Assignment #7

Select a Vulcraft composite deck to support 150 psf service live load on a 10 ft clear span. The steel deck is to be used on a three-span condition and shoring is not permitted. Use normal weight concrete with f'c = 3000 psi

Selected Deck: 2VLI17 - Note: If you used a different deck, use mathcad sheet to enter your information and check answer.

Allowable Live Load given in table on pg 46 = 157 psf. This is greater than the specified 150 psf. The construction clear span for a 3-span condition is 13'-0" which is greater than the specified 10 ft. Deck is OK

Properties:

- D := 4-in
- t := 2 in
- W1 := 39 psf
- L := 10 ft
- Sp := 0.589 in^3/ft
- Sn := 0.589 in^3/ft
- Ip := 0.633 in^4/ft
- In := 0.633 in^4/ft
- Fy := 40 ksi
- Fballow := 0.6 Fy
- Fballow = 24 ksi or 36 ksi (whichever is less)

#1) Check construction SDI criteria for the steel deck selected

Define loads

- W1 = slab weight + deck weight
  - W1 = 39 psf Chart on pg 46

- W2 = 20 psf construction load
  - W2 := 20 psf Sec 3.2a

- P1 = 150 lb concentrated load
  - P1 := 150 lb Sec 3.2a

For the 3-span Stress check- 3 cases on page 56

Case 1

positive moment

\[ M1 := \left[ (0.20 \cdot P1 \cdot L) + 0.094 \cdot W1 \cdot L^2 \right] \]

\[ M1 = 666.6 \text{ lb*ft} \]

Positive Moment Stress

\[ fb1 := \frac{M1 \cdot 12}{Sp \cdot 1000} \]

\[ fb1 = 13.58 \text{ ksi} \]

\[ fb1 = 13.581 \text{ ksi} < Fballow = 24 \text{ ksi} \text{ OK} \]

Case 2

positive moment

\[ M2 := 0.094 \cdot (W1 + W2) \cdot L^2 \]

\[ M2 = 554.6 \text{ lb*ft} \]

Positive Moment Stress

\[ fb2 := \frac{M2 \cdot 12}{Sp \cdot 1000} \]

\[ fb2 = 11.3 \text{ ksi} \]
Fall 05

\[ fb_2 = 11.299 \text{ ksi} < F_{allow} = 24 \text{ ksi} \quad \text{OK} \]

**Case 3**

negative moment

\[ M_3 := 0.117 \cdot (W_1 + W_2) \cdot L^2 \]

\[ M_3 = 690.3 \text{ lb*ft} \]

negative Moment Stress

\[ fb_3 := \frac{M_3 \cdot 12}{S_n \cdot 1000} \]

\[ fb_3 = 14.06 \text{ ksi} \]

\[ fb_3 = 14.064 \text{ ksi} < F_{allow} = 24 \text{ ksi} \quad \text{OK} \]

Check Deflection for 3-span (pg 56)

\[ E := 29000000 \text{ psi} \]

\[ \Delta 1 := \frac{W_1 \cdot L^4}{E \cdot I_p \cdot 1728} \]

\[ \Delta 1 = 0.253 \text{ in} \]

Allowable Deflection

\[ \Delta_{allow} := \frac{L \cdot 12}{180} \]

\[ \Delta_{allow} = 0.667 \text{ in} \]

which is less than 3/4"

\[ \Delta 1 = 0.253 \text{ in} < \Delta_{allow} = 0.667 \text{ in} \]

\[ \text{Therefore deflection is OK} \]

#2) Determine the maximum stress (forwork stress plus composite section stress) in the steel deck under service load

Find area of steel in 1 ft section

\[ t_s := 0.0538 \text{ in} \]

From given geometry on pg 46

\[ l_s := 2 \cdot 2.5 \text{ in} + 2 \cdot 2.24 \text{ in} + 5 \text{ in} \]

\[ l_s = 14.48 \text{ in} \]

Area of steel

\[ A_s := t_s \cdot l_s \]

\[ A_s = 0.779 \text{ in}^2 \]

Mod. Ratio

\[ n := 9 \]

Given on pg 46

\[ y_{c.g.s} := \frac{l_p}{S_p} \cdot 1 \text{ in} \]

\[ y_{c.g.s} = 1.075 \text{ in} \]

Transform cracked concrete section to equivalent steel

\[ b := 12 \text{ in} \]

\[ b_{eff} := \frac{b}{n} \]

\[ b_{eff} = 1.333 \text{ in} \]

Sum areas about the cracked neutral axis to determine location of \( y \) cracked

set initial value for \( y_c \) to use in Given/Find function

\[ y_c := 1 \text{ in} \]

Given

\[ b_{eff} \cdot y_c \cdot \frac{y_c}{2} - A_s \left( D - y_c - y_{c.g.s} \right) = 0 \]

\[ y_c := \text{Find}(y_c) \]
Determine if cracked of section (Parallel Axis Theorem)

\[ I_{cr} := \frac{b_{eff} y_c^3}{3} + I_p + A_s (D - y_{c.g.s} - y_c)^2 \]

\[ I_{cr} = 3.66 \text{ in}^4 \]

Calculate maximum tensile stress in deck due to live load only

From table on pg 46

\[ w_{ll} := 150 \frac{\text{lbf}}{\text{ft}} \text{ per foot} \]

\[ M_{ll} := \frac{w_{ll} L^2}{8} \]

\[ M_{ll} = 1875 \text{lbf} \cdot \text{ft} \quad \text{M}_{ll} = 22500 \text{lbf} \cdot \text{in} \]

\[ f_{\text{deckll}} := \frac{M_{ll} (D - y_c)}{I_{cr}} \]

\[ f_{\text{deckll}} = 16.264 \text{ ksi} < F_{\text{allow}} = 24 \text{ ksi} \quad \text{OK} \]

Check the maximum tensile locked formwork stress in the deck due to dead load

\[ W_1 = 39 \frac{\text{lbf}}{\text{ft}} \text{ per foot} \]

\[ M_{dl} := 0.08 \cdot W_1 \cdot L^2 \]

Maximum Moment equation for 3-span beam with only concrete weight uniformly distributed everywhere.

\[ M_{dl} = 312 \text{lbf} \cdot \text{ft} \]

\[ f_{\text{deckdl}} := \frac{M_{dl}}{S_p} \]

\[ f_{\text{deckdl}} = 6.357 \text{ ksi} \]

Total stress on deck

\[ f_{\text{total}} := f_{\text{deckll}} + f_{\text{deckdl}} \]

\[ f_{\text{total}} = 22.6 \text{ ksi} \quad \sim = \quad F_{\text{allow}} = 24 \text{ ksi} \quad \text{OK} \]

#3) Determine the necessary temperature and shrinkage reinforcement.

See section 5.5 for SDI criteria (pg 54)

\[ A_{\text{req}} := 0.00075 \cdot \text{t} \cdot \text{12-in} \]

\[ A_{\text{req}} = 0.018 \text{ in}^2 \text{ per foot} \]

Can not be less than area of 6x6 W1.4 x W1.4

\[ A_{6x6} := 0.014 \cdot \text{in}^2 \cdot \text{2} \]

\[ A_{6x6} = 0.028 \text{ in}^2 \text{ per foot} \]

Must use minimum of 6x6 W1.4 x W1.4 to meet criteria

This section is also recommended on table pg 47
#4) Design negative moment reinforcement to provide continuity and control cracking

Live Load factor \( ll := 1.7 \)

Negative Moment over support for 3 spans \( M_{\text{neg}} := \frac{ll \cdot w \cdot L^2}{12} \)

\[ M_{\text{neg}} = 2125 \text{ lbf} \cdot \text{ft} \]

Find moment capacity of slab (per foot width)

**Flexure Negative Moment - Compression on Bottom, Tension on Top**

Yield of Steel \( f_y := 60 \text{ ksi} \)

Concrete comp. strength \( f_c := 3 \text{ ksi} \)

Width \( b_{\text{comp}} := 5 \text{ in} \) area of concrete on bottom in compression (see geometry of deck)

Assume #3 bars \( d_b := 0.375 \text{ in} \) \( A_{\text{bar}} := \frac{\pi \cdot d_b^2}{4} \)

\[ A_{\text{bar}} = 0.11 \text{ in}^2 \] per foot width

Cover \( c := 0.75 \text{ in} \)

Distance to compression face \( D := D - c - \frac{d_b}{2} \)

**Sum of forces in horizontal direction = 0** \( C=T \)

\[ C = 0.85 f_c a b \quad T = A_s f_y \]

Find value of \( a \)

\[ a_1 := \frac{A_{\text{bar}} f_y}{0.85 f_c b_{\text{comp}}} \quad a_1 = 0.52 \text{ in} \] compression zone in concrete

Sum of moments = 0 \( \sum \text{ moments about C} \)

Force \( T_1 := A_{\text{bar}} f_y \)

Distance \( z_1 := d_1 - \frac{a_1}{2} \quad z_1 = 2.803 \text{ in} \)

Determine minimum required area of steel for negative moment \( M_{\text{neg}} = 2125 \text{ lbf} \cdot \text{ft} \)

\[ M_{\text{n1}} := T_1 \cdot z_1 \quad M_{\text{n1}} = 1547.703 \text{ lbf} \cdot \text{ft} \]

Factored Nominal Capacity \( \phi := 0.9 \) ACI 318 factor for flexure

\[ A_{\text{req}} := 1 \text{ in}^2 \]

Given

\[ \phi A_{\text{req}} f_y \left( d_1 - \frac{a_1}{2} \right) = M_{\text{neg}} \]

\[ A_{\text{req}} := \text{Find}\left( A_{\text{req}} \right) \]
\[
A_{\text{req}} = 0.168 \text{ in}^2 \quad \text{per foot width} \quad \text{# of bars per foot width} \quad \frac{A_{\text{req}}}{A_{\text{bar}}} = 1.526
\]

Need # 3 bars at 6" spacing
psf := \frac{\text{lbf}}{\text{ft}^2}
\[ L := L \cdot 1 \cdot \text{ft} \]
\[ W := W \cdot \frac{\text{lb}f}{\text{ft}} \]
\[ S := S \cdot \text{in}^3 \]
\[ t := t \cdot \text{in} \]
Area of steel (per foot) \[ A_s := 0.087 \text{ in}^2 \]