Bridge and Structures Office
Washington State
Department of Transportation

Design Memorandum

TO: All Design Section Staff
FROM: Bijan Khaleghi
DATE: December 9, 2011
SUBJECT: Moment Slab

This memorandum provides guidelines for design of barrier–moment slab systems on Geosynthetic and structural earth walls.

The guidelines provided herein are based on NCHRP Report 663 with the exception that a resistance factor of 0.5 shall be used to determine rotational resistance. This guideline is applicable for TL-3, TL-4 and TL-5 barrier systems as defined in Section 13 of AASHTO LRFD *Bridge Design Specifications.*

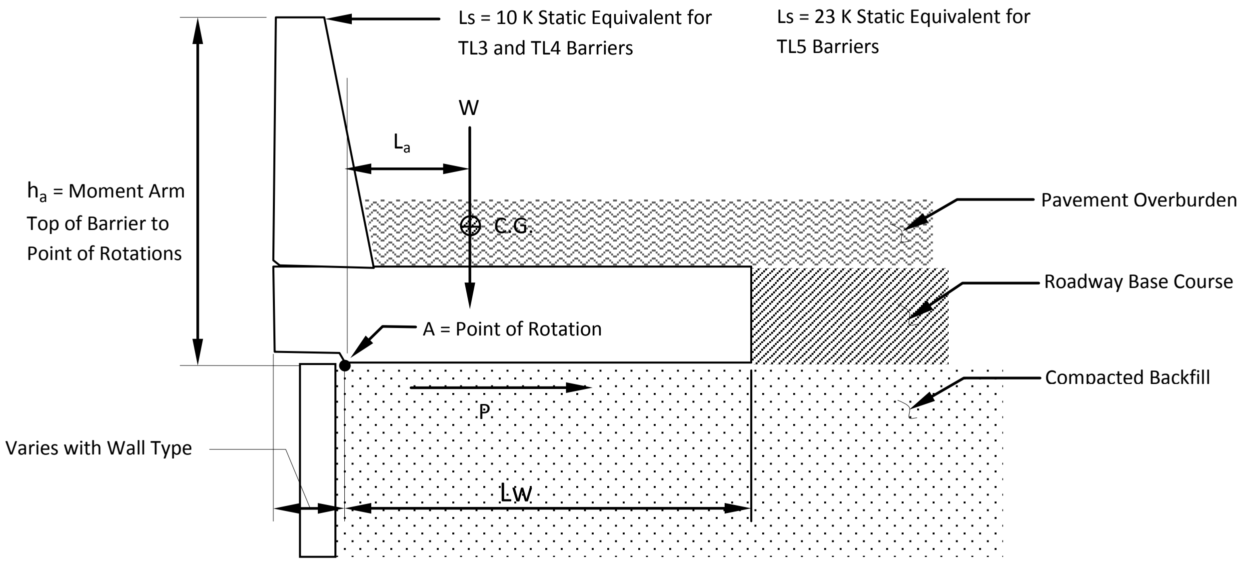

Figure 1 Global Stability of Barrier–Moment Slab System

GUIDELINES FOR MOMENT SLAB DESIGN

Structural Capacity

The structural capacity of the barrier and concrete moment slab shall be designed using impulse Traffic Loads (TL-3, TL-4, TL-5) in accordance with Sections 5 and 13 of *AASHTO LRFD Bridge Design Specifications*. Any section along the moment slab should not fail in shear, bending, or torsion when the barrier is subjected to the design impact load. The moment slab reinforcement shall be designed to resist forces developed at the base of the barrier. The torsion capacity of the moment slab must be equal to or greater than the traffic barrier moment generated by the specified TL impulse load (TL-3, TL-4, TL-5) applied to the top of the barrier.

Global Stability

Sliding and overturning stability of the moment slab shall be based on an Equivalent Static Load (ESL) applied to the top of the traffic barrier. For TL-3 and TL-4 barrier systems, the ESL shall be 10 kips. For TL-5 barrier systems, the ESL shall be 23 kips.

The Equivalent Static Load (ESL) is assumed to distribute over the length of the moment slab through rigid body behavior. Any coupling between adjacent moment slabs or friction that may exist between free edges of the moment slab and the surrounding soil should be neglected.

Minimum and Maximum Dimensions

Moment slabs shall have a minimum width of 4.0 feet measured from the point of rotation to the heel of the slab and a minimum average depth of 0.83 feet. Moment slabs meeting these minimum requirements are assumed to provide rigid body behavior up to a length of 60 feet for end barrier and interior barrier impacts.

Rigid body behavior may be increased from 60 feet to a maximum of 120 feet if the torsional rigidity constant of the moment slab is proportionately increased and the reinforcing steel is designed to resist combined shear, moment, and torsion from TL impulse loads.

For example: Rigid Body Length = $(J'/J_{60})x(60\text{ ft.}) \leq 120$ feet.

The torsional rigidity constant for moment slabs shall be based on a solid rectangle using the following formula:

$$J = a \cdot b^3 \left[\frac{16}{3} - 3.36\left(\frac{b}{a}\right)\left(1 - \frac{b^4}{12a^4}\right)\right]$$

where:

2a = total width of moment slab

2b = average depth of moment slab

For example:

Minimum Moment Slab Width = 48 inches: a=24 inches

Minimum Moment Slab Average Depth = 10 inches: b=5 inches

$J = J_{60} = 13{,}900\text{ in}^4$

Sliding of the Barrier

The factored static resistance to sliding (ϕP) of the barrier–moment slab system along its base shall satisfy the following condition

$$\phi P \geq \gamma L_s \qquad (1)$$

where:

Ls = equivalent static load (10 kips for TL-3 and TL-4) (23 kips for TL-5)

ϕ= resistance factor (0.8) Supersedes *AASHTO 10.5.5.3.3—Other Extreme Limit States*

γ= load factor (1.0) for TL-3 and TL-4 [crash tested extreme event]
load factor (1.2) for TL-5 [untested extreme event]

P = static resistance (kips)

P shall be calculated as:

$$P = W \tan \phi_r \qquad (2)$$

where:

W = weight of the monolithic section of barrier and moment slab between joints or assumed length of rigid body behavior whichever is less, plus any material laying on top of the moment slab

ϕ_r = friction angle of the soil on the moment slab interface (°)

If the soil–moment slab interface is rough (e.g., cast in place), ϕ_r is equal to the friction angle of the soil ϕ_s. If the soil–moment slab interface is smooth (e.g., precast), tan ϕ_r shall be reduced accordingly (0.8 tan ϕ_s

Overturning of the Barrier

The factored static moment resistance (ϕM) of the barrier-moment slab system to overturning shall satisfy the following condition (Figure 1

$$\phi M \geq \gamma L_s h_a \qquad (3)$$

where:

A = point of rotation, where the toe of the moment slab makes contact with compacted backfill adjacent to the fascia wall

L_w = width of moment slab

L_s = equivalent static load (10 kips for TL-3 and TL-4) (23 kips for TL-5)

ϕ= resistance factor (0.5) Supersedes *AASHTO 10.5.5.3.3—Other Extreme Limit States and NCHRP Report 663*

γ= load factor (1.0) for TL-3 and TL-4 [crash tested extreme event]
load factor (1.2) for TL-5 [untested extreme event]

h_a = moment arm taken as the vertical distance from the point of impact due to the dynamic force (top of the barrier) to the point of rotation A

M = static moment resistance (kips-ft)

M shall be calculated as:

$$M = W (L_a) \qquad (4)$$

W = weight of the monolithic section of barrier and moment slab between joints or assumed length of rigid body behavior whichever is less, plus any material laying on top of the moment slab

L_a = horizontal distance from the center of gravity of the weight W to point of rotation A

The moment contribution due to any coupling between adjacent moment slabs, shear strength of the overburden soil, or friction which may exist between the backside of the moment slab and the surrounding soil should be neglected.

GUIDELINES FOR THE SOIL REINFORCEMENT

Design of the soil reinforcement shall be in accordance with the WSDOT Geotechnical Design Manual, Chapter 15.

DESIGN OF THE WALL PANEL

The wall panels shall be designed to resist the dynamic pressure distributions as defined in the WSDOT Geotechnical Manual, Chapter 15.

The wall panel shall have sufficient structural capacity to resist the maximum design rupture load for the wall reinforcement designed in accordance with the WSDOT Geotechnical Manual, Chapter 15.

The static load is not included because it is not located at the panel connection.

BACKGROUND:

Much of the design experience with barrier–moment slab systems for Structural Earth Walls and Geosynthetic Walls is based on traffic barrier loads specified in Sections 11 and 13 of the *AASHTO LRFD Bridge Design Specifications*. The TL loads listed in Section 13 are dynamic impulse loads that are inconsistent with static equilibrium calculation used to evaluate sliding and overturning of the moment slab. NCHRP 663 provides an equivalent static load methodology for TL-3 and TL-4 barriers and recommends a maximum distribution length of 60 feet for a moment slab system that is 4.5 feet wide with an average depth of 0.75 feet. The WSDOT minimum dimensions of 4.0 feet wide and 0.83 feet average depth were developed as a reasonable equivalent to the moment slab that was used for NCHRP 663.

NCHRP 663 assumed that a barrier–moment slab design would generate 1 in. movement or less at the top of the barrier during impact. This 1 inch dynamic movement is considered acceptable as it would likely require little or no repair and should not affect the impact performance of the barrier system.

WSDOT isolates the top of the wall panel from contact with the moment slab and requires the point of rotation to be where the toe of the moment slab makes contact with the compacted backfill. Resistance factors of 0.8 for extreme event sliding and 0.5 for extreme event overturning are specified to provide design tolerance for unexpected variation in wall backfill and deviations in wall alignment.

If you have any questions regarding these issues, please contact Dick Stoddard at 705-7217 or Bijan Khaleghi at 360-705-7181.

cc: Mark Gaines, Bridge Construction - 47354
F. Posner, Bridge and Structures – 47340

Delete Article 10.3.3 and replace with following:

10.3.3 Traffic Barrier Moment Slab

A. General

The guidelines provided herein are based on NCHRP Report 663 with the exception that a resistance factor of 0.5 shall be used to determine rotational resistance. This guideline is applicable for TL-3, TL-4 and TL-5 barrier systems as defined in Section 13 of AASHTO LRFD *Bridge Design Specifications.*

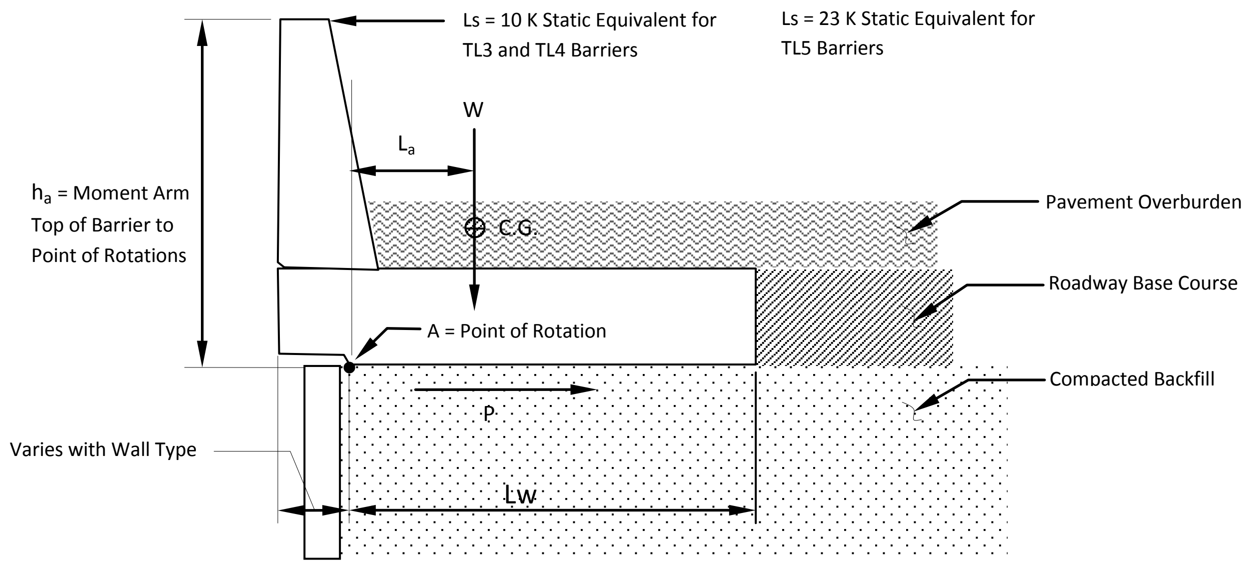

Figure 1 Global Stability of Barrier–Moment Slab System

B. GUIDELINES FOR MOMENT SLAB DESIGN

1. Structural Capacity

The structural capacity of the barrier and concrete moment slab shall be designed using impulse Traffic Loads (TL-3, TL-4, TL-5) in accordance with Sections 5 and 13 of *AASHTO LRFD Bridge Design Specifications*. Any section along the moment slab should not fail in shear, bending, or torsion when the barrier is subjected to the design impact load. The moment slab reinforcement shall be designed to resist forces developed at the base of the barrier. The torsion capacity of the moment slab must be equal to or greater than the traffic barrier moment generated by the specified TL impulse load (TL-3, TL-4, TL-5) applied to the top of the barrier.

2. **Global Stability**

Sliding and overturning stability of the moment slab shall be based on an Equivalent Static Load (ESL) applied to the top of the traffic barrier. For TL-3 and TL-4 barrier systems, the ESL shall be 10 kips. For TL-5 barrier systems, the ESL shall be 23 kips.

The Equivalent Static Load (ESL) is assumed to distribute over the length of the moment slab through rigid body behavior. Any coupling between adjacent moment slabs or friction that may exist between free edges of the moment slab and the surrounding soil should be neglected.

3. **Minimum and Maximum Dimensions**

Moment slabs shall have a minimum width of 4.0 feet measured from the point of rotation to the heel of the slab and a minimum average depth of 0.83 feet. Moment slabs meeting these minimum requirements are assumed to provide rigid body behavior up to a length of 60 feet for end barrier and interior barrier impacts.

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For example:

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$J = J_{60} = 13{,}900\ in^4$

4. **Sliding of the Barrier**

The factored static resistance to sliding (ϕP) of the barrier–moment slab system along its base shall satisfy the following condition (Figure 2)

$$\phi P \geq \gamma L_s \quad (1)$$

where:

Ls = equivalent static load (10 kips for TL-3 and TL-4) (23 kips for TL-5)

ϕ= resistance factor (0.8) Supersedes *AASHTO 10.5.5.3.3—Other Extreme Limit States*

γ= load factor (1.0) for TL-3 and TL-4 [crash tested extreme event]
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where:

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L_w = width of moment slab

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M = static moment resistance (kips-ft)

M shall be calculated as:

$M = W\ (L_a)$ (4)

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