Flexural Analysis of GFRP Decks with Fibers: Hybrid 1 and Hybrid 2

Scope: Analyze the Flexural Capacity of the Fiber Decks
Calculated by: Jared McRory

Assumptions and Analysis Criteria:

Slab Thickness: $t_{slab} := 203\ mm$ $c_c := 38.1\ mm$ (Clear Cover)

Width of Slab: $b_{slab} := 1219\ mm$

Reinforcement: $S_{bar} := 152\ mm$ $d_{bar} := 19\ mm$ $A_{bar} := \frac{\pi \cdot d_{bar}^{\ 2}}{4} = 283.529\ mm^2$

$F_{ult} := 825\ MPa$ $E_f := 56.5\ GPa$ $A_f := 6 \cdot A_{bar} = (1.701 \cdot 10^3)\ mm^2$

Concrete: $f'_c := 43.7\ MPa$

$\beta_1 := 0.85 - \left(\frac{f'_c - 4000\ psi}{1000\ psi}\right) \cdot 0.05 = 0.733$ $\varepsilon_{cu} := 0.003$

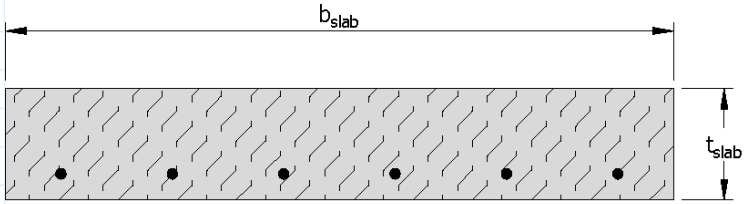
Fibers: $f_{ravg} := \frac{1.122}{3}\ MPa = 0.374\ MPa$

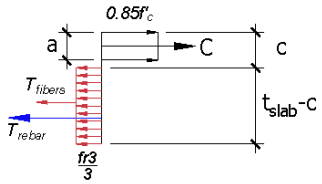
$d_2 := t_{slab} - \left(c_c + \frac{d_{bar}}{2}\right) = 155.4\ mm$

$\rho_f := \frac{A_f}{b_{slab} \cdot d_2} = 0.00898$ ACI 440.1R, Eq. 7.2.1a

$\rho_{fb} := 0.85 \cdot \beta_1 \cdot \frac{f'_c}{F_{ult}} \cdot \left(\frac{E_f \cdot 0.003}{E_f \cdot 0.003 + F_{ult}}\right) = 0.00563$ ACI 440.1R, Eq. 7.2.1b

$\rho_f > \rho_{fb}$ Therefore, Compression Controlled.





Guess a value for c: $c := 75 \cdot mm$

$\mathbf{c} := \mathbf{root}\left(A_f \cdot E_f \cdot \varepsilon_{cu} \cdot \left(\frac{d_2 - c}{c}\right) - 0.85 \cdot f'_c \cdot b_{slab} \cdot \beta_1 \cdot c + f_{ravg} \cdot (t_{slab} - c) \cdot b_{slab}, c\right) = 33.698\ mm$

$a := \mathbf{c} \cdot \beta_1 = 24.704\ mm$

$M_n := d_2 \cdot A_f \cdot E_f \cdot \varepsilon_{cu} \cdot \left(\frac{d_2 - \mathbf{c}}{\mathbf{c}}\right) - 0.85 \cdot f'_c \cdot b_{slab} \cdot \beta_1 \cdot \mathbf{c} \cdot 0.5 \cdot a + f_{ravg} \cdot (t_{slab} - \mathbf{c}) \cdot b_{slab} \cdot \left(t_{slab} - \frac{(t_{slab} - \mathbf{c})}{2}\right) = 157.15\ kN \cdot m$

Flexural Analysis of GFRP Decks with Fibers: Hybrid 3, Hybrid 2 million

Scope: Analyze the Flexural Capacity of the Fiber Decks
Calculated by: Jared McRory

Assumptions and Analysis Criteria:

Slab Thickness: $t_{slab} := 203\ mm$ $c_c := 38.1\ mm$ (Clear Cover)

Width of Slab: $b_{slab} := 1219\ mm$

Reinforcement: $S_{bar} := 152\ mm$ $d_{bar} := 19\ mm$ $A_{bar} := \frac{\pi \cdot d_{bar}^{\ 2}}{4} = 283.529\ mm^2$

$F_{ult} := 825\ MPa$ $E_f := 56.5\ GPa$ $A_f := 6 \cdot A_{bar} = (1.701 \cdot 10^3)\ mm^2$

Concrete: $f'_c := 40.5\ MPa$

$\beta_1 := 0.85 - \left(\frac{f'_c - 4000\ psi}{1000\ psi}\right) \cdot 0.05 = 0.756$ $\varepsilon_{cu} := 0.003$

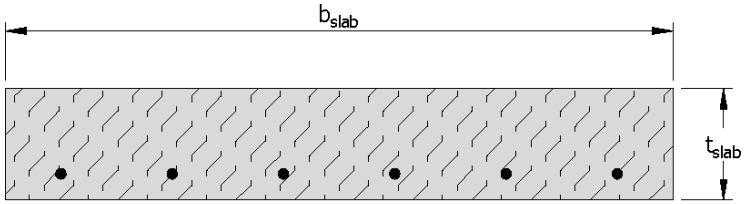
Fibers: $f_{ravg} := \frac{1.40}{3}\ MPa = 0.467\ MPa$

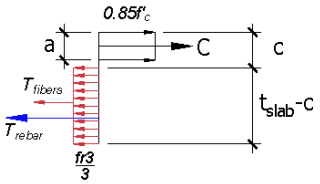
$d_2 := t_{slab} - \left(c_c + \frac{d_{bar}}{2}\right) = 155.4\ mm$

$\rho_f := \frac{A_f}{b_{slab} \cdot d_2} = 0.00898$ ACI 440.1R, Eq. 7.2.1a

$\rho_{fb} := 0.85 \cdot \beta_1 \cdot \frac{f'_c}{F_{ult}} \cdot \left(\frac{E_f \cdot 0.003}{E_f \cdot 0.003 + F_{ult}}\right) = 0.00538$ ACI 440.1R, Eq. 7.2.1b

$\rho_f > \rho_{fb}$ Therefore, Compression Controlled.





Guess a value for c: $c := 25 \cdot 3 \cdot mm$

$\mathbf{c} := \mathbf{root}\left(A_f \cdot E_f \cdot \varepsilon_{cu} \cdot \left(\frac{d_2 - c}{c}\right) - 0.85 \cdot f'_c \cdot b_{slab} \cdot \beta_1 \cdot c + f_{ravg} \cdot (t_{slab} - c) \cdot b_{slab}, c\right) = 34.663\ mm$

$a := \mathbf{c} \cdot \beta_1 = 26.216\ mm$

$M_n := d_2 \cdot A_f \cdot E_f \cdot \varepsilon_{cu} \cdot \left(\frac{d_2 - \mathbf{c}}{\mathbf{c}}\right) - 0.85 \cdot f'_c \cdot b_{slab} \cdot \beta_1 \cdot \mathbf{c} \cdot 0.5 \cdot a + f_{ravg} \cdot (t_{slab} - \mathbf{c}) \cdot b_{slab} \cdot \left(t_{slab} - \frac{(t_{slab} - \mathbf{c})}{2}\right) = 153.037\ kN \cdot m$

Flexural Analysis of GFRP Decks with Fibers: Hybrid 1 million

Scope: Analyze the Flexural Capacity of the Fiber Decks
Calculated by: Jared McRory

Assumptions and Analysis Criteria:

Slab Thickness: $t_{slab} := 203\ mm$ $c_c := 38.1\ mm$ (Clear Cover)

Width of Slab: $b_{slab} := 1219\ mm$

Reinforcement: $S_{bar} := 152\ mm$ $d_{bar} := 19\ mm$ $A_{bar} := \frac{\pi \cdot d_{bar}^{\ 2}}{4} = 283.529\ mm^2$

$F_{ult} := 825\ MPa$ $E_f := 56.5\ GPa$ $A_f := 6 \cdot A_{bar} = (1.701 \cdot 10^3)\ mm^2$

Concrete: $f'_c := 48.5\ MPa$

$\beta_1 := 0.85 - \left(\frac{f'_c - 4000\ psi}{1000\ psi}\right) \cdot 0.05 = 0.698$ $\varepsilon_{cu} := 0.003$

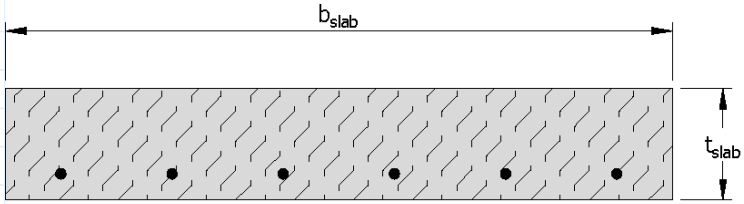
Fibers: $f_{ravg} := \frac{1.12}{3}\ MPa = 0.373\ MPa$

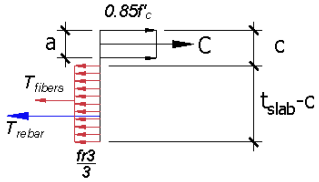
$d_2 := t_{slab} - \left(c_c + \frac{d_{bar}}{2}\right) = 155.4\ mm$

$\rho_f := \frac{A_f}{b_{slab} \cdot d_2} = 0.00898$ ACI 440.1R, Eq. 7.2.1a

$\rho_{fb} := 0.85 \cdot \beta_1 \cdot \frac{f'_c}{F_{ult}} \cdot \left(\frac{E_f \cdot 0.003}{E_f \cdot 0.003 + F_{ult}}\right) = 0.00595$ ACI 440.1R, Eq. 7.2.1b

$\rho_f > \rho_{fb}$ Therefore, Compression Controlled.





Guess a value for c: $c := 25 \cdot 3 \cdot mm$

$\mathbf{c} := \mathbf{root}\left(A_f \cdot E_f \cdot \varepsilon_{cu} \cdot \left(\frac{d_2 - c}{c}\right) - 0.85 \cdot f'_c \cdot b_{slab} \cdot \beta_1 \cdot c + f_{ravg} \cdot (t_{slab} - c) \cdot b_{slab}, c\right) = 32.855\ mm$

$a := \mathbf{c} \cdot \beta_1 = 22.942\ mm$

$M_n := d_2 \cdot A_f \cdot E_f \cdot \varepsilon_{cu} \cdot \left(\frac{d_2 - \mathbf{c}}{\mathbf{c}}\right) - 0.85 \cdot f'_c \cdot b_{slab} \cdot \beta_1 \cdot \mathbf{c} \cdot 0.5 \cdot a + f_{ravg} \cdot (t_{slab} - \mathbf{c}) \cdot b_{slab} \cdot \left(t_{slab} - \frac{(t_{slab} - \mathbf{c})}{2}\right) = 163.038\ kN \cdot m$

Flexural Analysis of Steel Reinforced Decks: Steel 1, Steel 2

Scope: Analyze the Flexural Capacity of the Fiber Decks
Calculated by: Jared McRory

Assumptions and Analysis Criteria:

Slab Thickness: $t_{slab} := 203\ mm$ $c_c := 38.1\ mm$ (Clear Cover)

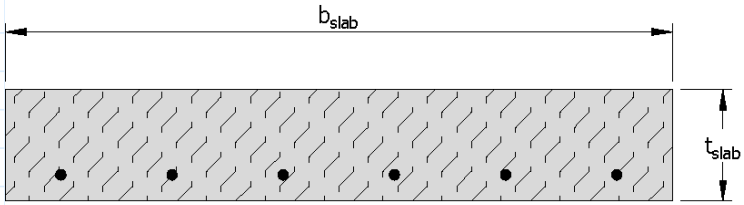
Width of Slab: $b_{slab} := 1219\ mm$

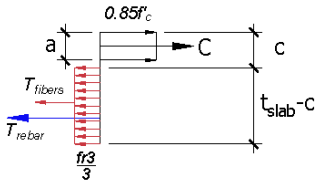
Reinforcement: $S_{bar} := 152\ mm$ $d_{bar} := 15.88\ mm$ $A_{bar} := \frac{\pi \cdot d_{bar}^{2}}{4} = 198.057\ mm^2$

$F_y := 490\ MPa$ $E_s := 221.2\ GPa$ $A_s := 8 \cdot A_{bar} = (1.584 \cdot 10^3)\ mm^2$

Concrete: $f'_c := 37\ MPa$

$\beta_1 := 0.85 - \left(\frac{f'_c - 4000\ psi}{1000\ psi}\right) \cdot 0.05 = 0.782$ $\varepsilon_{cu} := 0.003$





$d := t_{slab} - \left(c_c + \frac{d_{bar}}{2}\right) = 156.96\ mm$

$a := \frac{A_s \cdot F_y}{0.85 \cdot \beta_1 \cdot b_{slab} \cdot f'_c} = 25.907\ mm$

$M_n := A_s \cdot F_y \cdot \left(d - \frac{a}{2}\right) = 111.804\ kN \cdot m$

Flexural Analysis of Steel Reinforced Decks: Steel 1 and 2 Million

Scope: Analyze the Flexural Capacity of the Fiber Decks
Calculated by: Jared McRory

Assumptions and Analysis Criteria:

Slab Thickness: $t_{slab} := 203\ mm$ $c_c := 38.1\ mm$ (Clear Cover)

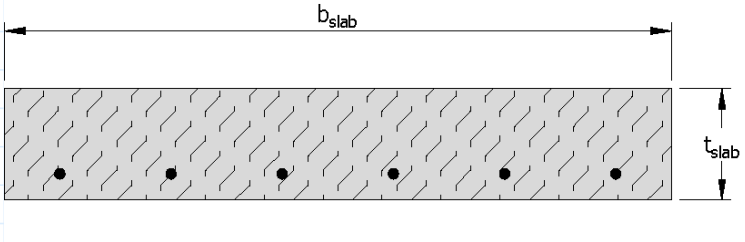
Width of Slab: $b_{slab} := 1219\ mm$

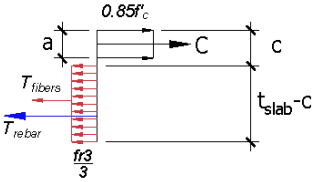
Reinforcement: $S_{bar} := 152\ mm$ $d_{bar} := 15.88\ mm$ $A_{bar} := \frac{\pi \cdot d_{bar}^{2}}{4} = 198.057\ mm^2$

$F_y := 490\ MPa$ $E_s := 221.2\ GPa$ $A_s := 8 \cdot A_{bar} = (1.584 \cdot 10^3)\ mm^2$

Concrete: $f'_c := 37.5\ MPa$

$\beta_1 := 0.85 - \left(\frac{f'_c - 4000\ psi}{1000\ psi}\right) \cdot 0.05 = 0.778$ $\varepsilon_{cu} := 0.003$





$d := t_{slab} - \left(c_c + \frac{d_{bar}}{2}\right) = 156.96\ mm$

$a := \frac{A_s \cdot F_y}{0.85 \cdot \beta_1 \cdot b_{slab} \cdot f'_c} = 25.681\ mm$

$M_n := A_s \cdot F_y \cdot \left(d - \frac{a}{2}\right) = 111.892\ kN \cdot m$

Flexural Analysis of GFRP Reinforced Decks: GFRP 1 and GFRP 2

Scope: Analyze the Flexural Capacity of the Fiber Decks
Calculated by: Jared McRory

Assumptions and Analysis Criteria:

Slab Thickness: $t_{slab} := 203\ mm$ $c_c := 38.1\ mm$ (Clear Cover)

Width of Slab: $b_{slab} := 1219\ mm$

Reinforcement: $S_{bar} := 152\ mm$ $d_{bar} := 19.05\ mm$ $A_{bar} := \frac{\pi \cdot d_{bar}^2}{4} = 285.023\ mm^2$

$F_{ult} := 825\ MPa$ $E_f := 56.5\ GPa$ $A_f := 8 \cdot A_{bar} = (2.28 \cdot 10^3)\ mm^2$

Concrete: $f'_c := 46.5\ MPa$

$\beta_1 := 0.85 - \left(\frac{f'_c - 4000\ psi}{1000\ psi}\right) \cdot 0.05 = 0.713$ $\varepsilon_{cu} := 0.003$

$d_2 := t_{slab} - \left(c_c + \frac{d_{bar}}{2}\right) = 155.375\ mm$

$\rho_f := \frac{A_f}{b_{slab} \cdot d_2} = 0.012039$ ACI 440.1R, Eq. 7.2.1a

$\rho_{fb} := 0.85 \cdot \beta_1 \cdot \frac{f'_c}{F_{ult}} \cdot \left(\frac{E_f \cdot 0.003}{E_f \cdot 0.003 + F_{ult}}\right) = 0.00582$ ACI 440.1R, Eq. 7.2.1b

$\rho_f > \rho_{fb}$ Therefore, Compression Controlled.

$f_f := \sqrt{\frac{(E_f \cdot 0.003)^2}{4} + \frac{0.85 \cdot \beta_1 \cdot f'_c}{\rho_f} \cdot E_f \cdot 0.003} - 0.5 \cdot E_f \cdot 0.003 = 550.735\ MPa$ ACI 440.1R, Eq. 7.2.2d

$a := \frac{A_f \cdot f_f}{0.85 \cdot f'_c \cdot b_{slab}} = 26.064\ mm$ ACI 440.1R, Eq. 7.2.2b

$M_n := A_f \cdot f_f \cdot \left(d - \frac{a}{2}\right) = 180.742\ kN \cdot m$ ACI 440.1R, Eq. 7.2.2a

Flexural Analysis of GFRP Reinforced Decks: GFRP 1 and 2 million

Scope: Analyze the Flexural Capacity of the Fiber Decks
Calculated by: Jared McRory

Assumptions and Analysis Criteria:

Slab Thickness: $t_{slab} := 203\ mm$ $c_c := 38.1\ mm$ (Clear Cover)

Width of Slab: $b_{slab} := 1219\ mm$

Reinforcement: $S_{bar} := 152\ mm$ $d_{bar} := 19.05\ mm$ $A_{bar} := \frac{\pi \cdot d_{bar}^2}{4} = 285.023\ mm^2$

$F_{ult} := 825\ MPa$ $E_f := 56.5\ GPa$ $A_f := 8 \cdot A_{bar} = (2.28 \cdot 10^3)\ mm^2$

Concrete: $f'_c := 50.95\ MPa$

$\beta_1 := 0.85 - \left(\frac{f'_c - 4000\ psi}{1000\ psi}\right) \cdot 0.05 = 0.681$ $\varepsilon_{cu} := 0.003$

$d_2 := t_{slab} - \left(c_c + \frac{d_{bar}}{2}\right) = 155.375\ mm$

$\rho_f := \frac{A_f}{b_{slab} \cdot d_2} = 0.012039$ ACI 440.1R, Eq. 7.2.1a

$\rho_{fb} := 0.85 \cdot \beta_1 \cdot \frac{f'_c}{F_{ult}} \cdot \left(\frac{E_f \cdot 0.003}{E_f \cdot 0.003 + F_{ult}}\right) = 0.00609$ ACI 440.1R, Eq. 7.2.1b

$\rho_f > \rho_{fb}$ Therefore, Compression Controlled.

$f_f := \sqrt{\frac{(E_f \cdot 0.003)^2}{4} + \frac{0.85 \cdot \beta_1 \cdot f'_c}{\rho_f} \cdot E_f \cdot 0.003} - 0.5 \cdot E_f \cdot 0.003 = 564.96\ MPa$ ACI 440.1R, Eq. 7.2.2d

$a := \frac{A_f \cdot f_f}{0.85 \cdot f'_c \cdot b_{slab}} = 24.402\ mm$ ACI 440.1R, Eq. 7.2.2b

$M_n := A_f \cdot f_f \cdot \left(d - \frac{a}{2}\right) = 186.481\ kN \cdot m$ ACI 440.1R, Eq. 7.2.2a