \left(h_f \cdot b_{eff}\right) \cdot \left(d - \frac{h_f}{2}\right)\right) \cdot \frac{1}{12000} = 1370.88 \quad k \cdot ft \quad > \quad M_u = 1040 \quad k \cdot ft$$

this is a case 1 beam with a < h_f

$$R_{N.} := \frac{M_u}{\phi \cdot b_{eff} \cdot d^2} \cdot 12000 = 320.99 \quad psi$$

using ACI Table A.13 to find ρ_{req}

$\rho_{req} := 0.0057 \qquad (R_N = 324.7\ psi)$

$$A_{s\_req} := \rho_{req} \cdot b_{eff} \cdot d = 8.208 \quad in^2$$

using ACI Table A.4 for bar size options

$4\ \#14$ $\quad A_s := 9.00 \quad in^2$ $\qquad b_{min} := 8.9\ in$ $\qquad b_{min}$ fits in $\quad b_w = 12 \quad in$
in 2 rows

Analyze:

$$\beta_1 := \begin{array}{|l} \text{if } f'_c \le 4000 \\ \quad \| 0.85 \\ \text{else if } 4000 < f'_c < 8000 \\ \quad \left\| 0.85 - \left(\frac{f'_c - 4000}{1000}\right) \cdot 0.05 \right. \\ \text{else if } f'_c \ge 8000 \\ \quad \| 0.65 \end{array}$$

$\beta_1 = 0.85$

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b_{eff}} = 3.309 \quad in$$

$$c := \frac{a}{\beta_1} = 3.893 \quad in$$

$$\varepsilon_t := \frac{d - c}{c}(0.003) = 0.0201 \qquad 0.0201 \ge 0.005$$

so it is ductile

<u>Singly Reinforced T-Beam Design</u>

$$M_N := A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right) \cdot \frac{1}{12 \cdot 1000} = 1275.551 \;\; k \cdot ft$$

$\phi \cdot M_N = 1148 \;\; k \cdot ft$ $\qquad$ $1148 > 1040$ $\qquad$ so minimum design capacity met

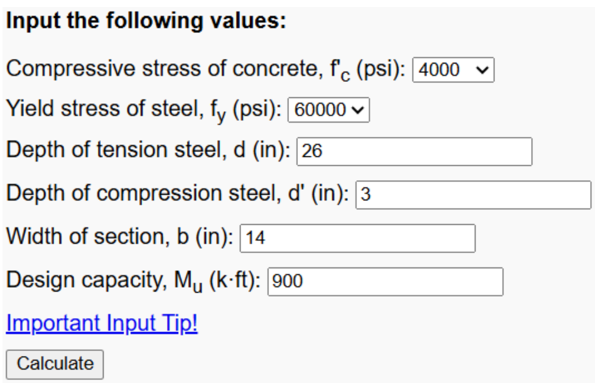
Doubly Reinforced Beam (DRB) Design

Purpose

This calculator helps the user in designing a doubly reinforced rectangular beam to meet a required factored moment, M_u, when a ductile singly reinforced solution does not exist. It computes the required steel area for tension and compression, lists bar options that meet required steel area and fit within the provided web width, and analyzes the user's chosen bar sets to confirm ACI compliance and adequate design strength.

How to Use the Calculator

Example Inputs


Input the following values:

Compressive stress of concrete, f'_c (psi): 4000

Yield stress of steel, f_y (psi): 60000

Depth of tension steel, d (in): 26

Depth of compression steel, d' (in): 3

Width of section, b (in): 14

Design capacity, M_u (k·ft): 900

Important Input Tip!

Calculate

Step A – Select material strengths

- **Concrete compressive strength, f'_c (psi):** dropdown (3000, 4000)
- **Steel yield strength, f_y (psi):** dropdown (40000, 50000, 60000)

Step B – Enter geometry and required design capacity

- **Depth to tension steel, d (in):** measured to the centroid of the tension steel
- **Depth to compression steel, d' (in):** measured to the centroid of the compression steel
- **Section width, b (in)**
- **Design capacity, M_u (k·ft):** required design moment

Step C – Tool checks if DRB is actually needed

- **If a ductile SRB solution exists:**
  Shows **"Ductile SRB solution does exist. DRB not necessary."** and stops.
- **If a ductile SRB solution does not exist:**
  Shows **"Ductile SRB solution does not exist. Must design DRB."** and proceeds to DRB sizing.

Step D – Compute Required Steel and Ductile Solution Check

- Click Calculate and the tool computes $A_{s,req}$ for tension and compression steel.
- It will say if you should not continue with the design if no ductile solution exists for your inputs.

$A_{s,req}$ = 9.03 in²

$A'_{s,req}$ = 2.44 in²

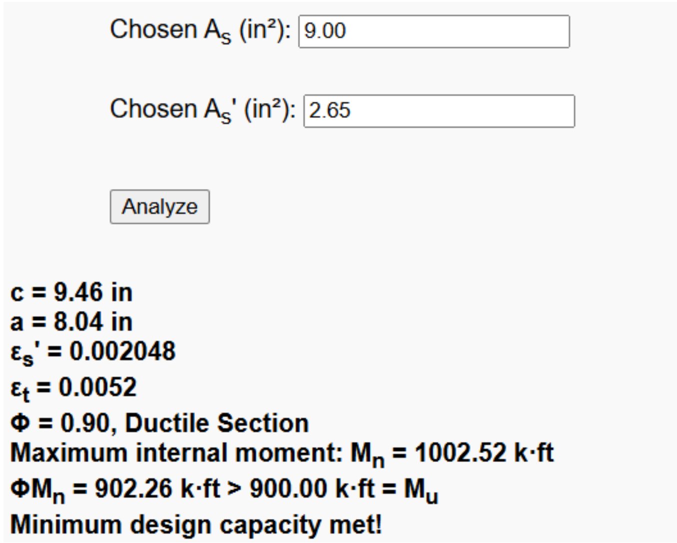
Bar Options:

Tension Steel Options			
Bar Selection	**Area (in²)**	**Rows**	**b_{min} (in)**
9#9 bars	9.00	3 rows	9.8
4#14 bars	9.00	2 rows	8.9
6#11 bars	9.37	2 rows	10.9
6#11 bars	9.37	3 rows	8.1
8#10 bars	10.12	2 rows	12.9
9#10 bars	10.12	3 rows	10.4

Compression Steel Options			
Bar Selection	**Area (in²)**	**Rows**	**b_{min} (in)**
2#10 bars	2.53	1 row	7.8
6#6 bars	2.65	1 row	14
3#9 bars	3.00	1 row	9.8
5#7 bars	3.01	1 row	12.8

Step D – Review Bar Options, Pick, and Analyze

- A filtered table of steel reinforcing options lists viable options for the design. Need more to choose from? Use the link to Tables 3 & 4.
- Enter the area of steel for your chosen bar set and click Analyze. It will tell you if your design meets the minimum design capacity.



Understanding Warnings and Errors

The calculator is designed to be explicit if something is off. Some messages are about incorrect inputs, while others have to do with the beam design. Here are the messages you may see and how to address them:

1. **Pop-up: Please enter all values.**
   - Trigger: Any required input is missing.
   - Fix: Complete all necessary fields.
2. **Bar option table shows nothing**
   - Trigger: No option in the internal table meets the steel requirements within the allowable width.
   - Fix: Increase b or consult Tables 3 & 4 for alternative options.
3. **Tension strain in steel is less than 0.004 and therefore is not ACI compliant. These section parameters cannot be used.**
   - Trigger: The most likely issue is the chosen area of steel is too large.
   - Fix: Choose an option that is less but still meets the minimum requirement.

Doubly Reinforced Beam (DRB) Design

Given:

$f'_c := 4000$ psi　　$d := 26 \ in$　　$d' := 3 \ in$　　$M_u := 900 \ k \cdot ft$

$f_y := 60000$ psi　　$b := 14 \ in$　　$\phi := 0.90$

Solution

if compression steel necessary?

$$R_N := \frac{M_u}{\phi \cdot b \cdot d^2} \cdot 12000 = 1267.963 \ psi \quad > \quad 912 \ psi$$ so yes it is necessary

for $\varepsilon_t = 0.005$, $\rho := 0.0181$

$$A_{s1} := \rho \cdot b \cdot d = 6.5884 \ in$$

$$a := \frac{A_{s1} \cdot f_y}{0.85 \cdot f'_c \cdot b} = 8.305 \ in \qquad c := \frac{a}{0.85} = 9.77 \ in$$

$$M_{N1} := A_{s1} \cdot f_y \cdot \left(d - \frac{a}{2}\right) \cdot \frac{1}{12000} = 719.705 \ k \cdot ft$$

$$M_{N2} := \frac{M_u}{\phi} - M_{N1} = 280.295 \ k \cdot ft$$

$$M_{N2} = A_{s2} \cdot f_y \cdot (d - d')$$

$$A_{s2} := \frac{M_{N2}}{f_y \cdot (d - d')} \cdot 12000 = 2.437 \ in^2$$

$$\varepsilon'_s := \frac{c - d'}{c} (0.003) = 0.002079 \quad > \quad 0.00207$$ so $f'_s = f_y$

$$A_{s\_req} := A_{s1} + A_{s2} = 9.026 \ in^2$$

$$A'_{s\_req} := A_{s2} = 2.437 \ in^2$$

using ACI Table A.4 for bar size options

for A_s　　2 rows　$4 \ \#14$　　$A_s := 9.00 \ in^2$　　$b_{min} = 8.9 \ in \le 14 \ in$

for A_s'　　1 row　$6 \ \#6$　　$A_s' := 2.65 \ in^2$　　$b_{min} = 14 \ in \le 14 \ in$

(must oversize to compensate for less steel)

Doubly Reinforced Beam (DRB) Design

Analyze:

assume $f'_s = f_y$

$T = C_c$

$a := \dfrac{f_y \cdot (A_s - A_s')}{0.85 \cdot f'_c \cdot b} = 8.004$ in $c := \dfrac{a}{0.85} = 9.417$ in

$\varepsilon'_s := \dfrac{c - d'}{c}(0.003) = 0.00204$ $0.00204 < 0.00207$ **INVALID ASSUMPTION**

$T = C_c + C_s'$

$$A_s \cdot f_y = 0.85 \cdot f'_c \cdot (c \cdot \beta_1) \cdot b + A_s' \cdot E_s \cdot \left(\frac{c - d'}{c} \cdot (0.003)\right)$$

$$c \cdot A_s \cdot f_y = 0.85 \cdot f'_c \cdot (c^2 \cdot \beta_1) \cdot b + A_s' \cdot E_s \cdot 0.003\ (c - d')$$

$$0.85 \cdot f'_c \cdot \beta_1 \cdot b \cdot c^2 + (A_s' \cdot E_s \cdot 0.003 - A_s \cdot f_y) \cdot c - 0.003\ A_s' \cdot E_s \cdot d' = 0$$

$c := 9.45609$ in

$a := c \cdot 0.85 = 8.038$ in

$\varepsilon'_s := \dfrac{c - d'}{c}(0.003) = 0.002048$

$f'_s := 29000000 \cdot \varepsilon'_s = 59398.74$ psi

$\varepsilon_t := \dfrac{d - c}{c}(0.003) = 0.0052$ $0.0052 \geq 0.005$ so ductile section

$$M_N := \left(\left(0.85 \cdot f'_c \cdot a \cdot b \cdot \left(d - \frac{a}{2}\right)\right) + \left(A_s' \cdot f'_s \cdot (d - d')\right)\right) \cdot \frac{1}{12 \cdot 1000} = 1002.517 \quad k \cdot ft$$

$\phi \cdot M_N = 902.27$ $k \cdot ft$

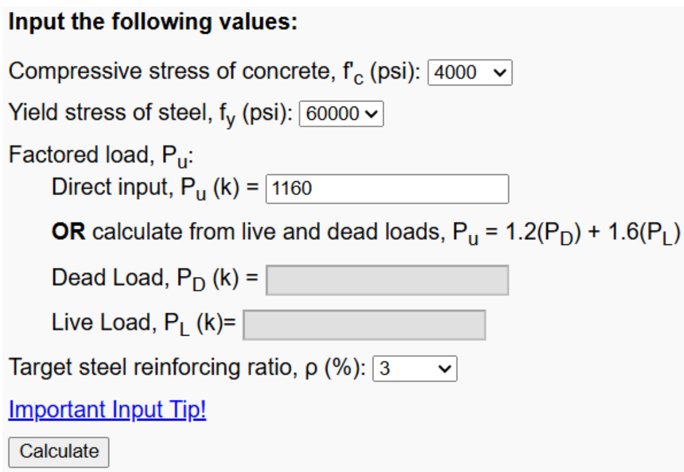
Square Column Design

Purpose

This tool helps the user size a square tied RC column for a given factored axial load P_u. It computes a target gross area $A_{g,\ target}$, offers rounded size options, calculates the required steel area, lists bar options, and complete tie design for selections.

How to Use the Calculator

Example Inputs



Step A – Select material strengths

- **Concrete compressive strength, f'_c (psi):** dropdown (3000, 4000)
- **Steel yield strength, f_y (psi):** dropdown (40000, 50000, 60000)

Step B – Enter the Factored Load P_u and choose target steel ratio

- **Factored Load**
  - **Direct input:** P_u (k)
  - **From loads:** $P_u = 1.2\ P_D + 1.6\ P_L$ (k)
- **Target steel reinforcing ratio ρ (%):** 2-7% (drop down)

Step C – Calculate target concrete area and pick section size

- Click calculate and the tool finds $A_{g,\ target}$
- Choose to either round up or round down and Continue Calculation

$A_{g,target}$ = 437.58 in

A_g Options:
Round Down: 20 in × 20 in, A_g = 400 in^2
Round Up: 22 in × 22 in, A_g = 484 in^2

Choose a size option and continue:

Select Column Size:

20 in × 20 in → Ag = 400 in²

Step D – Compute require steel area and pick bars

- The tool computes $A_{st,req}$ for steel and lists bar options that meet or exceed this value.
- Choose an option.

Required steel area, $A_{st,req}$: 15.38 in^2

Bar Options:

Number of Bars	Bar Number (#)	Area (in^2)	Bar Diameter
4	18	16	2.257
8	14	18	1.693
6	18	24	2.257
8	18	32	2.257

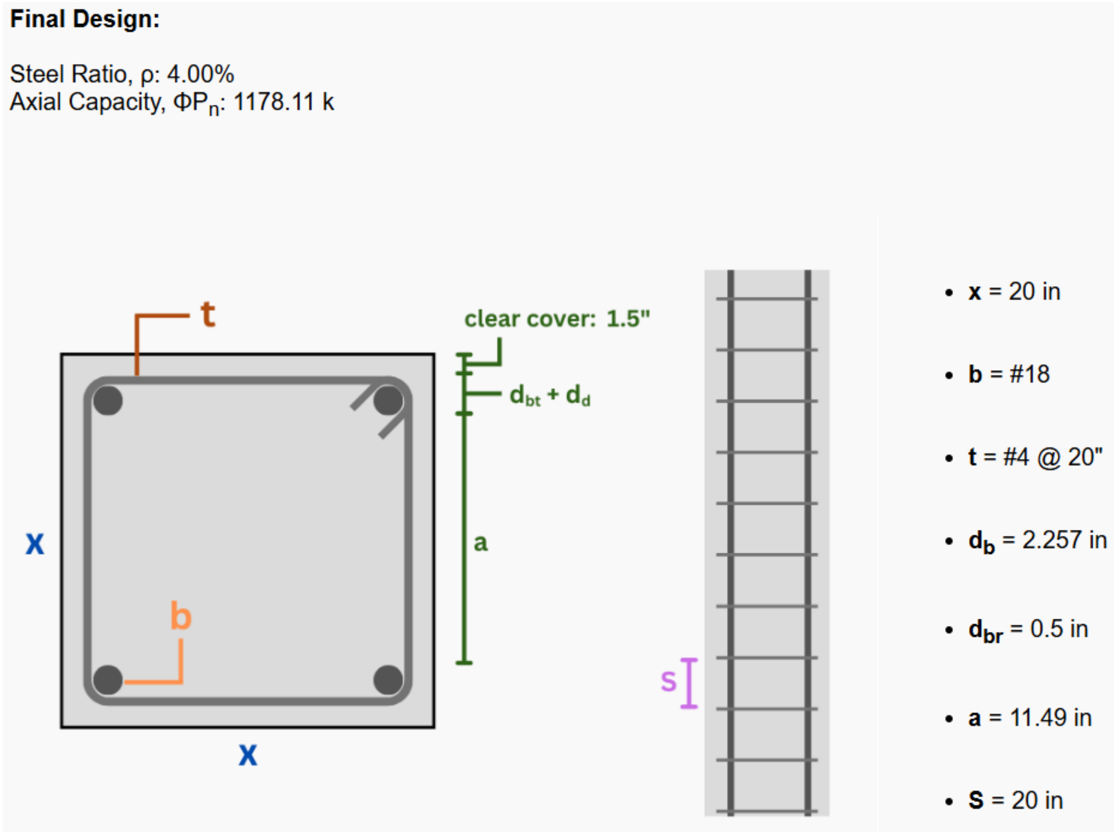
The four corner bars must be the same size. When using 6 or 8 bars, the additional bars can be a secondary size.
Use Table 3 to make a different combination on your own.
This program can only continue with tie design for design with all bars the same size.

Choose a bar option and continue design:

Select a Bar Option:

4 bars - #18 - 16 in² - 2.257 in

Step E – See Final Design



Error Handling & What the Messages Mean

The calculator is designed to be explicit if something is off. Some messages are about incorrect inputs while others have to do with the beam design. Here are the messages you may see and how to address them:

1. **Pop-up: Please enter all values.**
    - Trigger: Any required input is missing.
    - Fix: Complete all necessary fields.
2. **The chosen design has a reinforcing ratio, ρ, that is outside of the allowable range (1% to 8%). This design has a reinforcing ratio of X%.**
    - Trigger: After bar selection, actual ρ is less than 1 % or greater than 8%.
    - Fix: Choose a different bar set or section size to bring steel ratio within 1-8%.

Square Column Design

Given:

$f'_c := 4000$ psi $\quad P_u := 1160 \quad k$

$f_y := 60000$ psi $\quad \rho_{target} := 0.03 \quad (3\%)$

Solution

for a square tied column $\quad \phi := 0.65 \quad \alpha := 0.80$

$$A_{g.} := 1.0$$

$$P_u \cdot 1000 = \phi \cdot \alpha \cdot \left(0.85 \cdot f'_c \cdot \left(A_{g.} - \rho_{target}\, A_{g.}\right) + \rho_{target} \cdot A_{g.} \cdot f_y\right)$$

$$A_{g\_req} := \textbf{find}\left(A_{g.}\right) = 437.577 \quad in^2$$

dimensional selection: $\quad 20\ in \cdot 20\ in \quad A_g := 400 \quad in^2$

$$A_{s.} := 1.0$$

$$P_u \cdot 1000 = \phi \cdot \alpha \cdot \left(0.85 \cdot f'_c \cdot \left(A_g - A_{s.}\right) + A_{s.} \cdot f_y\right)$$

$$A_{st\_req} := \textbf{find}\left(\mathrm{A_{s.}}\right) = 15.38\ in^2$$

bar selection $A_{st} > A_{st\_req}$

$4\ \#18 \quad A_{st} := 16\ in^2 \quad \rho := \dfrac{A_{st}}{A_g} = 0.04 \quad$ good (between 0.01 and 0.08)

tie design - #4 bars

$$S = min\left(48\ d_{bt}, 16\ d_b, least.lateral.dim\right)$$

$$S := min\left(48 \cdot 0.5, 26 \cdot 2.257, 20\right) = 20 \quad in$$

design capacity

$$\phi P_N := \phi \cdot \alpha \cdot \left(0.85 \cdot f'_c \cdot \left(A_g - A_{st}\right) + A_{st} \cdot f_y\right) \cdot \frac{1}{1000} = 1178.11 \quad k$$

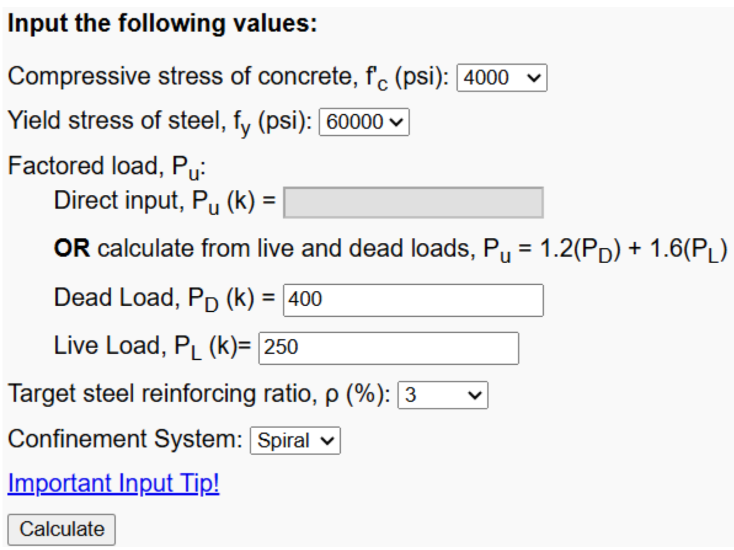
Circular Column Design

Purpose

This tool helps the user size a circular tied RC column for a given factored axial load P_u with either a tied or spiral confinement. It computes a target gross area $A_{g,\ target}$, offers rounded size options, calculates the required steel area, lists bar options, and completes confinement design for selections.

How to Use the Calculator

Example Inputs



Step A – Select material strengths

- **Concrete compressive strength, f'_c (psi):** dropdown (3000, 4000)
- **Steel yield strength, f_y (psi):** dropdown (40000, 50000, 60000)

Step B – Enter the Factored Load P_u, then choose target steel ratio and confinement system

- **Factored Load**
  - **Direct input:** P_u (k)
  - **From loads:** $P_u = 1.2\ P_D + 1.6\ P_L$ (k)
- **Target steel reinforcing ratio ρ (%):** 2-7% (drop down)
- **Confinement system:** Tied or Spiral (drop down)

Step C – Calculate target concrete area and pick section size

- Click calculate and the tool finds $A_{g,\ target}$

- Choose to either round up or round down and Continue Calculation

$A_{g,req}$ = 270.77 in

A_g Options:
Round Down: 18 in diameter, A_g = 254.47 in^2
Round Up: 20 in diameter, A_g = 314.16 in^2

Choose a size option and continue:

Select Column Size:

20 in diameter → Ag = 314.16 in²

Step D – Compute require steel area and pick bars

- The tool computes $A_{st,req}$ for steel and lists bar options that meet or exceed this value.
- Choose an option.

Required steel area, $A_{st,req}$: 5.52 in^2

Bar Options:

Number of Bars	Bar Number (#)	Area (in^2)	Bar Diameter
6	9	6	1.128
10	7	6.01	0.875
8	8	6.28	1
6	10	7.59	1.27

A minimum of four longitudinal bars of equal size is required in tied columns, and six in spiral columns.
Any additional bars beyond the minimum may be of a secondary size, provided they are symmetrically arranged.
Use Table 3 to make a different combination on your own.
This program can only continue with design for design with all bars the same size.

Choose a bar option and continue design:

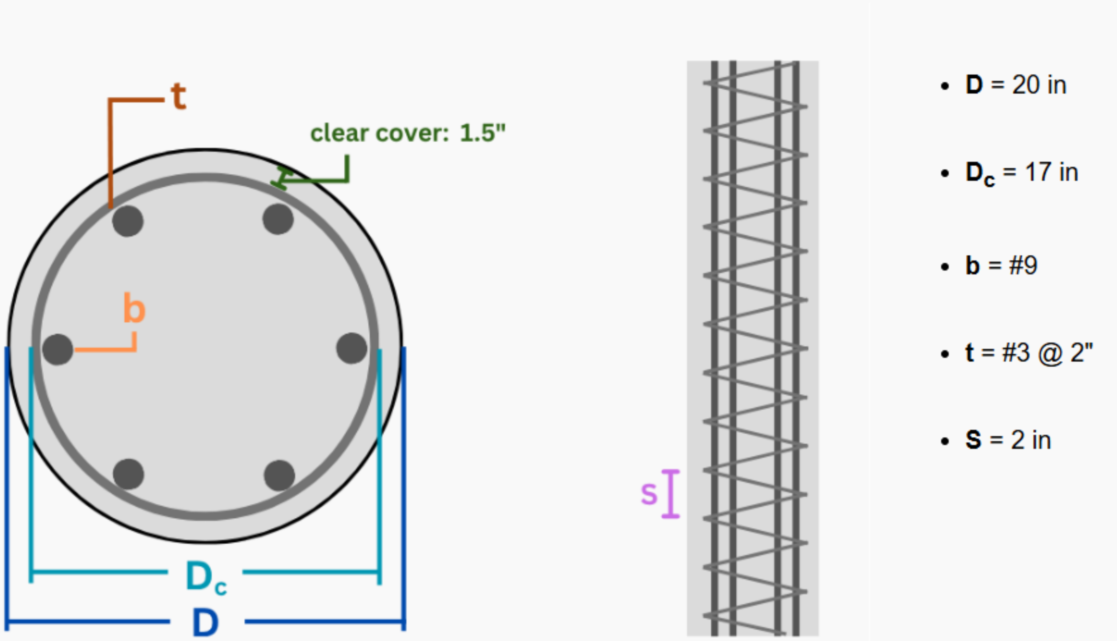
Select a Bar Option:

6 bars - #9 - 6 in² - 1.128 in

Step E – See Final Design

Final Design:

Steel Ratio, ρ: 1.91%
Axial Capacity, ΦP_n: 897.44 k



Error Handling & What the Messages Mean

The calculator is designed to be explicit if something is off. Some messages are about incorrect inputs while others have to do with the beam design. Here are the messages you may see and how to address them:

1. **Pop-up: Please enter all values.**
    - Trigger: Any required input is missing.
    - Fix: Complete all necessary fields.
2. **Pop-up: Please select a confinement type.**
    - Trigger: Confinement not selected.
    - Fix: Chose Tied or Spiral
3. **The chosen design has a reinforcing ratio, ρ, that is outside of the allowable range (1% to 8%). This design has a reinforcing ratio of X%.**
    - Trigger: After bar selection, actual ρ is less than 1 % or greater than 8%.
    - Fix: Choose a different bar set or section size to bring steel ratio within 1-8%.

Circular Column Design

Given:

$f'_c := 4000$ psi $\qquad P_D := 400 \quad k \qquad \rho_{target} := 0.03 \quad (3\%)$

$f_y := 60000$ psi $\qquad P_L := 250 \quad k \qquad confinement = spiral$

Solution

for a circular spiral column $\qquad \phi := 0.75 \qquad \alpha := 0.85$

$P_u := 1.2 \cdot P_D + 1.6\ P_L = 880 \quad k$

Guess Values

$A_{g.} := 1.0$

Constraints

$$P_u \cdot 1000 = \phi \cdot \alpha \cdot \left(0.85 \cdot f'_c \cdot \left(A_{g.} - \rho_{target}\ A_{g.}\right) + \rho_{target} \cdot A_{g.} \cdot f_y\right)$$

Solver

$A_{g\_req} := \mathbf{find}\left(A_{g.}\right) = 270.771 \quad in^2$

dimensional selection: $\qquad D := 20 \quad in \qquad A_g := 314.16 \quad in^2$

Guess Values

$A_{s.} := 1.0$

Constraints

$$P_u \cdot 1000 = \phi \cdot \alpha \cdot \left(0.85 \cdot f'_c \cdot \left(A_g - A_{s.}\right) + A_{s.} \cdot f_y\right)$$

Solver

$A_{st\_req} := \mathbf{find}\left(A_{s.}\right) = 5.517\ in^2$

bar selection $A_{st} > A_{st\_req}$

$6\ \#9 \qquad A_{st} := 6 \quad in^2 \qquad \rho := \dfrac{A_{st}}{A_g} = 0.019$ $\qquad$ good (between 0.01 and 0.08)

spiral design - #3 bars

$D_c := D - 3 = 17 \quad in \qquad A_c := \dfrac{\pi}{4}\ D_c^{\ 2} = 226.98 \quad in^2$

$$\rho_s := 0.45 \cdot \left(\frac{A_g}{A_c} - 1\right) \cdot \frac{f'_c}{f_y} = 0.0115$$

$$S(o.c.) = \frac{4 \cdot a_s\left(D_c - d_{bs}\right)}{\rho_s \cdot D_c^{\ 2}} \qquad S(o.c.) := \frac{4 \cdot 0.11 \cdot \left(D_c - \dfrac{3}{8}\right)}{\rho_s \cdot D_c^{\ 2}} = 2.197 \quad in$$

so use $S(o.c.) = 2\ in$

$$\phi P_N := \phi \cdot \alpha \cdot \left(0.85 \cdot f'_c \cdot \left(A_g - A_{st}\right) + A_{st} \cdot f_y\right) \cdot \frac{1}{1000} = 897.44 \quad k$$