Asymmetric Barriers

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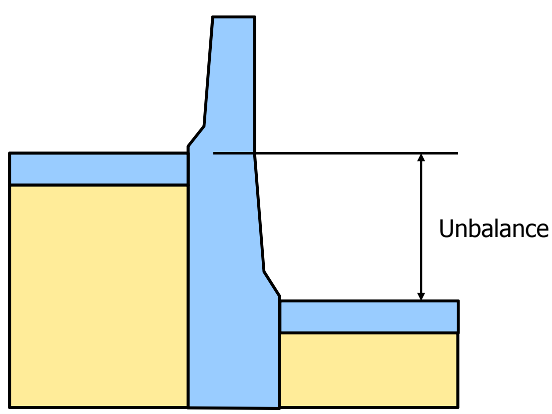
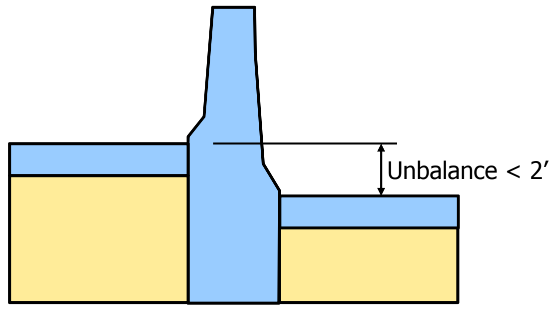
Overview

- **What is an Asymmetric Barrier?**
  - Median barrier with unbalanced roadway elevations



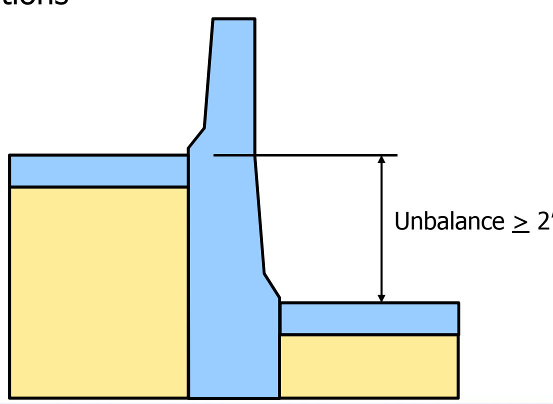
Overview

- **When Do We Need to Design?**
  - Unbalance < 2', provide equivalent overturning resistance as standard unreinforced median barrier



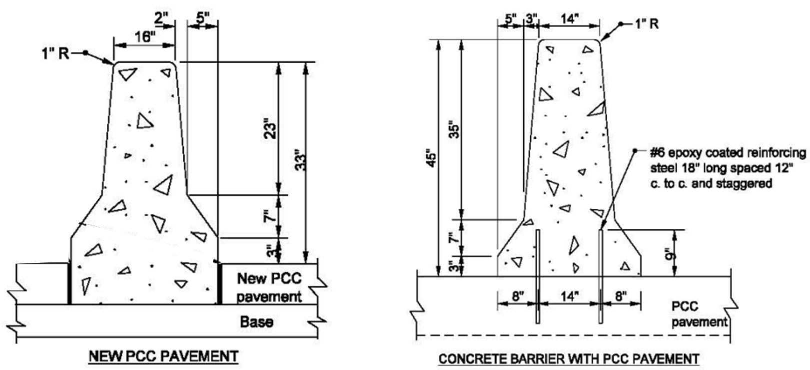
Overview

- **When Do We Need to Design?**
  - Unbalance > 2', design as a reinforced retaining wall in accordance with AASHTO LRFD Bridge Design Specifications



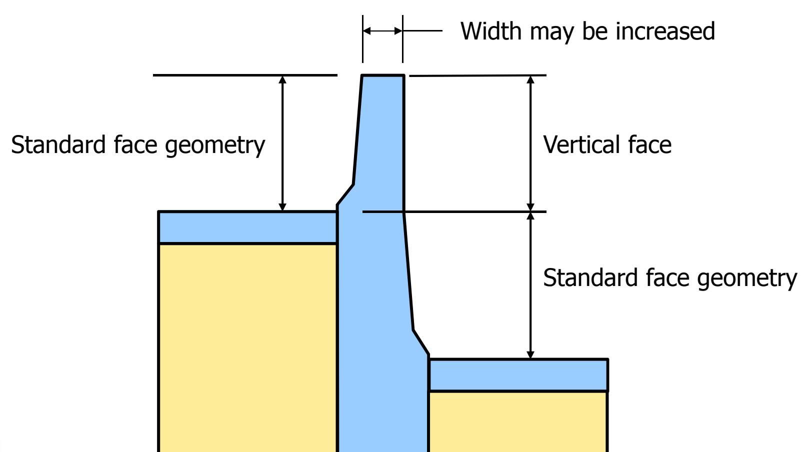
Overview

- **What Shape is the Barrier?**
  - Based on standard 33″ or 45″ median barrier (E 602-CCMB-04)



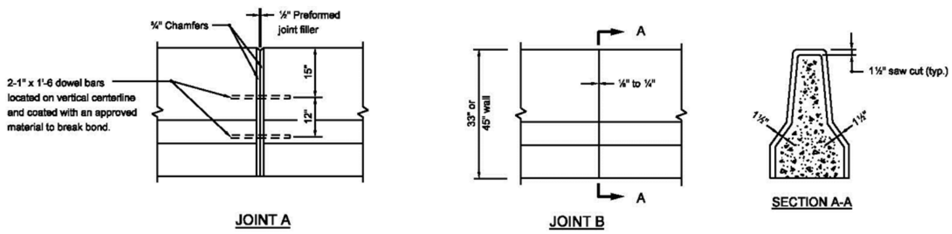
Overview

- **What Shape is the Barrier?**
  - Geometry of faces should remain standard



Overview

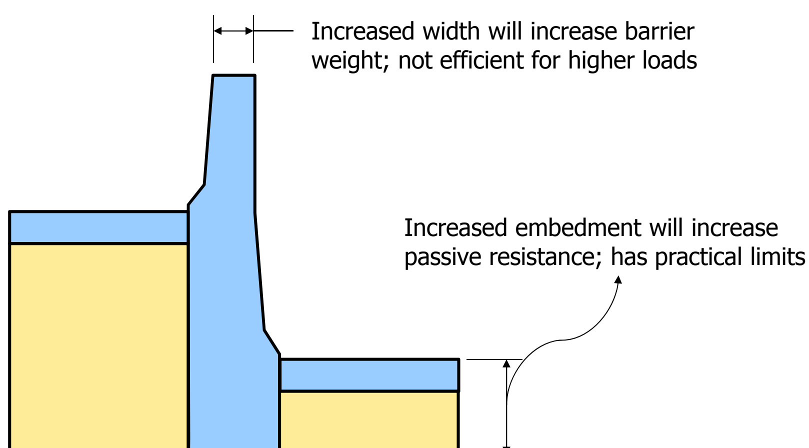
- **What Shape is the Barrier?**
  - Joint 'B' spacing doesn't apply to reinforced (i.e. $\geq$ unbalance) barriers (E 602-CCMB-02)



FORMED IN PLACE OR SLIP FORMED JOINTS

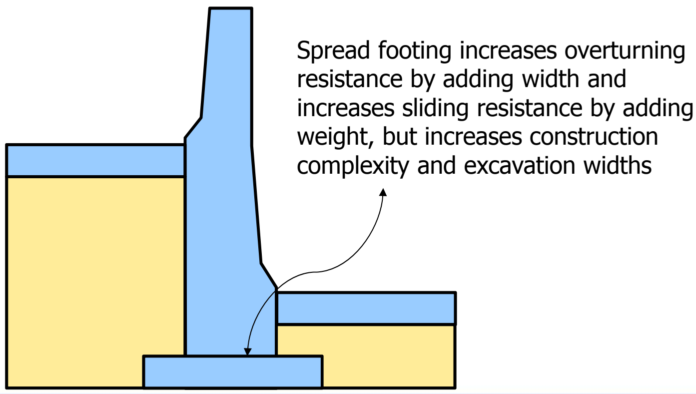
Overview

- **How can Resistance be Increased?**
  - Increase width and/or embedment



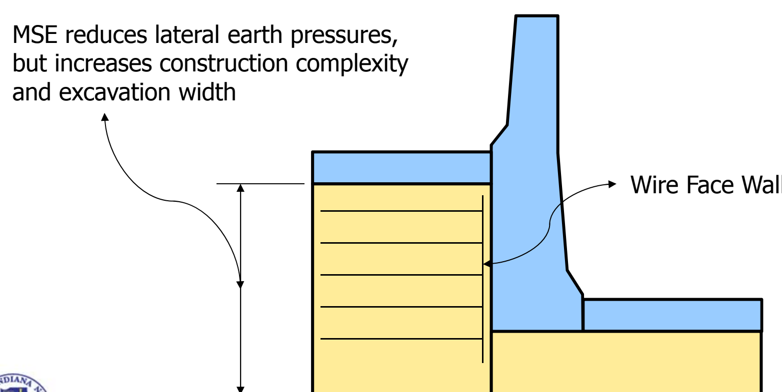
Overview

- **How can Resistance be Increased?**
  - Add a spread footing



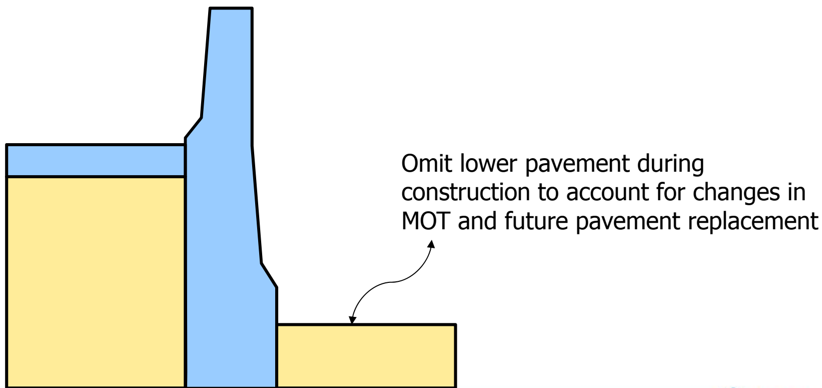
Overview

- **How can Resistance be Increased?**
  - Incorporate mechanically stabilized earth (MSE) (reduces resistance demand)



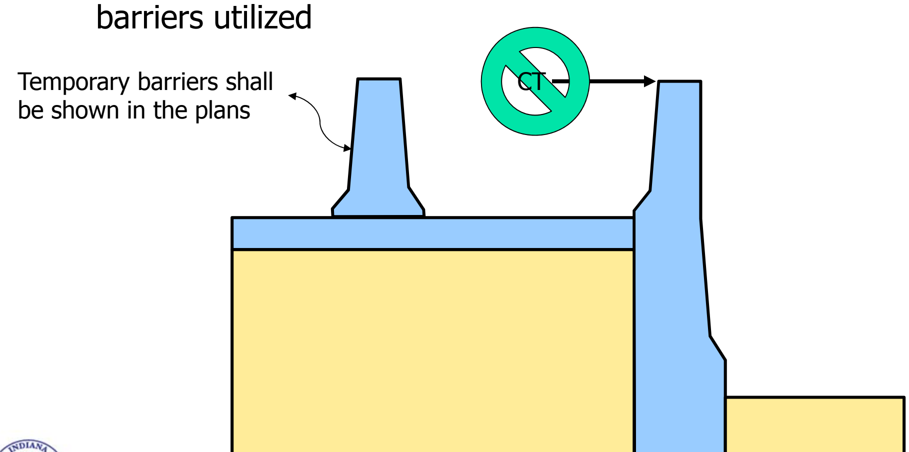
Load Cases

- **Case 1 – During Construction**
  - Lower pavement not included in analysis, regardless of anticipated construction sequence



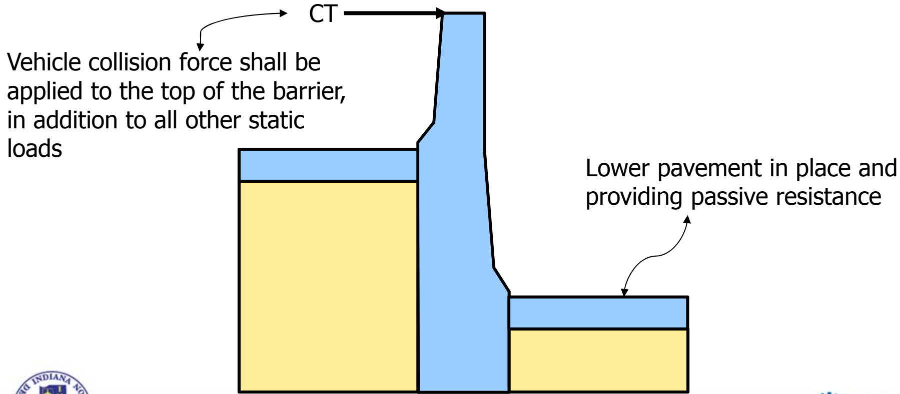
Load Cases

- **Case 1 – During Construction**
  - Vehicle collision force (CT) not required if temporary barriers utilized



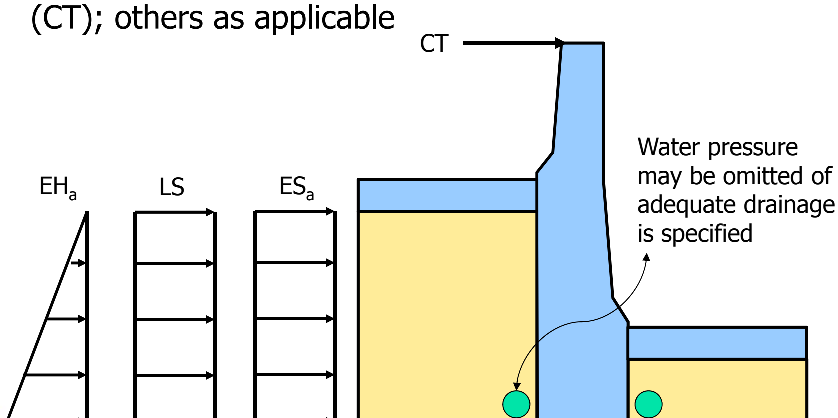
Load Cases

- **Case 2 – Final In-Service Configuration**
  - Lower pavement in place and vehicle collision force applied



Loading

- **Driving Forces**
  - Active earth pressure (EH_a), live load surcharge (LS), dead load surcharge (ES_a), and vehicle collision force (CT); others as applicable

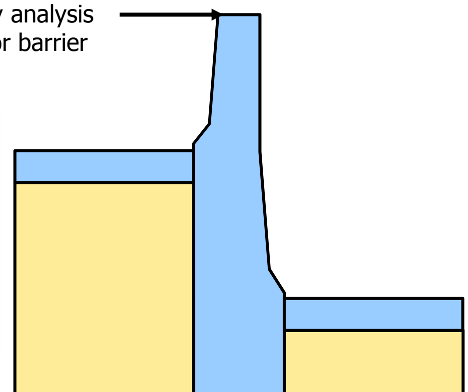


Loading

- **Driving Forces**
  - Vehicle collision force (CT) varies depending on the element being designed

CT = 10 kips, for stability analysis
CT = LRFD section 13, for barrier reinforcing

NCHRP Report 663 indicates that a vehicle collision force of 10 kips is appropriate for static equilibrium (overturning and sliding) analysis. Forces given in LRFD section 13 are impact loads appropriate for reinforced concrete design.



Loading

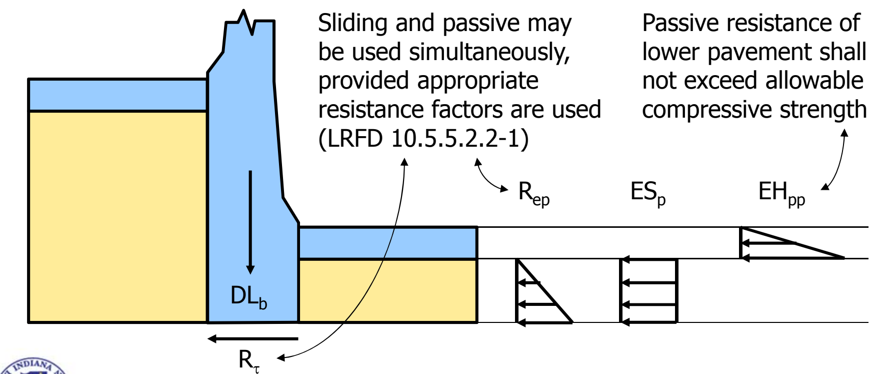
- **Driving Forces**
  - Load combinations and load factors shall be as given in LRFD Table 3.4.1.1
  - Load factors during construction may be reduced as appropriate, per section 3.4.2 of the LRFD Specifications

When investigating Strength Load Combinations I, III, and V during construction, load factors for the weight of the structure and appurtenances, *DC* and *DW*, shall not be taken to be less than 1.25.

Unless otherwise specified by the Owner, the load factor for construction loads and for any associated dynamic effects shall not be less than 1.5 in Strength Load Combination I. The load factor for wind in Strength Load Combination III shall not be less than 1.25.

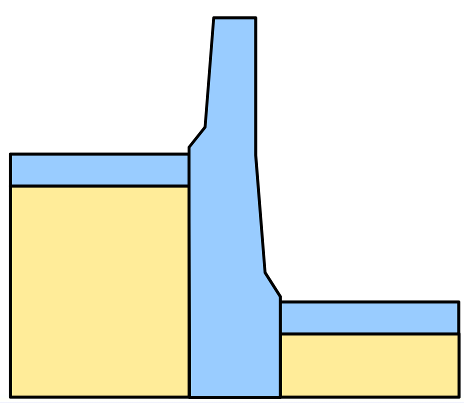
Loading

- **Resisting Forces**
  - Passive earth pressure (R_{ep}), dead load surcharge (ES_p), pavement passive resistance (EH_{pp}), barrier self-weight (DL_b), and sliding resistance (R_τ)



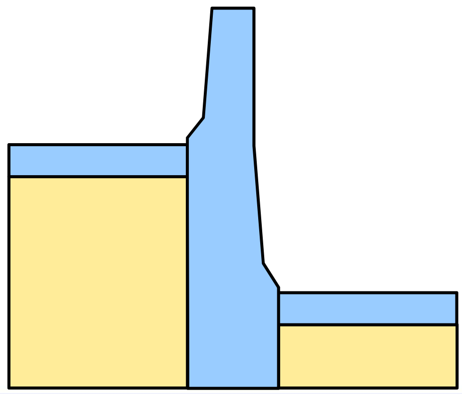
Stability Analysis

- **Sliding Check**
  - Sliding shall be checked per Section 10.6.3.4 of the LRFD Specifications



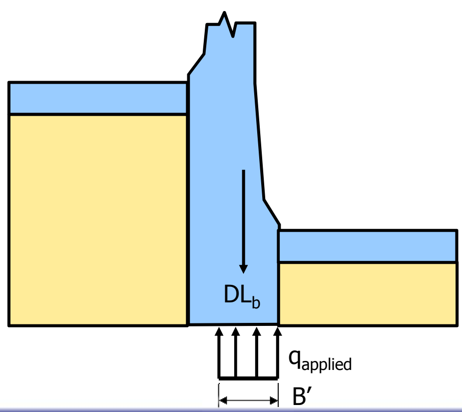
Stability Analysis

- **Overturning Check**
  - Overturning shall be checked per Section 11.6.3.3 of the LRFD Specifications



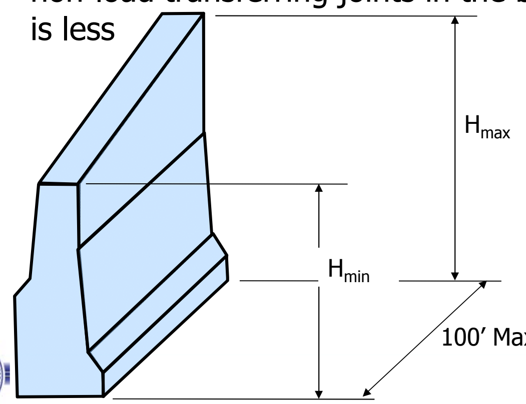
Stability Analysis

- **Bearing Resistance Check**
  - Bearing resistance shall be checked per Section 11.6.3.2 of the LRFD Specifications



Stability Analysis

- **Design Height and Length**
  - Design height of the barrier shall not be taken as less than the average height of barrier within a 100 foot length of barrier, or the length of barrier between non-load transferring joints in the barrier, whichever is less



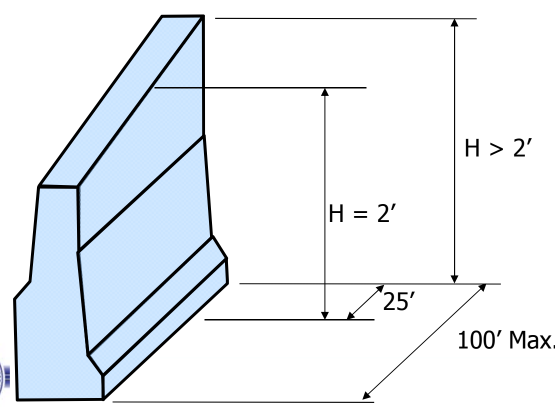
$H_{design} = (H_{max} – H_{min}) \times ½$

However,

$\mathbf{(H_{max} – H_{design}) \leq 1}$ **foot**

Stability Analysis

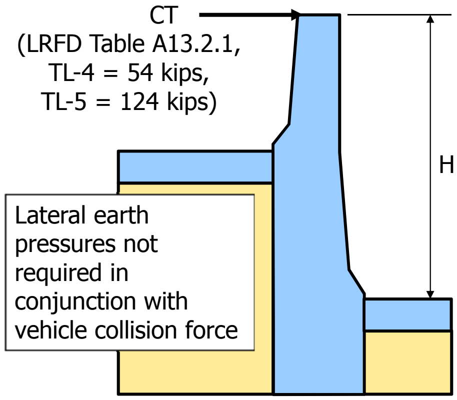
- **Design Height and Length**
  - If at least 25 feet of the barrier within this length has an unbalanced height > 2 feet, the barrier should be designed for an unbalanced height > 2 feet

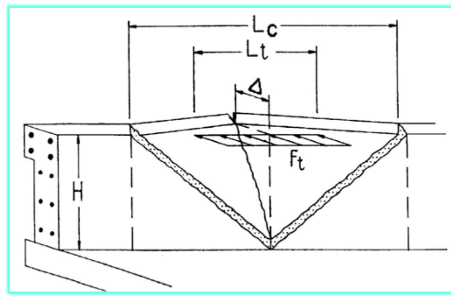


Design as a <u>reinforced</u> retaining wall in accordance with AASHTO LRFD Bridge Design Specifications

Reinforcing Design

- Barrier reinforcing shall be designed in accordance with section A13.3 of the LRFD Specifications

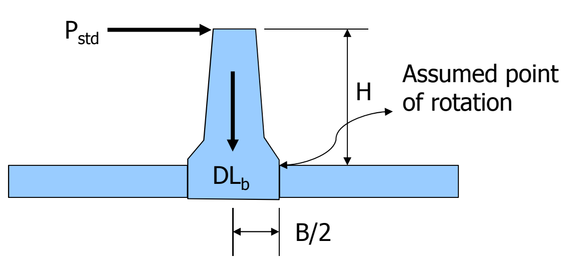




Example – Less than 2'

- Calculate the overturning resistance of standard median barrier

$$P_{std} = (DL_b \times B/2) / H$$

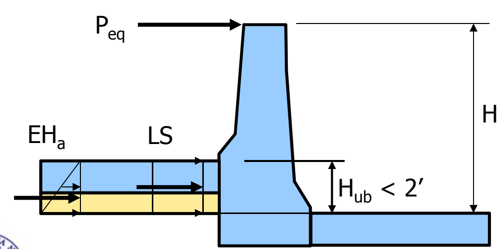


Example – Less than 2′

- Calculate the overturning moments due to earth pressures and convert that to and equivalent force at the top of the barrier

$$M_{ot} = (EH_a \times H_{ub}/3) + (LS \times H_{ub}/2)$$

$$P_{eq} = M_{ot}/H$$



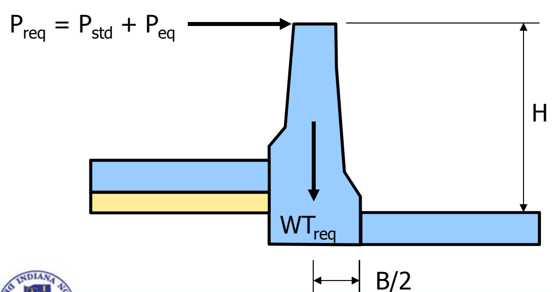
Notes:
1. Lateral earth pressure forces should be factored
2. Upper pavement has been conservatively assumed as soil in this example

Example – Less than 2′

- Calculate the total required lateral moment resistance and determine the required barrier weight

$$M_{req} = P_{req} \times H$$

$$WT_{req} = M_{req}/(B/2)$$



Note:
Moment resistance can also be increased by widening the barrier instead of, or in conjunction with, increasing the barrier depth

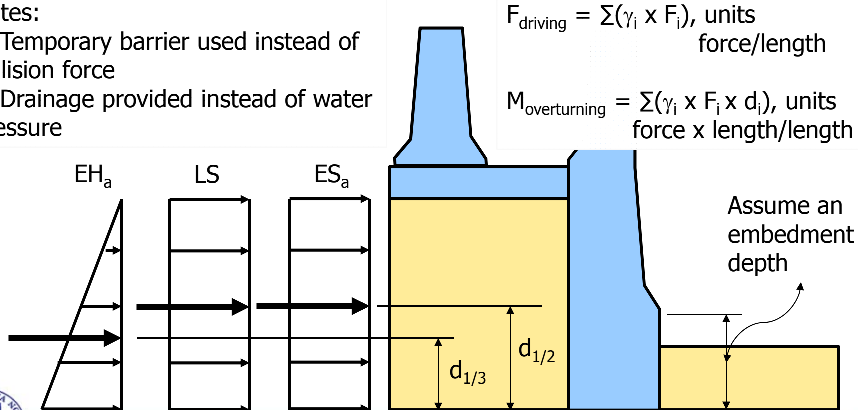
Example – Greater than 2′

- **Case 1 – During Construction**
  - Assume an embedment depth and calculate the driving lateral forces and overturning moment

Notes:
1. Temporary barrier used instead of collision force
2. Drainage provided instead of water pressure

$F_{driving} = \Sigma(\gamma_i \times F_i)$, units force/length

$M_{overturning} = \Sigma(\gamma_i \times F_i \times d_i)$, units force x length/length



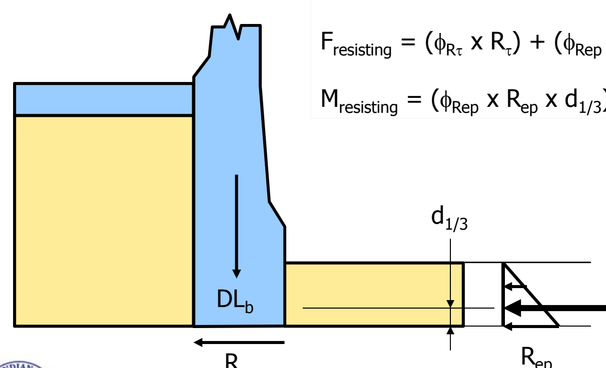
Example – Greater than 2′

- **Case 1 – During Construction**
  - Calculate the resisting forces and moments

$R_\tau = DL_b \times \tan(\delta)$

$F_{resisting} = (\phi_{R\tau} \times R_\tau) + (\phi_{Rep} \times R_{ep})$

$M_{resisting} = (\phi_{Rep} \times R_{ep} \times d_{1/3})$

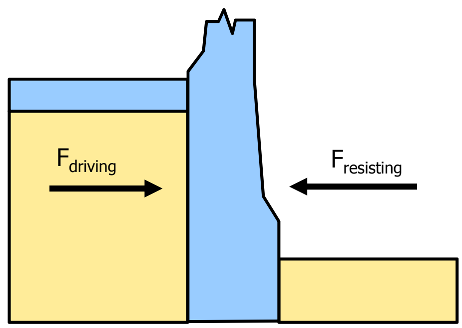


Example – Greater than 2′

- **Case 1 – During Construction**
  - Check sliding resistance

If, $F_{resisting} > F_{driving,}$ Sliding resistance is adequate

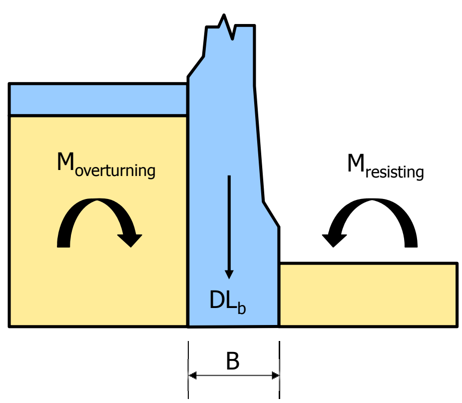
If, $F_{resisting} < F_{driving,}$ Sliding resistance is deficient. Increase resistance by increasing barrier weight (width), embedment depth, or decrease driving force (MSE, etc.)



Example – Greater than 2′

- **Case 1 – During Construction**
  - Check overturning
    - Determine the net factored lateral load moments

$M_{net} = M_{overturning} - M_{resisting}$ (moments taken about center of barrier, B/2)



Example – Greater than 2′

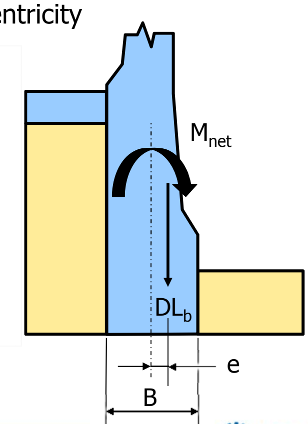
- **Case 1 – During Construction**
  - Check overturning
    - Calculate the eccentricity of the applied loads and check against the maximum allowable eccentricity

e_{max} = B/3 (per LRFD section 11.6.3.3)

e = M_{net}/DL_b

If e_{max} > e, overturning resistance is acceptable

If e_{max} < e, overturning resistance is deficient, increase resistance by increasing barrier weight (width), embedment depth, or decrease driving force (MSE, etc.)



Example – Greater than 2′

- **Case 1 – During Construction**
  - Check bearing pressure
    - Calculate the effective barrier width due to the eccentricity of the applied loads and determine the applied bearing pressure

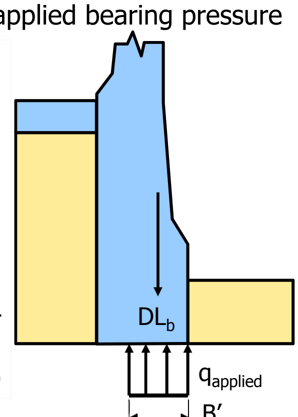
B′ = B – 2e

$q_{applied}$ = DL_b/ B′

$q_{max\ allowable}$ = Per geotechnical recommendations

If $q_{max\ allowable}$ > $q_{applied}$, bearing pressure is acceptable

If $q_{max\ allowable}$ < $q_{applied}$, bearing pressure is deficient. Increase resistance by increasing barrier weight (width), embedment depth, or decrease driving force (MSE, etc.)

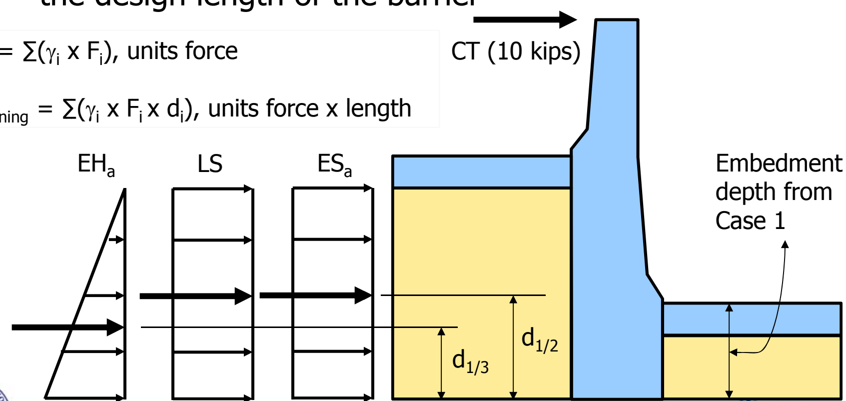


Example – Greater than 2′

- **Case 2 – Final Condition**
  - Using the Case 1 section geometry, calculate the driving forces and overturning moment applied over the design length of the barrier

$F_{driving} = \Sigma(\gamma_i \times F_i)$, units force

$M_{overturning} = \Sigma(\gamma_i \times F_i \times d_i)$, units force x length



Example – Greater than 2′

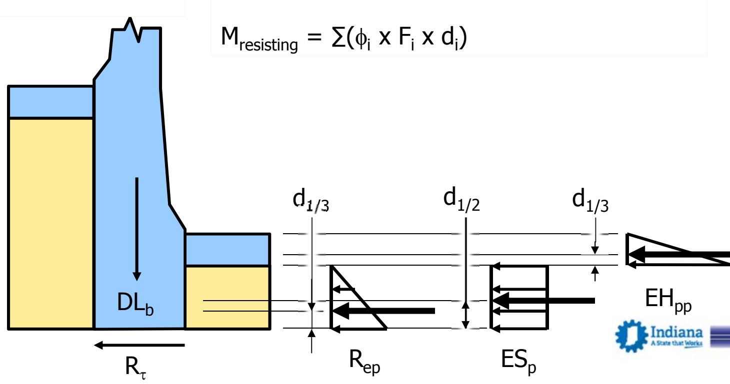
- **Case 2 – Final Condition**
  - Calculate the resisting forces and moments

Note:
The passive resistance of the lower pavement shall not exceed the allowable compressive strength

$R_\tau = DL_b \times \tan(\delta)$

$F_{resisting} = \Sigma(\phi_i \times F_i)$

$M_{resisting} = \Sigma(\phi_i \times F_i \times d_i)$

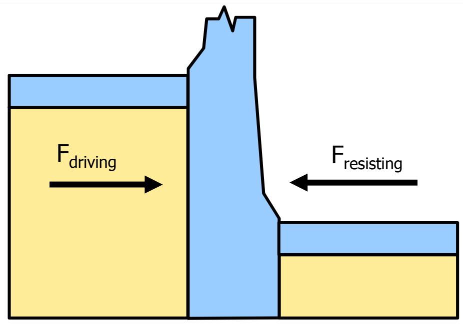


Example – Greater than 2′

- **Case 2 – Final Condition**
  - Check sliding resistance

If, $F_{resisting} > F_{driving,}$ Sliding resistance is adequate

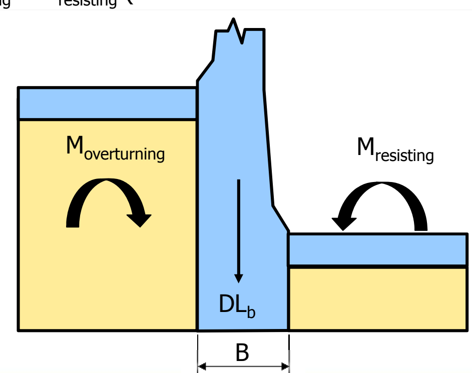
If, $F_{resisting} < F_{driving,}$ Sliding resistance is deficient. Increase resistance by increasing barrier weight (width), embedment depth, barrier design length or decrease driving force (MSE, etc.)



Example – Greater than 2′

- **Case 2 – Final Condition**
  - Check overturning
    - Determine the net factored lateral load moments

$M_{net} = M_{overturning} - M_{resisting}$ (moments taken about center of barrier, B/2)



Example – Greater than 2′

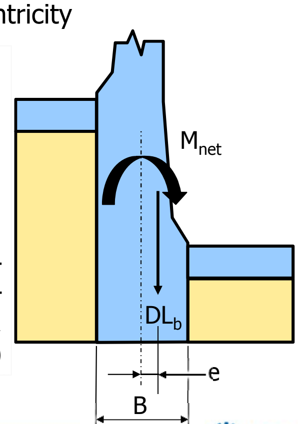
- **Case 2 – Final Condition**
  - Check overturning
    - Calculate the eccentricity of the applied loads and check against the maximum allowable eccentricity

e_{max} = B/3 (per LRFD section 11.6.3.3)

$e = M_{net}/DL_b$

If $e_{max} > e$, overturning resistance is acceptable

If $e_{max} < e$, overturning resistance is deficient. Increase resistance by increasing barrier weight (width), embedment depth, barrier design length or decrease driving force (MSE, etc.)



Example – Greater than 2′

- **Case 2 – Final Condition**
  - Check bearing pressure
    - Calculate the effective barrier width due to the eccentricity of the applied loads and determine the applied bearing pressure

B′ = B – 2e

$q_{applied} = DL_b/ B'$

$q_{max\ allowable}$ = Per geotechnical recommendations

If $q_{max\ allowable} > q_{applied}$, bearing pressure is acceptable

If $q_{max\ allowable} < q_{applied}$, bearing pressure is deficient. Increase resistance by increasing barrier weight (width), embedment depth, design length or decrease driving force (MSE, etc.)