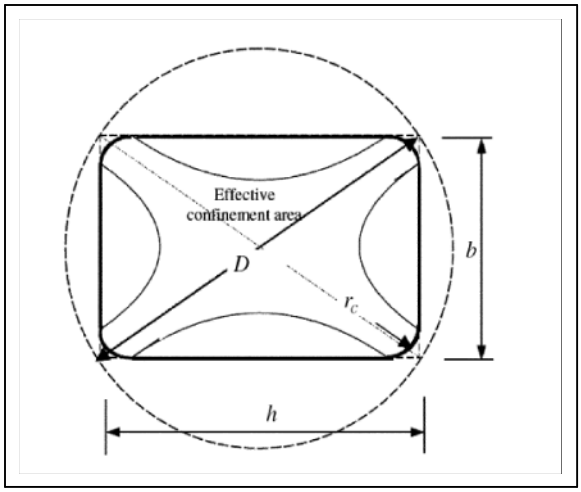
this spreadsheet is intended to calculate the net axial confinement strengthening of FRP wraps applied to bridge columns. Reference document ACI 440.2R-08. Use of FRP wraps for axial confinement strengthening is not recommended for members featuring side aspect ratios *h*/*b* greater than 2.0, or face 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)




ColumnType :=

Circular
Rectangular

ColumnType = "Rectangular"

Inputs

FRP

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

Concrete

$f'_c := 3500psi$ comcrete 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

$h := 60in$

$b := 48in$ Input h and b dimensions. leave as default if circular column.

$r_c := 3in$ corner radius typically 3 in, but manufacturer recommended value

$D_c := 42in$ input the circular column dimension. leave as default if rectangular column.

$$D := \begin{cases} \sqrt{b^2 + h^2} & \text{if ColumnType = "Rectangular"} \\ D_c & \text{otherwise} \end{cases}$$

ACI equation 12-8 for equivalent circular cross section

$D = 76.837\ in$

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

Gross cross section area

$A_g = 2880\ in^2$

effective concrete confinement cross sectional area ratio ($A_e/A_c$) 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.

$$EffectiveConfinementRatio := \frac{\left[1 - \frac{\left[\frac{b}{h} \cdot (h - 2r_c)^2 + \frac{h}{b} \cdot (b - 2r_c)^2\right]}{3A_g} - \rho_g\right]}{1 - \rho_g}$$

ACI equation 12-11

EffectiveConfinementRatio = 0.464

Shape Factors (non circular shapes). For circular shapes, ACI 12.1.2 specifies $\kappa_a$ and $\kappa_b$ set to 1

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

ACI Equation 12-9

$\kappa_a = 0.297$

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

ACI Equation 12-10

$\kappa_b = 0.519$

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, $\varepsilon_{ccu}$

$$f_l := \frac{2E_f \cdot n \cdot t_f \cdot \varepsilon_{fe}}{D}$$

ACI equation 12-4

$f_l = 22.333\,\text{psi}$

$$f'_{cc} := f'_c + 0.95 \cdot 3.3 \cdot \kappa_a \cdot f_l$$

ACI equation 12-3

$f'_{cc} = 3521\,\text{psi}$

$$\varepsilon_{ccu} := \varepsilon'_c \cdot \left[1.50 + 12\kappa_b \cdot \frac{f_l}{f'_c} \left(\frac{\varepsilon_{fe}}{\varepsilon'_c}\right)^{0.45}\right]$$

$\varepsilon_{ccu} = 0.003$ 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 $\geq$ 0.08

Additional strength contribution of the FRP wrap

$\phi := 0.65$

axial compression strength reduction factor, $\Phi$ per ACI 318

$$P_{net} := 0.8 \cdot \phi \cdot \left[ 0.85 \left( f'_{cc} - f'_c \right) \cdot A_g \cdot \left( 1 - \rho_g \right) \right]$$

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

$P_{net} = 25.9 \cdot kip$