Reinforce Concrete Calculator

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Honors Project Report

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Abstract

This project presents the development of a web-based platform containing eight interactive calculators for reinforced concrete (RC) analysis and design. The tools were created to assist students in understanding and applying principles from *ACI 318: Building Code Requirements for Structural Concrete* by automating common equations for beam and column design. The calculators allow users to input material strengths, member dimensions, loads and reinforcement options. The results provided align with traditional hand calculations and drawn diagrams. Features such as dropdown menus and input validation were included to improve clarity and reduce user error.

The project required translating engineering formulas into code using JavaScript and HTML, with Plotly.js employed for visualizations. Developing these tools posed challenges, particularly in generating dynamic diagrams and graphs, but ultimately resulted in a functional and user-friendly interface. The calculators serve as an accessible educational resource for students learning reinforced concrete analysis and design, providing an option between manual calculations and professional grade software. Future improvements could extend the scope to include shear design in beams, slab design, and eccentric column loading, as well as enhanced reporting features.

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Introduction

Reinforced concrete (RC) is one of the most widely used materials in structural engineering. Beam and column design require repeated application of standard equations to size these members, determine their required reinforcement, and check strength capacities. While professional engineers often rely on advanced software packages, students learn the hand calculation process and utilize it to gain a solid base understanding of the principles. At the introductory level, tools that reveal how parameter changes affect design outcomes provide valuable insight while reducing the need for repetitive manual calculations.

The purpose of this project was to create eight web-based interactive calculators that perform common RC analysis and design tasks. It required an understanding of RC analysis and design principles, as well as the translation of those principles into code using JavaScript and HTML. As an honors project, this work was done with the motivation to aid future students in their understanding of RC analysis and design. Standard reinforced concrete equations have been automated and presented in a digital format that is technically accurate and user-friendly. Knowing how design parameters affect the member capacity is essential, and this platform is intended to serve as an educational resource to make that more intuitive.

The calculators are accessible through the project website at the following link: Reinforced Concrete Calculators (https://obracewell.github.io/RCBeamCalculator/)

Technical Framework

The calculators in this project were made following the completion of CES4702 Analysis and Design in Reinforced Concrete at the University of Florida, taught by Dr. Kurtis Gurley. It was developed to reflect the principles of reinforced concrete analysis and design established in *ACI 318: Building Code Requirements for Structural Concrete*. Each calculation tool implements standard equations that are commonly used in preliminary design and analysis. Users can explore how different material properties, member dimensions, applied loads, and reinforcement choices affect structural performance. The calculators were developed as an educational resource for students taking CES4702.

Concrete and steel were treated as homogeneous and isotropic materials, with compressive strength of concrete (f'_c) and yield strength of steel (f_y) being chosen by the user from a small list. Analysis of beams was done considering Phase III Behavior, otherwise referred to as analysis at failure. Analysis at failure is part of practical design and incorporated into design codes and methods such as Load Resistance Factor Design (LRFD). Beam design focused on flexural strength only, while shear strength and deflection checks were considered outside the scope of this project. Strength reduction factors were applied when appropriate to provide design-level values.

Design and analysis equations were implemented directly in code, with input fields corresponding to user-defined parameters. For further design choices like reinforcement combinations, the program provides feasible options from the calculations, much like in traditional methods where one uses equations and tables to design. Graphical outputs of stress and strain diagrams were included for beam analysis to illustrate how results change with varying parameters.

In professional practice, reinforced concrete design is typically done using advanced structural analysis software with comprehensive capabilities. They are powerful and include wide ranges of structural elements, but they take significant training to use successfully and are not accessible to students. The calculators developed in this project, while less complex, are student friendly and focus on the core processes.

Calculator Design

The reinforced concrete calculator website is a collection of eight interactive tools designed to assist with basic structural analysis and design tasks. Each calculator follows a consistent structure: users enter their known parameters, and the program uses these inputs to compute the analysis or design quantities. In the design cases, the user is tasked with choosing intermediate inputs from program generated tables. Calculations are done according to ACI 318 principles. The site was built using HTML and JavaScript, with Plotly.js integrated for graphical visualization for the beam analysis calculators. To minimize error, some input fields are given as dropdown menus and an instructional pop-up directs the user. Output values and error messages are displayed clearly and simply. The overall design emphasized both clarity and efficiency, so that results could be obtained quickly without requiring the user to read through multi-step calculations or input all necessary values.

Representative Examples of Code vs. Hand Calculation

Rather than providing the code for all eight calculators, below are a few representative examples that demonstrate how analysis and design formulas were implemented in code. Each example shows the hand calculation process and the corresponding JavaScript implementation. This comparison shows how the principles of reinforced concrete analysis and design were translated into a working digital tool.

Example: Square Column Design – Target Area of Concrete ($A_{g,target}$)

This is a simple formula that utilizes the user's inputs and coded constants.

<u>Hand Calculation</u>

Formula:	$P_u = \phi\alpha\ [0.85 \cdot f'_c\ (A_g - \rho_{target} \cdot A_g) + \rho_{target} \cdot A_g \cdot f_y]$
Substitution:	$444k = 0.65 \cdot 0.8\ [0.85 \cdot 4ksi\ (A_g - 0.02 \cdot A_g) + 0.02 \cdot A_g \cdot 60ksi]$
Result:	$A_{g,target} = 188.4\ in^2$

Code Implementation

```
          //Calculate Ag,target
const Agreq = (Pu*1000) / (phi*alpha*(0.85*fc*(1-rhoi) + fy*rhoi));
output += `A<sub>g,target</sub> = ${Agreq.toFixed(2)} in<br><br>`;
```

The formula was rearranged in the code and handles unit conversions.

Example: SRB Analysis – Strain in Steel (ε_t) and Ductility Determination (φ)

This is a multi-step calculation that uses a piecewise function from ACI to determine ϕ.

Hand Calculation

$\varepsilon_t = \frac{d-c}{c}(0.003)$

ϕ = $\{0.9, \varepsilon_t \geq 0.005 \quad 0.65 + (\varepsilon_t - 0.002)(\frac{250}{3}) \ \times, \varepsilon_t < 0.004 \, , 0.004 \ < \ \varepsilon_t \ < 0.005$

Using a given parameter (d) and a previously calculated value (c), the steel strain is determined and used to find the ductility with the piecewise function.

Code Implementation

```
       // Solve for strain in steel
const stlstrain = ((d - c) / c) * 0.003;
output += `&#949;<sub>t</sub> = ${stlstrain.toFixed(4)}\n`;

// Calculate phi
let phi;
if (stlstrain >= 0.005) {
    phi = 0.9;
    output += `&#934 = ${phi.toFixed(2)}, Ductile Section\n`;
} else if (stlstrain >= 0.004 && stlstrain < 0.005) {
    phi = 0.65 + (stlstrain - 0.002) * (250 / 3);
```

```
    output += `&#934 = ${phi.toFixed(2)}, <span
style="color:orange;">Transition Zone</span>\n`;

} else {

    errorMessage += 'Tension strain in steel is less than 0.004 and therefore
is not ACI compliant.\n';

    errorMessage += 'These section parameters cannot be used.\n';

}
```

The program uses an if-else statement to determine the ductility. It prints the value and tells the user more about the ductility or if the section cannot be used.

Example: SRB Design – Required Reinforcing Ratio (ρ_{req})

When doing this calculation by hand, it is typical to use a table from ACI which assigns normalized capacity values (R_N) with reinforcing ratio values (ρ). The program uses a formula to find ρ_{req}.

<u>Hand Calculations</u>

$R_N = M_u / (\phi b d^2)$

$= [460 / (0.9 \cdot 12 \cdot 25.5^2)] \cdot 12000$

$= 786.02$ psi

From table –

$R_N = 789.3$ psi $\rightarrow \rho = 0.0152$

Result: $\rho_{req} = 0.0152$

When utilizing the table, it is acceptable to use the R_N value closest to the calculated value

<u>Code Implementation</u>

```
let Rn = (Mu*12000)/(0.9*b*d*d);
let preq = ((0.85*fc)/fy)*(1-sqrt(1-((2*Rn)/(0.85*fc))));
```

Using the equation finds $\rho_{req} = 0.0151167$. This is a more accurate result, but the difference in the table value and the equation value are so small that a hand calculated design and website output would most likely be the same.

These representative cases demonstrate the process of converting reinforced concrete analysis and design equations into automated calculations within the website. The calculators provide reliable outputs that mirror traditional hand methods.

Input Parameters and Output Results

Each calculator was designed with a consistent input structure to minimize user confusion or error. For all eight tools, drop down menus were used for compressive stress of concrete and yield stress of steel. This limits the users options, but it avoids the situations of unrealistic or invalid entries. Drop down menus are used in other instances where the user should be limited with their input values. Other numeric entries were placed in text boxes with units clearly labeled. Results are returned in a bold and unit-labeled format (e.g., "**ϕM_n = 322.89 k·ft**"). In design cases where multiple options were presented, the program displays them in tables or lists for easy comparison and selection. Graphs or diagrams are displayed after numeric outputs. The input parameters and output results were formatted in a way that prioritized clarity and user readability.

Accuracy and Limitations

The calculators were developed to closely follow the provisions of ACI 318 and were cross-checked against traditional hand calculations to confirm their accuracy. In all tested cases, the outputs matched expected values within a rounding tolerance. This demonstrates the reliability of the coding logic. The tested cases used did not cover any cases of extreme size or loading. These tools are intended for educational purposes and do not have the same abilities as professional-grade structural analysis software. The scope of the project was limited to specific beam and column cases taught at the undergraduate level. These limitations reflect a deliberate balance between usability, coding complexity, and project scope.

Challenges and Engineering Decisions

Coding Challenges

One of the most significant challenges in developing this project was learning entirely new programming languages. My prior coding experience was limited to MATLAB, so I was unfamiliar with JavaScript and HTML. I had learned the structural analysis and design equations and processes, but skills such as structuring the layout, styling the interface, and translating engineering formulas to code were all learned for the purpose of this project. To accelerate this process, I relied on AI software as a learning tool, which provided examples, explanations, and debugging help.

A particularly difficult aspect was producing a graphical output using Plotly.js. Because the diagram and graphs I needed to produce were irregular and dynamically based, it required extensive trial and error to correctly format for a proper display. This aspect of the project was time-intensive, but worth the effort. This output is essential for illustrating how changing input parameters influences the final beam design.

Engineering Decisions

Several key decisions shaped the scope and design of the calculators. For example, I chose to omit beam shear design as it is a process largely dependent on what the designer prefers. Additionally, the standards for shear design may be adjusted in the near future so the calculator would then be out of date. Another choice made was to only design short columns for concentric loading with accidental eccentricity rather than include more calculators for eccentric loading conditions. Decisions such as these allowed for a manageable and complete final product.

A reoccurring trade-off was usability versus complexity. There are more cases of beam and column analysis and design than what the tools present, but intentionally limiting them to common use cases allows for the best learning opportunities. It reduces error from both the user and on the coding side. The tools are easy to use and have the complexity necessary to produce accurate and informative results.

General Reflections

There were points during the design of the website where initial ideas had to be adjusted. For example, when creating the final column design diagrams, my first plan was to create a fully dynamic, plotted diagram with Plotly. However, the variability of the diagram would require many complex line equations which was impractical. Instead, I created non-dynamic diagrams with labeled variables, which communicated the final design in a neat and simpler way.

Overall, I am proud of how the tools look and function from a user experience standpoint. Engineering formulas dictated the math behind the outputs, but interface layout, spacing, labeling, and icon navigation were all design choices I had to make. I could have made the calculators in MATLAB, but it would have lacked in accessibility and aesthetics. The end result is a set of calculators that are technically accurate as well as easy to use.

Conclusion and Future Work

This project successfully delivered a functional website containing eight reinforced concrete calculators that reflect the principles of ACI 318. The tools feature a streamlined interface and produce reliable outputs that match traditional hand calculations. The following core objectives were achieved: to reinforce understanding of structural analysis and design principles, to practically apply programming skills, and to create a practical tool for both learning and preliminary design.

Several opportunities exist for future improvement and expansion of this product. For beams, additional calculators covering shear design and deflection would provide a more complete picture of their behavior and design. For columns, the addition of eccentric loading cases for short columns would better reflect real-world design conditions. Although CES4702 does not cover slab design, adding a calculator for this element would round out the necessary components for a simple structure. A further improvement to the existing calculators would be the inclusion of an automatically generated report that documents the intermediate calculations and assumptions, providing users with a look at the design process for their selected parameters. With these improvements, the project could expand from its initial scope and serve as both a teaching aid and a practical design resource.

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.

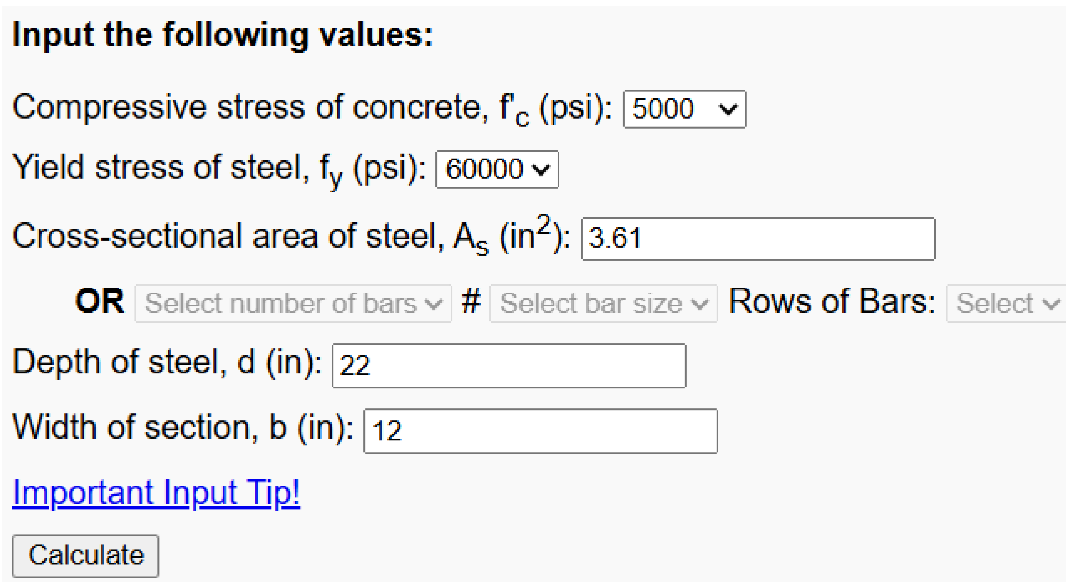
Singly Reinforced Beam (SRB) Analysis

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

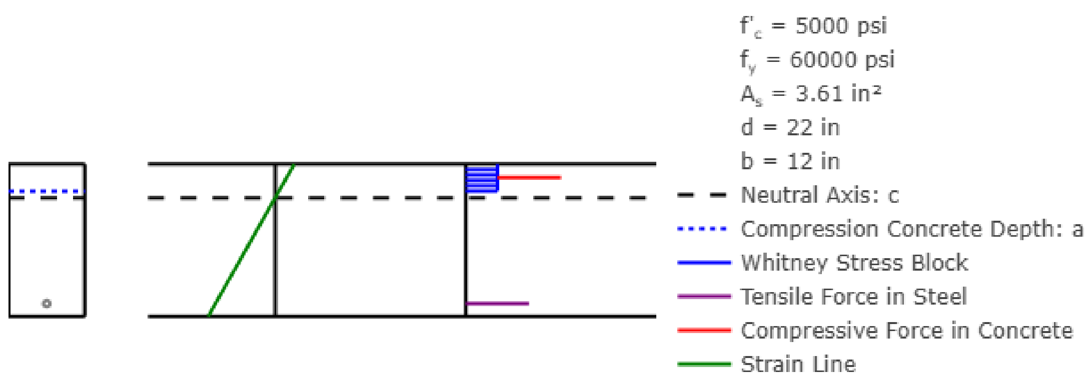
- **Depth to steel, d (in):** Measured to centroid of tension steel.
- **Beam width, b (in):** Rectangular section width.

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
β_1 = 0.80
c = 5.31 in
ε_t = 0.0094
Φ = 0.90, Ductile Section
Maximum internal moment: M_n = 358.77 k·ft
Usable/design capacity: ΦM_n = 322.89 k·ft
Steel reinforcing ratio: ρ = 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

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

$A_{s,min}$ check:

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

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

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

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

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

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

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

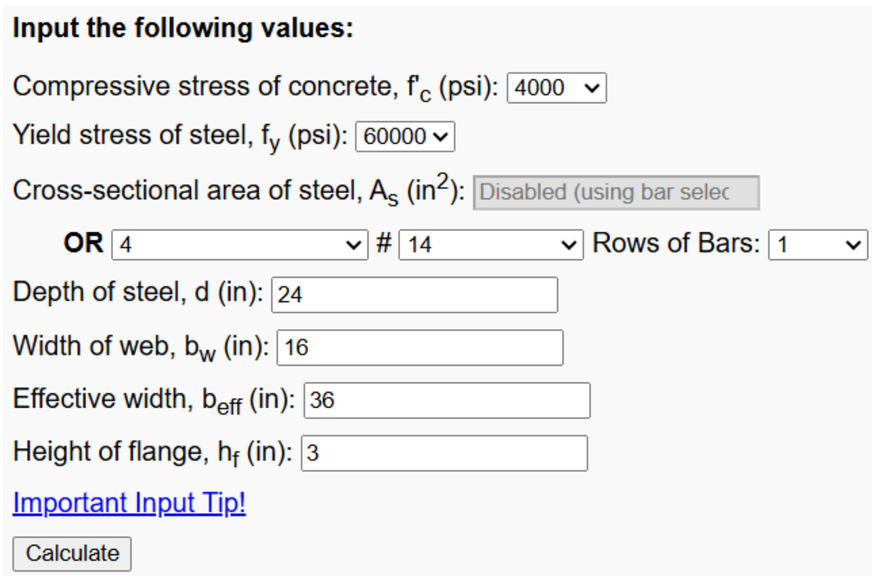
Singly Reinforced T-Beam Analysis

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

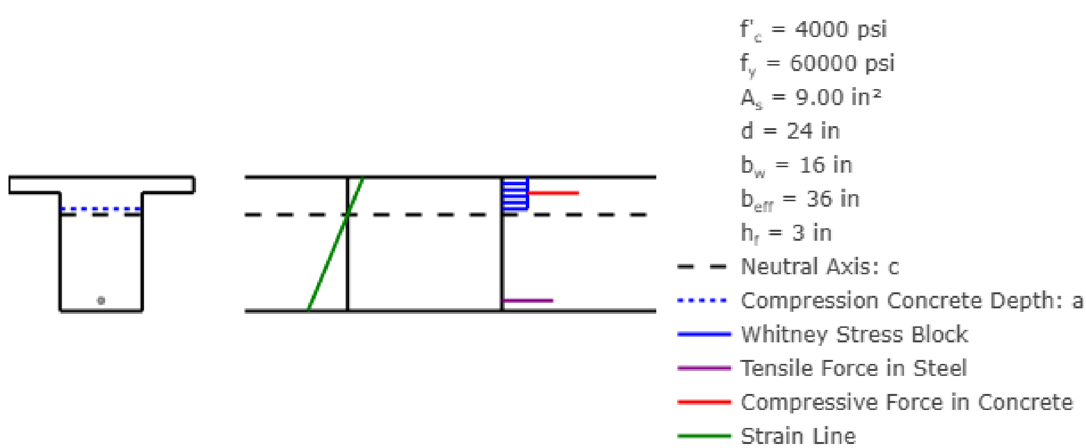
- **Depth to steel, d (in)**, measured to the centroid of the tension steel
- **Width of web, b_w (in)**
- **Effective flange width, b_{eff} (in)**
- **Height of flange, h_f (in)**

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 $\varepsilon_t \geq 0.005 \rightarrow$ **Ductile Section**, $\phi = 0.9$
   - If $0.004 \leq \varepsilon_t < 0.005 \rightarrow$ **Transition Zone**
   - If $\varepsilon_t < 0.004 \rightarrow$ 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

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

$\beta_1 = 0.85$

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

$A_{s,min}$ check:

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

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

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

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

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

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

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

Singly Reinforced T-Beam Analysis

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

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

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

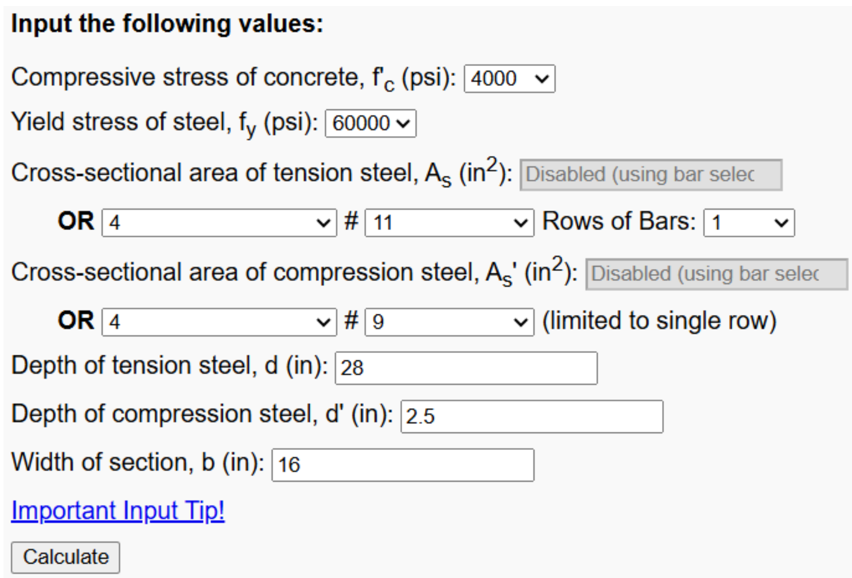
Doubly Reinforced Beam (DRB) Analysis

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

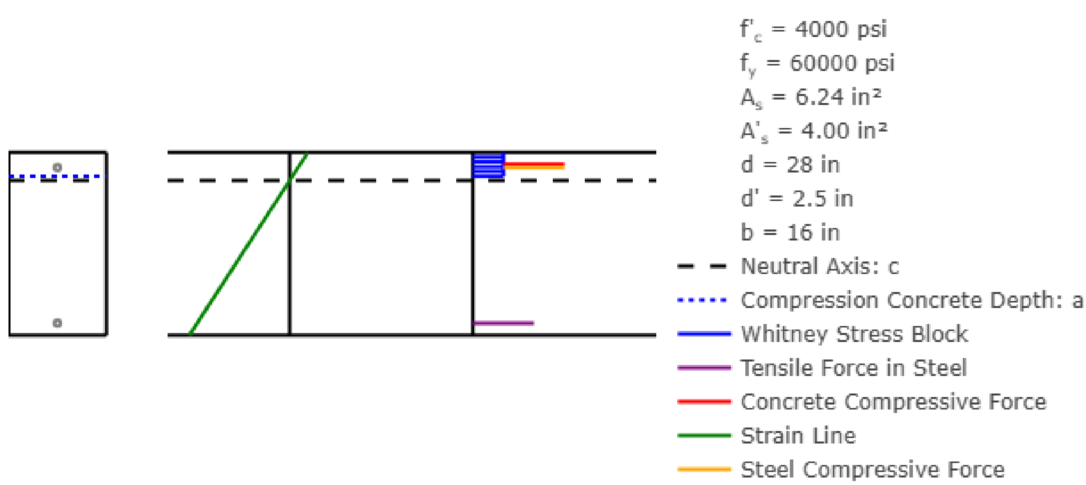
- **Depth to tension steel, d (in):** measured to the centroid of the tension steel
- **Depth to compression steel, d' (in):** measured to the centroid of the compression steel
- **Beam width, b (in):** rectangular section width

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

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 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 $\varepsilon_t \geq 0.005 \rightarrow$ **Ductile Section**, $\phi = 0.9$
   - If $0.004 \leq \varepsilon_t < 0.005 \rightarrow$ **Transition Zone**
   - If $\varepsilon_t < 0.004 \rightarrow$ 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

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

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

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

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

$T = C_c + C_s'$

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

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

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

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

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

$c_2 := 4.6394\ in$

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

Doubly Reinforced Beam (DRB) Analysis

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

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

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

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

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

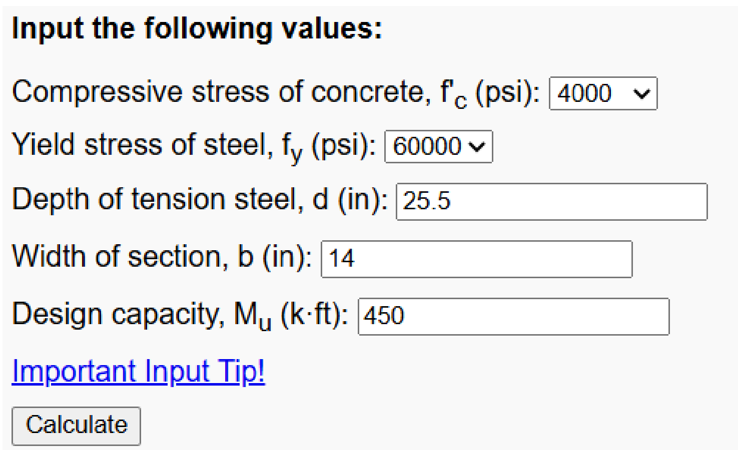
Singly Reinforced Beam (SRB) Design

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}

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

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

using ACI Table A.4 for bar size options

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

Analyze:

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

$\beta_1 = 0.85$

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

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

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

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

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

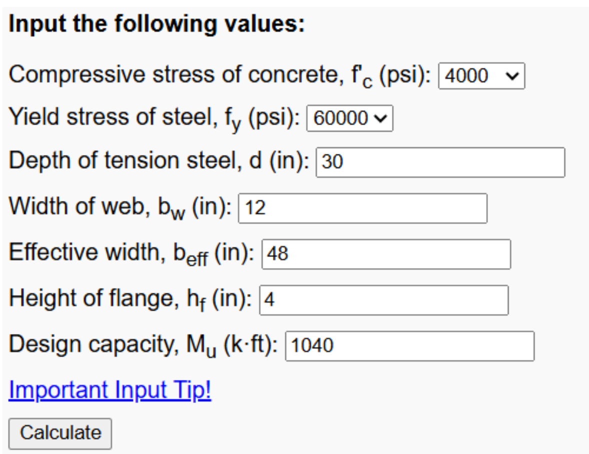
Singly Reinforced T-Beam Design

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



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.

Singly Reinforced T-Beam Design

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

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

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

Analyze:

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

$\beta_1 = 0.85$

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

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

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

so it is ductile

Singly Reinforced T-Beam Design

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

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

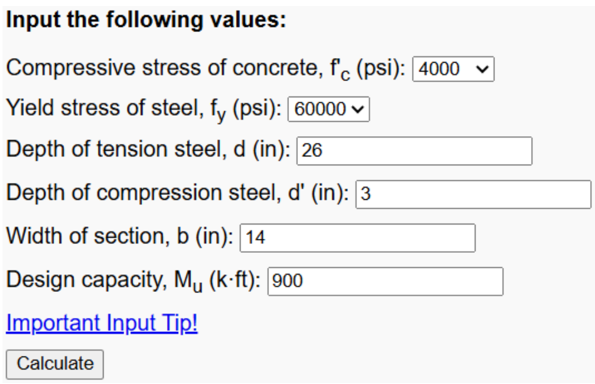
Doubly Reinforced Beam (DRB) Design

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



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

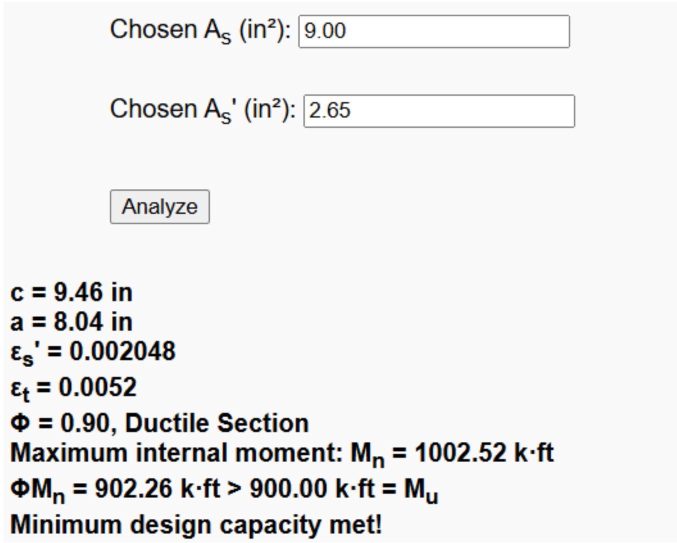
Bar Options:

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 $\quad d := 26 \; in \quad d' := 3 \; in \quad M_u := 900 \; k \cdot ft$

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

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

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

(must oversize to compensate for less steel)

Doubly Reinforced Beam (DRB) Design

Analyze:

assume $f'_s = f_y$

$T = C_c$

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

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

$T = C_c + C_s'$

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

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

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

$c := 9.45609 \quad in$

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

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

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

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

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

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

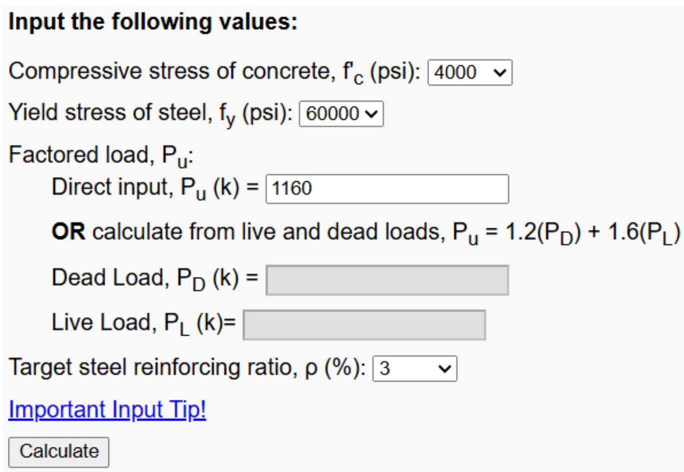
Square Column Design

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:

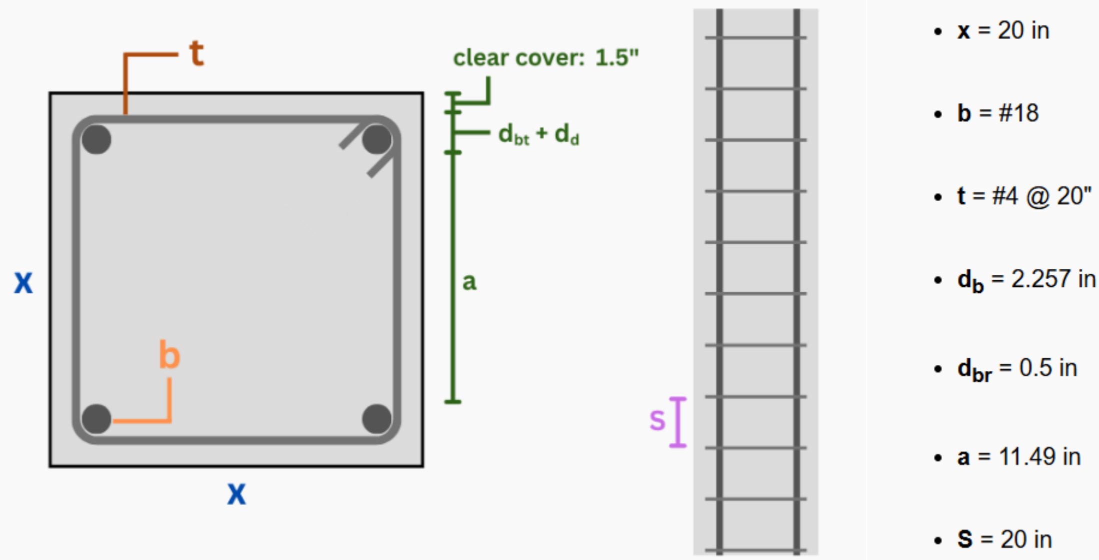
Select a Bar Option:

4 bars - #18 - 16 in² - 2.257 in

Step E – See Final Design

Final Design:

Steel Ratio, ρ: 4.00%
Axial Capacity, ΦP_n: 1178.11 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. **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%.

<u>Square Column Design</u>

Given:

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

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

Solution

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

$A_{g.} := 1.0$

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

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

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

$A_{s.} := 1.0$

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

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

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

$4 \ \#18 \quad A_{st} := 16 \ in^2 \quad \rho := \dfrac{A_{st}}{A_g} = 0.04$ 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

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

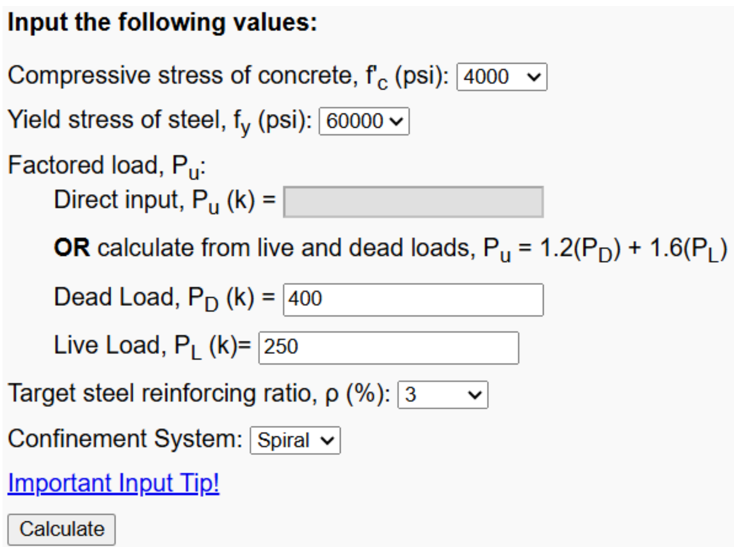
Circular Column Design

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



Input the following values:

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

Yield stress of steel, f_y (psi): 60000

Factored load, P_u:

Direct input, P_u (k) =

OR calculate from live and dead loads, $P_u = 1.2(P_D) + 1.6(P_L)$

Dead Load, P_D (k) = 400

Live Load, P_L (k)= 250

Target steel reinforcing ratio, ρ (%): 3

Confinement System: Spiral

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 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

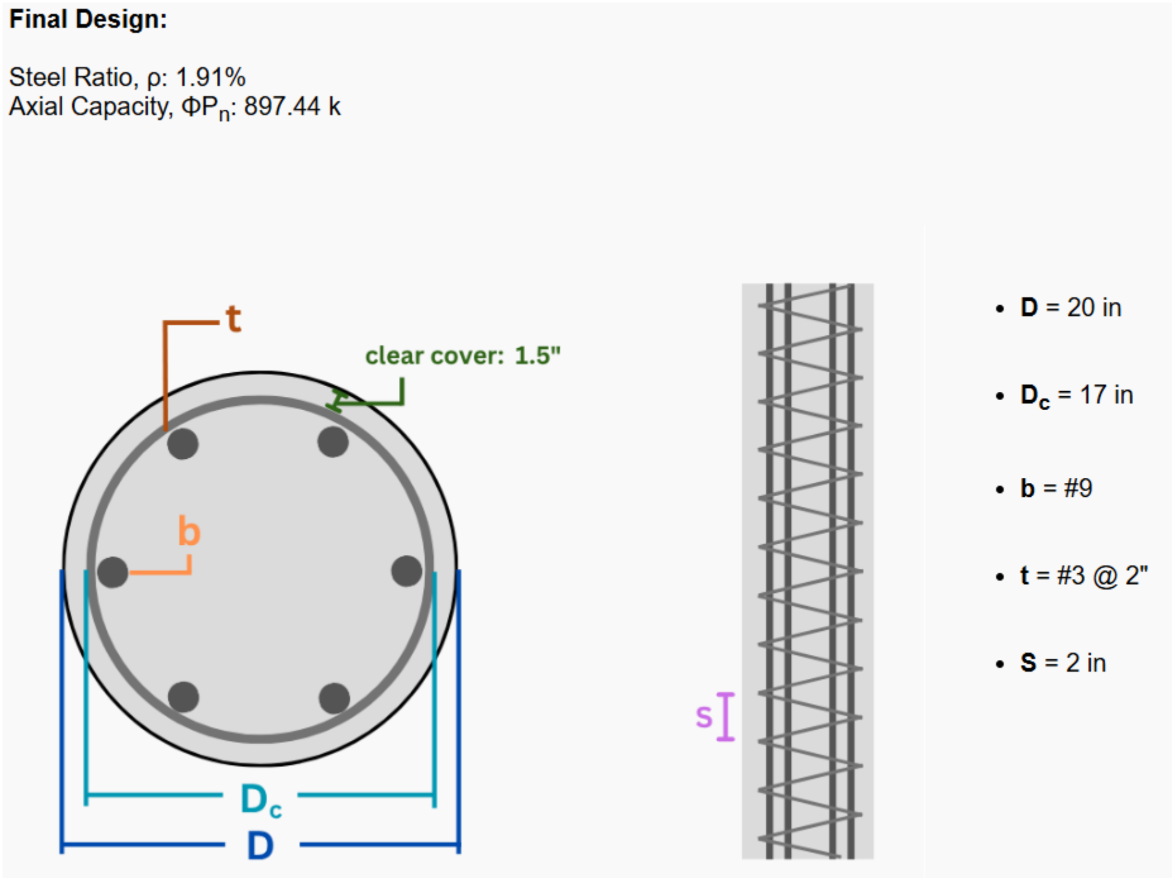
A minimum of four longitudinal bars of equal size is required in tied columns, and six in spiral columns.
Any additional bars beyond the minimum may be of a secondary size, provided they are symmetrically arranged.
Use Table 3 to make a different combination on your own.
This program can only continue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



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 $\quad P_D := 400 \quad k \quad \rho_{target} := 0.03 \quad (3\%)$

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

Solution

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

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

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

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

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

spiral design - #3 bars

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

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

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

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