This spreadsheet is intended to calculate the net axial confinement strengthening of FRP wraps applied to bridge columns. Reference document ACI 440.2R-08. Use of FRP wraps for axial confinement strengthening is not recommended for members featuring side aspect ratios $h/b$ greater than 2.0, or face dimensions $b$ or $h$ exceeding 36 in., unless testing demonstrates their effectiveness (ACI 12.1.2).

**Definition section - information from manufacturer's data sheets and bridge plans**

**Column Dimensions (Figure 12-3 from ACI 440.2R-08)**

![Diagram of column dimensions](image)

| ColumnType := | Circular | ColumnType = "Rectangular"
| ColumnType := | Rectangular |

**Inputs**

**FRP**

- $\varepsilon_f := 0.0167$ Fiber ultimate strain (in/in), provided by manufacturer
- $E_f := 33000000$ psi Fiber tensile modulus (psi), provided by manufacturer
- $n := 1$ number of FRP wraps, typically 2 but modified as needed
- $t_f := 0.0065$ in FRP thickness (in), provided by manufacturer
Concrete

\[ f'_c := 3500 \text{psi} \]

Concrete compressive strength (psi), substructure concrete MDOT Grade S2 is 3500 psi.

\[ \rho_g := 0.02 \]

Longitudinal steel reinforcement ratio assumed at 0.02

\[ \varepsilon'_c := 0.002 \]

Maximum strain of unconfined concrete corresponding to \( f'_c \), in./in; may be taken as 0.002

Column

\[ h := 60 \text{in} \]

Input \( h \) and \( b \) dimensions. Leave as default if circular column.

\[ b := 48 \text{in} \]

Corner radius typically 3 in, but manufacturer recommended value

\[ r_c := 3 \text{in} \]

Corner radius typically 3 in, but manufacturer recommended value

\[ D_c := 42 \text{in} \]

Input the circular column dimension. Leave as default if rectangular column.

\[ D := \sqrt{\frac{b^2 + h^2}{D_c}} \text{ if ColumnType = "Rectangular"} \]

ACI equation 12-8 for equivalent circular cross section

\[ D = 76.837 \text{ in} \]

\[ A_g := \begin{cases} b \cdot h & \text{if ColumnType = "Rectangular"} \\ \frac{\pi D^2}{4} & \text{otherwise} \end{cases} \]

Gross cross section area

\[ A_g = 2880 \text{ in}^2 \]

effective concrete confinement cross sectional area ratio \( \left( \frac{A_g}{A_c} \right) \) for non-circular shapes

This ratio is used for non-circular cross sections to calculate the appropriate shape factors, \( \kappa_a \) and \( \kappa_b \), which depend on the area of effectively confined concrete and the side-aspect ratio \( h/b \).

See ACI section 12.1.2.

\[ \text{EffectiveConfinementRatio} := \left[ 1 - \frac{3A_g}{1 - \rho_g} \right] \]

ACI equation 12-11
EffectiveConfinedmentRatio = 0.464

Shape Factors (non circular shapes). For circular shapes, ACI 12.1.2 specifies $\kappa_a$ and $\kappa_b$ set to 1.0

1. $\kappa_a := \begin{cases} \text{EffectiveConfinedmentRatio} \left( \frac{b}{h} \right)^2 & \text{if ColumnType} = \text{"Rectangular"}, \\ 1.0 & \text{otherwise} \end{cases}$

$\kappa_a = 0.297$

2. $\kappa_b := \begin{cases} \text{EffectiveConfinedmentRatio} \left( \frac{h}{b} \right)^{0.5} & \text{if ColumnType} = \text{"Rectangular"}, \\ 1.0 & \text{otherwise} \end{cases}$

$\kappa_b = 0.519$

FRP Strain efficiency factor, $\kappa_\varepsilon$

$\kappa_\varepsilon := 0.55$ Per ACI section 12.1

FRP effective strain at failure, $\varepsilon_{fe}$

$\varepsilon_{fu} := 0.85 \cdot \varepsilon_f$ FRP ultimate strain reduced by environmental factor of 0.85 per ACI table 9-1

$\varepsilon_{fe} := \begin{cases} \kappa_\varepsilon \cdot \varepsilon_{fu} & \text{if } \kappa_\varepsilon \cdot \varepsilon_{fu} < 0.004, \\ 0.004 & \text{otherwise} \end{cases}$ ACI Equation 12-12. Limited to ensure the shear integrity of the confined concrete.

$\varepsilon_{fe} = 0.004$

Maximum compressive strain in the confined concrete, $\varepsilon_{ccu}$

$f_i := \frac{2E_f \cdot n \cdot f_l \cdot \varepsilon_{fe}}{D}$ ACI equation 12-4

$f_i = 22.333 \text{ psi}$

$f_{cc} := f_c + 0.95 \cdot 3.3 \cdot \kappa_a \cdot f_i$ ACI equation 12-3

$f_{cc} = 3521 \text{ psi}$

$\varepsilon_{ccu} := \varepsilon_c \cdot \left[ 1.50 + 12 \kappa_b \left( \frac{f_i}{f_c} \cdot \left( \frac{\varepsilon_{fe}}{\varepsilon_c} \right)^{0.45} \right) \right]$ Note that $\varepsilon_{ccu}$ must be $\leq 0.01$ per ACI equation 12-7.
ConfinementRatio := \frac{f_l}{f_c}

ConfinementRatio = 0.006

ACI recommends the confinement ratio to be ≥ 0.08

Additional strength contribution of the FRP wrap

\phi := 0.65

axial compression strength reduction factor, \phi per ACI 318

\( P_{net} := 0.8 \cdot \phi \left[ 0.85 \left( f_{cc} - f_c \right) \cdot A_g \cdot (1 - \rho g) \right] \)

Modified from ACI equation 12-1b, to determine the net axial strength contribution of FRP

\( P_{net} = 25.9 \text{-kip} \)