Concrete Deck design - Flexure in Overhang

Bridge deck overhangs is designed to satifsay the following three different design cases.
1. Horisontal vehicular collision force
2. Vertical vehicular collision force
3. Dead and Live loads

This document shows how to analyze the design for 1st desgin case, based on FHWA LRFD Steel Bridge Design Example.

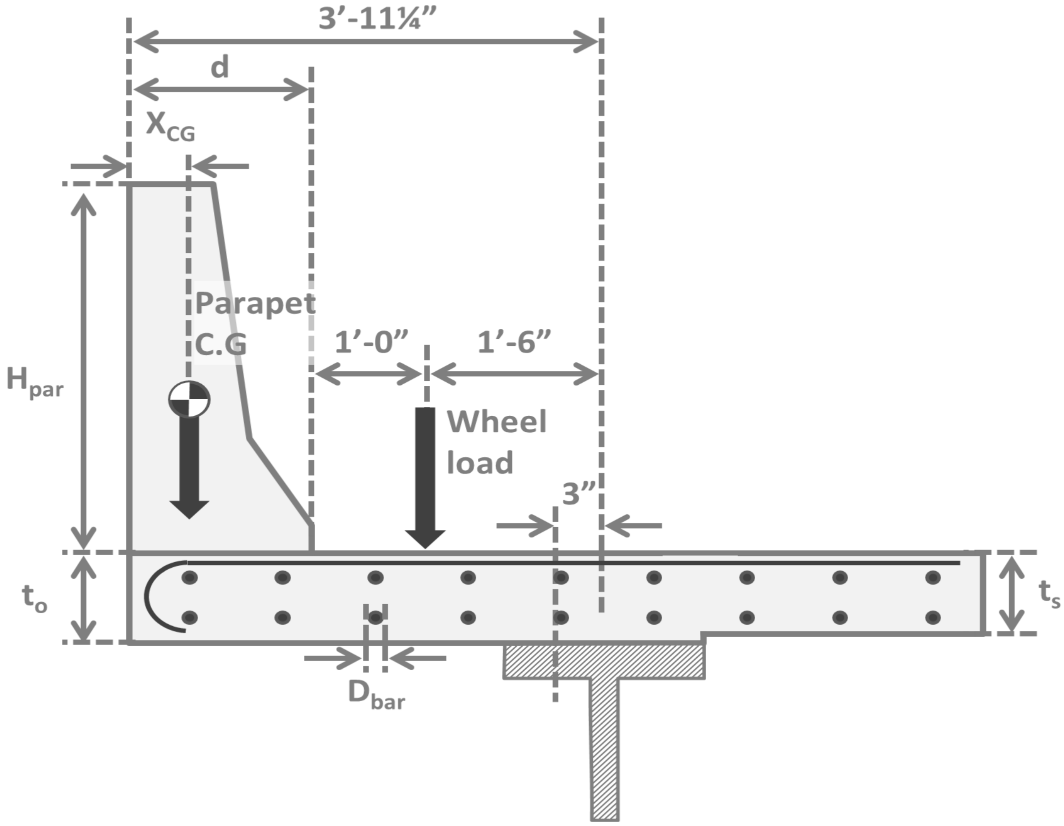

Figure 1 : Deck overhang dimensions and Live loads

References:
- (Spec) : AASHTO LRFD Bridge Design Specification
- (Manual) : Load and Resistance Factor Design (LRFD) for Highway Bridge Superstructures
    - (Exam) : Design Examples

Desin parameters

Deck geometries

Deck top cover $Cover_t := 2.5\ \mathbf{inch}$

Reference : Spec-Table 5.12.3-1

Deck bottom cover $Cover_b := 1.0\ \mathbf{inch}$

Reference: Spec-Table 5.12.3-1

Overhang thickness $t_o := 9\ \mathbf{inch}$

Slab thickness $t_s := 8.5\ \mathbf{inch}$

bar diameter $D_{bar} := 0.625\ \mathbf{inch}$

bar area $A_{bar} := \left(\frac{D_{bar}}{2}\right)^2 \cdot \pi = 0.307\ \mathbf{in}^2$

Width at parapet base $d := 1\mathbf{ft} + 5.25\ \mathbf{inch} = 1.438\ \mathbf{ft}$

Weight per foot $W_{par} := 0.53\ \frac{1000 \cdot \mathbf{lb}}{\mathbf{ft}}$

Parapet height $H_{par} := 3.5\ \mathbf{ft}$

Parapet properties

Moment capacity at base $M_{co} := 28.21\ \frac{1000 \cdot \mathbf{lb} \cdot \mathbf{ft}}{\mathbf{ft}}$

Parapet center of gravity $X_{CG} := 6.16\ \mathbf{inch}$

Reinforment properties

Reinforced Concrete density $w_c := 0.150 \dfrac{1000\cdot lb}{ft^3}$

Concrete 28-day compressive strength (Type A (AE)) $f_c := 4.0 \dfrac{1000\cdot lb}{inch^2}$

Reference: Spec-Table C.5.4.2.1-1

Reinforcement strength $f_y := 60 \dfrac{1000\cdot lb}{inch^2}$

Reference: Spec-5.4.3

Factors for Extreme event limit state

Resistance factor $\phi_{ext} := 1.0$

Reference : Spec-1.2.3.1

Load factor for Permanent loads $\gamma_{pDC} := 1.25$

Reference : Spec-Table 3.4.1-2

Vehicular collision and Dead load moment

Dead load moment of Deck $M_{DC\_deck} := \gamma_{pDC}\cdot\dfrac{w_c\cdot t_o\cdot d^2}{2} = 0.145\cdot 1000\ lb$

Dead load moment of Parapet $M_{DC\_par} := \gamma_{pDC}\cdot W_{par}\cdot\left(d - X_{CG}\right) = 0.612\cdot 1000\ lb$

Total design factored moment $M_{total} := M_{co} + M_{DC\_deck} + M_{DC\_par}$

$M_{total} = 28.968\cdot 1000\ lb$

Critical wall length, Total transverse resistance and Tensile force

Critical wall length over which the yield line machanism occurs
Reference : Spec-A13.3.1-2

$$L_c := \frac{L_t}{2} + \sqrt{\left(\frac{L_t}{2}\right)^2 + \frac{8 \cdot H_{par} \cdot (M_b + M_w)}{M_c}}$$

Total transverse resistance of the railing
Reference : Spec-A13.3.1-1

$$R_w := \left(\frac{2}{2 \cdot L_c - L_t}\right) \cdot \left(8 \cdot M_b + 8 \cdot M_w + \frac{M_c \cdot L_c^{\,2}}{H_{par}}\right)$$

In order to obtain the above values, use the following conditions which are given in the reference (Design Examples).

Longitudinal length of distribution of impact force $\quad L_t := 4\ \mathbf{ft}$

Additional flexural resistance of beam in addition to M_w $\quad M_b := 0\ \mathbf{1000 \cdot lb \cdot ft}$

Flexural resistance of the wall about an axis parallel to the longitudinal axis of the bridge $\quad M_c := 16.00\ \frac{\mathbf{1000 \cdot lb \cdot ft}}{\mathbf{ft}}$

Flexural reistance of the wall about its vertical asis $\quad M_w := 18.52\ \mathbf{1000 \cdot lb \cdot ft}$

Thus, the following can be obtained.

Critical wall length $\quad L_c = 8.034\ \mathbf{ft}$

Total transverse resistance $\quad R_w = 73.454 \cdot \mathbf{1000\ lb}$

Axial tensile force
Reference : Spec-A13.4.2

$$T := \frac{R_w}{L_c + 2 \cdot H_{par}} = 4.886\ \frac{\mathbf{1000\ lb}}{\mathbf{ft}}$$

Area of steel

$$d_e := t_o - Cover_t - \frac{D_{bar}}{2} = 6.188\ \mathbf{in}$$

Effective depth

Witdh of the compression face $b := 12\ \mathbf{inch}$

$$R_n := \frac{M_{total} \cdot 12\ \mathbf{inch}}{\phi_{ext} \cdot b \cdot d_e^{\,2}} = 0.757\ \frac{\mathbf{1000\ lb}}{\mathbf{in^2}}$$

Coefficient of resistance

$$\rho := 0.85 \cdot \left(\frac{f_c}{f_y}\right) \cdot \left(1.0 - \sqrt{1.0 - \frac{2 \cdot R_n}{0.85 \cdot f_c}}\right) = 0.014$$

Reinforcement ratio

$$A_s := \rho \cdot \frac{b}{\mathbf{ft}} \cdot d_e = 1.073\ \frac{\mathbf{in^2}}{\mathbf{ft}}$$

Required Area of steel

In order to satisfy the above required area, use two #5 bar bundled at 6.0 inches

Area of steel $$A_s := \frac{2 \cdot \left(0.31\ \mathbf{inch^2}\right)}{\left(6\ \mathbf{inch}\right)} = 1.240\ \frac{\mathbf{in^2}}{\mathbf{ft}}$$

Check the moment resistance

Tension in reinforcement $T_a := A_s \cdot f_y = 74.400 \, \frac{\mathbf{1000\ lb}}{\mathbf{ft}}$

Compression in concrete $C := T_a - T = 69.514 \, \frac{\mathbf{1000\ lb}}{\mathbf{ft}}$

Depth of equivalent stress block $a := \dfrac{C}{0.85 \cdot f_c \cdot \left(\dfrac{b}{\mathbf{ft}}\right)} = 1.704 \, \mathbf{in}$

Nomincal flexural resistance $M_n := T_a \cdot \left(d_e - \dfrac{a}{2}\right) - T \cdot \left(\dfrac{d_e}{2} - \dfrac{a}{2}\right)$

$M_n = 32.168 \cdot \mathbf{1000\ lb}$

Factored flexural resistance $M_r := \phi_{ext} \cdot M_n = 32.168 \cdot \mathbf{1000\ lb}$

Check the condition of resistance $\begin{cases} \text{"OK"} & M_r \geq M_{total} \\ \text{"NG"} & \text{otherwise} \end{cases} = \text{"OK"}$