TECH-LINE

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Grid Reinforced Concrete Deck Overhang Design Guidelines

Combination concrete parapet and metal railing.

Six test levels for bridge railings are provided in Section 13 of the **AASHTO LRFD Bridge Design Specifications**, which correspond to the test levels found in the NCHRP Report 350, *"Recommended Procedures for the Safety Performance Evaluation of Highway Features."* Lower test levels correspond to lower service level roadways. Higher test levels correspond to higher levels of service roadways or when required for unfavorable site conditions. For the most part, railings that satisfy the minimum requirements of Test Level Four (TL-4) are considered satisfactory for the majority of interstate design requirements.

Barrier rebar extending from cast-in-place deck.

Barrier systems need to be shown that they are structurally and geometrically crashworthy and reinforcing steel from the barrier must have sufficient embedment length to develop the yield strength. Decks are designed on a case-by-case basis and are not individually crash tested when crash testing barriers. Therefore, proper design of the deck overhang is essential to ensure that in a collision, the damage to the structure will be contained in the barrier and not extend to the deck. To achieve this, the deck should be designed stronger than the railing system. This will facilitate repair of the crash damage and minimize the cost to perform the repairs. However, yield line analysis of many barriers has shown that the resistance (R_w) of the barrier greatly exceeds the imposed design collision force (F_t) specified in AASHTO Table A13.2-1. For these situations, several state departments of transportation stipulate that the deck overhang shall carry the lesser of the calculated barrier capacity (R_w) or a percentage of design collision force (F_t), say 120% or 133%.

With vehicular collisions, a tensile force (T) is transmitted to the deck per unit width and can be calculated with AASHTO Equation A13.4.2-1. FHWA Publication HI-95-017 cites that continuous concrete barriers conservatively distribute the load a distance (L) at 30° from the limits of the critical wall length of the yield line failure pattern (L_c) at the face of the barrier to the design section for negative moment over the fascia girder.

Although Section 13 in the AASHTO LRFD Specification was developed for conventional reinforced concrete decks, the guidelines are applicable to grid reinforced concrete decks as well. In accordance with AASHTO A13.4.1, bridge deck overhangs shall be designed for the following design cases considered separately:

- *Design Case 1* - Transverse and longitudinal forces specified in Article A13.2 & Extreme Event Load Combination II limit state.
- *Design Case 2* - Vertical forces specified in Article A13.2 & Extreme Event Load Combination II limit state.
- *Design Case 3* - Loads specified in Article 3.6.1 that occupy the overhang & Load Combination Strength I limit state.

Concrete barrier being placed during slip-form operation.

Design Case 1

In Design Case 1, the deck overhang supporting a continuous concrete barrier must have a moment resistance (M_s) in the presence of tensile force (T), equal to the sum of the moment of resistance of the barrier at its base (M_c) and the dead load moments, i.e., $M_S \geq M_{DL} + M_C$. Although the colliding vehicle is on the bridge, crash testing observations show that the wheels near the barrier were not in contact with the deck at moment of the collision. Therefore, the traditional live load effects need not be included in this case.

Design Case 2

For instances with continuous concrete parapets and combinations of concrete parapet and metal railings, Design Case 2 produces relatively small force effects and can therefore be ignored.

Design Case 3

Design Case 3 is the conventional design of the overhang considering the dead loads and the design truck wheel live load placed no closer than 1'-0" from the face of the barrier in accordance with Section 3.6.1.3.1. The width of the equivalent strip for load distribution shall be calculated in accordance with Section 4.6.2.1.3 for overhangs.

Depending on the system specified, grid reinforced concrete deck overhangs can cantilever approximately 30% to 50% of the design interior span and may be increased with additional reinforcement. See the attached sample calculations for an unfilled grid deck composite with reinforced concrete slab which follow the AASHTO LRFD design requirements.

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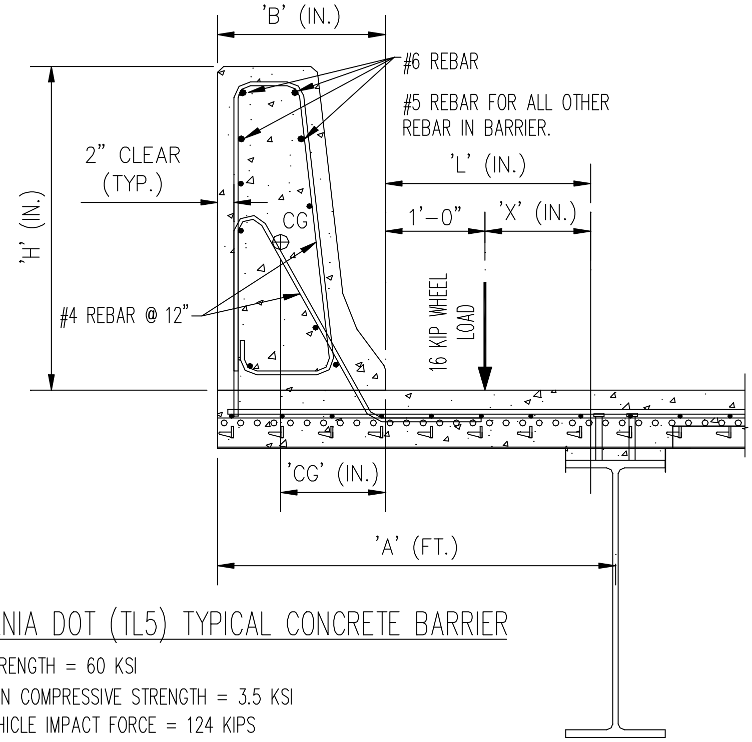
Calculation of Deck Moment Capacity and Stresses for cantilevered Exodermic deck

PennDOT T5, Type 1 Barrier Properties (Collision within a segment):
(Parapet capacity needs to be increased near expansion joints or lower performance level may be accepted in the expansion joint region)

Barrier Height (H)	42.0	in.
Width of Barrier at Base (B)	20.25	in.
Location of barrier centroid from gutterline of barrier (CG)	12.64	in.
Barrier Weight	650	lbs/l.f.
Moment Resistance of the parapet at its base (M_C)	17.83	kip-ft./ft.
Load Capacity of Parapet (Failure Mechanism 2 Controls) (R_w)	134.4	kips
Barrier Failure Length (Failure Mechanism 2) (L_c)	190.7	in.



PENNSYLVANIA DOT (TL5) TYPICAL CONCRETE BARRIER

REBAR YIELD STRENGTH = 60 KSI
CONCRETE DESIGN COMPRESSIVE STRENGTH = 3.5 KSI
TRANSVERSE VEHICLE IMPACT FORCE = 124 KIPS
LONGITUDINAL DISTRIBUTION LENGTH OF IMPACT FORCE = 8 FT.
VERTICAL FORCE OF VEHICLE LAYING ON TOP OF BARRIER = 80 KIPS

Cantilever Variables - Input ***(In Drop Down Box or in Red)***

Distance from centerline of fascia stringer to edge of deck (A)				4.000 ft
Is the Cantilever Section Full Depth Concrete (to the bottom of tee)?				Yes

This is the Design Main Bearing Bar (WT) and Spacing. (It cannot be revised here)

Design Deck:	WT 4 x 5	@	8 in. c-c	50 ksi steel

This is the Rebar in the Deck Section Parallel to the WT's. (It cannot be revised here)

Design Rebar in Deck:	# 5	@	4 in. c-c

Input the Rebar in the Cantilevered Section of the Deck. Recommend that designer try to make the Rebar configuration of the deck work before changing the primary rebar size or adding auxiliary rebar. Designer to ensure that development length and bundled bars are within specifications.

Note: If the Auxiliary rebar is specified and is not placed one bar between the primary bars or lapped with the primary bars, the spacing must be expressed as the effective spacing. If Auxiliary rebar is not specified, enter a zero (0) in the bar size cell.

Primary Cantilever Rebar #	5	@	4	in. c-c	(Start with Design Rebar in Deck)
Auxiliary Cantilevered Rebar #	0	@	6	in. c-c	

Operational Importance (η_I)	1.05	AASHTO LRFD 1.3.5
Multiple Presence Factor (m)	1.2	AASHTO LRFD 3.6.1.1.2
Dynamic Load Allowance (Impact) (IM)	1.33	AASHTO LRFD 3.6.2.1
Dead Load Factor	1.25	AASHTO LRFD Table 3.4.1-2
FWS Dead Load Factor	1.5	AASHTO LRFD Table 3.4.1-2
Live Load Factor	1.75	AASHTO LRFD Table 3.4.1-1

Cantilever Variables - Data

Fascia Girder Flange Width	7.005	in.
Overall Height from bottom of main bar to top of selected concrete thickness=	7.07	in.
Weight of Deck	85.43	lbs/sq.ft.
Design Section in the Cantilever (L) AASHTO LRFD 4.6.2.1.6	26.00	in.
Distance from Point of Support to Wheel Load (X = L - 12 in.)	14.00	in.
Design Section for Negative Moment (L + Distance to barrier CG)	38.64	in.
Deck Cantilever DL Moment (M_{DL1})	0.634	kip-ft./ft.
Barrier Cantilever DL Moment (M_{DL2})	2.093	kip-ft./ft.
FWS DL Moment (M_{DL3})	0.000	kip-ft./ft.
Total Dead Load Moment ($M_{DL} = M_{DL1} + M_{DL2} + M_{DL3}$)	2.727	kip-ft./ft.
Tension Force in Deck (T)	7.31	kip/ft.

Case 1: Transverse and Longitudinal Collision Forces at the Extreme Event Limit State

Plastic Moment Capacity for Deck Section (M_p)	31.99	kip-ft./ft.
Effective Moment Capacity for Deck Section in the Presence of Tension Force (M_{Peff})	**30.40**	kip-ft./ft.
$M_{DL} + M_C$	**20.56**	kip-ft./ft.

$$M_{Peff} \geq M_{DL} + M_C$$ OKAY ← CHECK

Case 2: Vertical Collision Force at the Extreme Event Limit State

In case of continuous concrete parapet, Case 2 produces relatively small force effects and, hence it can be ignored. (Reference: FHWA/NHI LRFD Training Course, Lecture 17, Section 17.2.6)

Case 3: Conventional Design (dead load and live load) at the Strength Limit State

Equivalent Strip Width (AASHTO LRFD 4.6.2.1.3)	4.72	ft.
Factored Dead Load Moment (M_{DL})	3.41	kip-ft./ft.
Factored Live Load plus Impact Moment (M_{LL+I})	11.04	kip-ft./ft.
Total Factored Design Moment (M)	14.45	kip-ft./ft.
Required Moment Capacity ($\eta_I M$)	15.17	kip-ft./ft.

Stresses

Rebar ($f_{s\text{-allow-rebar}} = \phi f_{y\text{-rebar}}$)	**54.0**	ksi
Rebar ($f_{s\text{-rebar}}$)	**40.8**	ksi

$$f_{s\text{-allow-rebar}} \geq f_{s\text{-rebar}}$$ OKAY ← CHECK

WT ($f_{s\text{-allow-WT}} = \phi f_{y\text{-steel}}$)	**50.0**	ksi
WT ($f_{s\text{-WT}}$)	**29.5**	ksi

$$f_{s\text{-allow-WT}} \geq f_{s\text{-WT}}$$ OKAY ← CHECK

Check Deflections

A. Deflection due to Live Load

Maximum deflection at the free end of a cantilever beam with a concentrated load at any point is given by: $\frac{Pb^2}{6EI}(3L-b)$

Cantilever deflection - AISC LRFD 2nd Ed. page 4-197, eq. 21

Deflection calculated at front face of barrier. Does not include additional stiffness offered by barrier.

Where:

P = Factored Concentrated Load per foot of deck =	9.46	kips	9464	lbs.
b = Distance from point of support to load =	1.167	ft. =	14.00	in.
L = Length of Cantilever (Design Section) =	2.167	ft. =	26.00	in.
I = the mom. of inertia for neg. bending at cantilever =	12.322	in^4		
E = modulus of elasticity of steel =	29.0E+6	lbs/in^2		

Deflection = 0.055 inches

Deflection $\leq$ L/300? OKAY ← CHECK

B. Deflection due to dead load of wet concrete (for cast-in-place decks) at end of cantilever

Maximum deflection at the unsupported end for a simple span with overhang is given by: $\frac{wa}{24EI}(3a^3+4a^2L-L^3)$

Cantilever deflection - AISC LRFD 2nd Ed. page 4-198, eq. 24

Where:

w = uniform load per foot =	85.43	lbs/ft =	7.12	lbs/in
a = cantilever overhang =	4.0000	ft. =	48	in.
L = beam spacing =	8.0000	ft. =	96	in.
I = the moment of inertia =	1.78361	in^4	for steel grid only	
E = modulus of elasticity of steel =	29.0E+6	lbs/in^2		

Deflection = 0.091 inches ← CHECK

(Positive value = Deflection downward)

Check for excess sag and the need to temporarily support