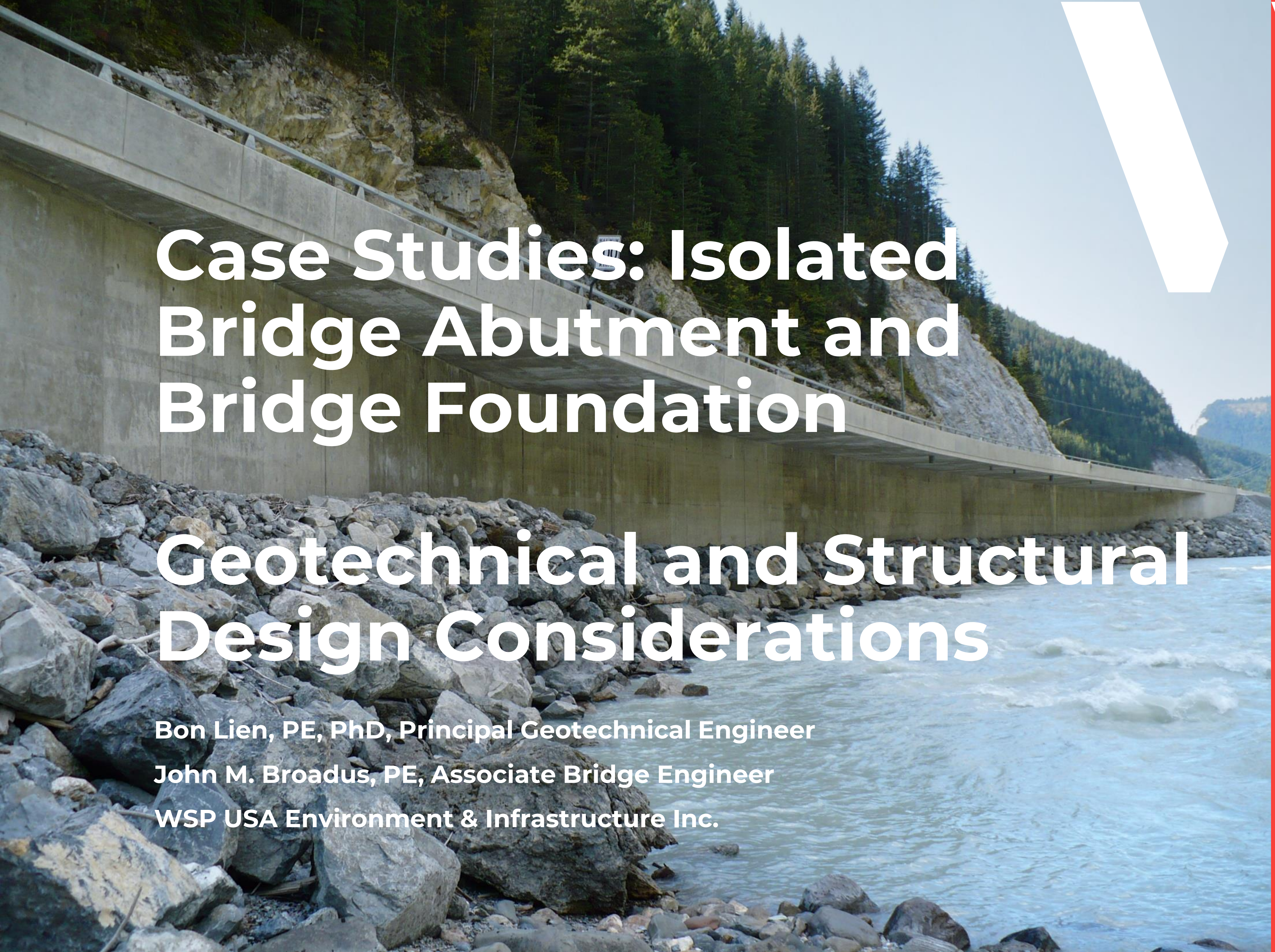


Case Studies: Isolated Bridge Abutment and Bridge Foundation

Geotechnical and Structural Design Considerations

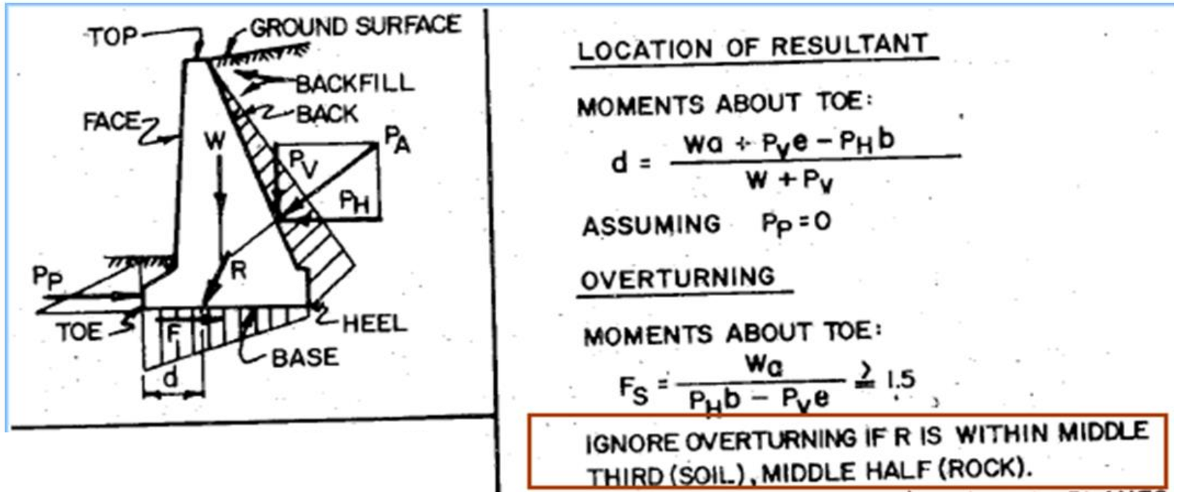
Bon Lien, PE, PhD, Principal Geotechnical Engineer

John M. Broadus, PE, Associate Bridge Engineer

WSP USA Environment & Infrastructure Inc.

STGEC 2022
Southeastern Transportation
Geotechnical Engineering Conference

How to check retaining wall overturning stability?



NAVFAC DM 7.2
Figure 15

Method #1

Service Load Allowable Stress Design (ASD)

FS = Resisting Moment / Overturning Moment (M_r/M_o)

Method #2 (Recommended for ASD)

Ignore M_r/M_o, if the resultant falls within middle one-third (soil) or middle one-half (rock)

STGEC 2022
Southeastern Transportation
Geotechnical Engineering Conference

Method #3

2007 AASHTO LRFD, Factored (Strength Limit State), resultant should fall within middle one-half (soil) or middle three-fourths (rock)

Method #4 (Recommended for LRFD)

2012/2014/2020 AASHTO LRFD, Factored (Strength Limit State), resultant should fall within **middle two-thirds (soil)** or **middle nine-tenths (rock)**

wsp

STGEC 2022
Southeastern Transportation
Geotechnical Engineering Conference

<u>Question</u>

Why “***<u>middle one-half</u>***” & “***<u>middle two-third;</u>***
different from “***<u>middle one-third</u>***”?

C11.6.3.3

The specified criteria for the location of the resultant, coupled with investigation of the bearing pressure, replaces the investigation of the ratio of stabilizing moment to overturning moment. Location of the resultant within the middle one-half of the base width for foundations on soil is based on the use of plastic bearing pressure distribution for the limit state.

2007 AASHTO LRFD

C11.6.3.3

The specified criteria for the location of the resultant, coupled with investigation of the bearing pressure, replace the investigation of the ratio of stabilizing moment to overturning moment. Location of the resultant within the middle two-thirds of the base width for foundations on soil is based on the use of plastic bearing pressure distribution for the limit state.

2012/2014/2020 AASHTO LRFD

However, based on personal communication with AASHTO personnel, reference of such "*plastic bearing pressure distribution*" was not identified...

C10.6.3.3

A comprehensive parametric study was conducted for cantilevered retaining walls of various heights and soil conditions. The base widths obtained using the LRFD load factors and eccentricity of $B/4$ were comparable to those of ASD with an eccentricity of $B/6$.

2007 AASHTO LRFD

C10.6.3.3

A comprehensive parametric study was conducted for cantilevered retaining walls of various heights and soil conditions. The base widths obtained using the LRFD load factors and eccentricity of $B/3$ were comparable to those of ASD with an eccentricity of $B/6$. For foundations on rock, to obtain equivalence with ASD specifications, a maximum eccentricity of $B/2$ would be needed for LRFD. However, a slightly smaller maximum eccentricity has been specified to account for the potential unknown future loading that could push the resultant outside the footing dimensions.

2012/2014/2020 AASHTO LRFD

Cautions

Do Not Mix Up the Use of Criteria between ASD and LRFD Designs

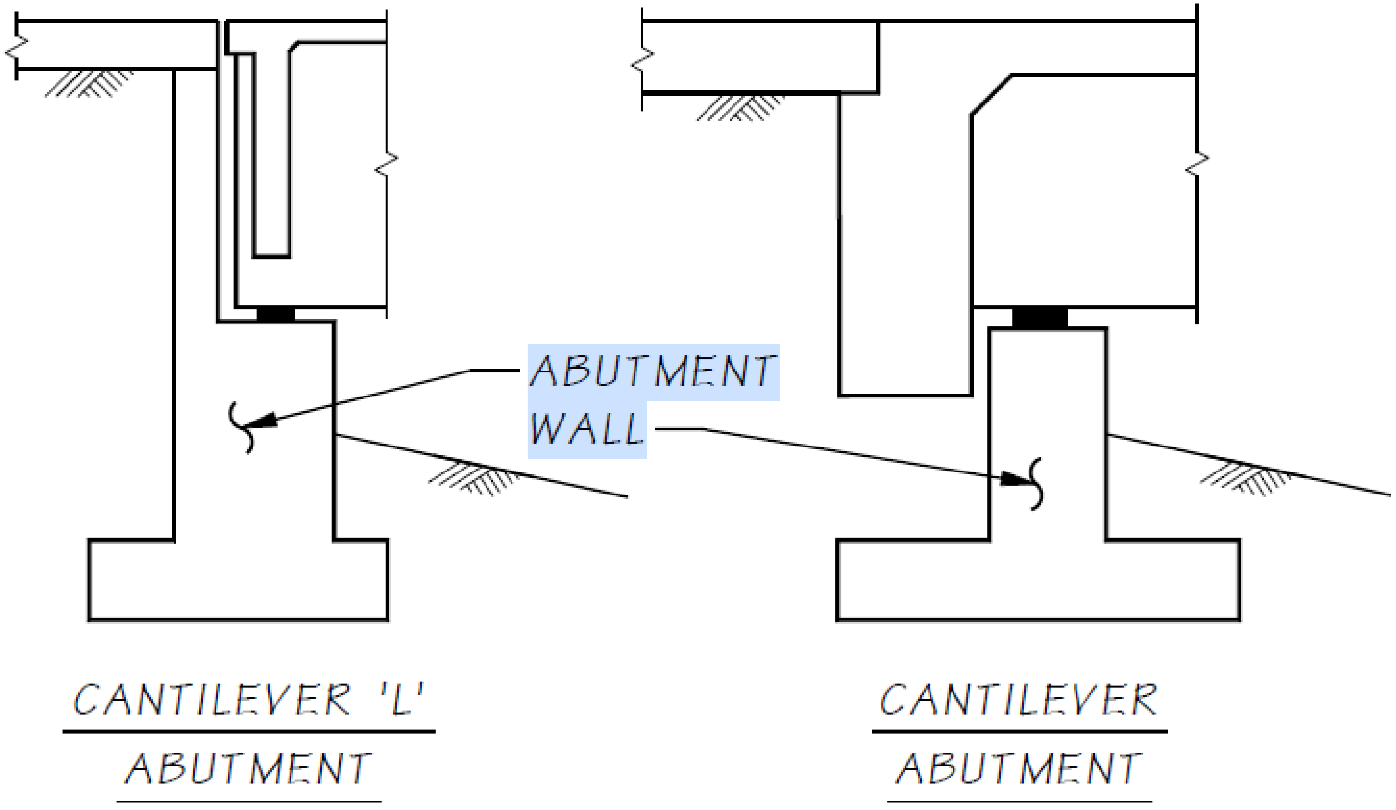
Case Studies: Isolated Bridge Abutment and Bridge Foundation

Geotechnical and Structural Design Considerations

Conventional Cast-in-Place (CIP) Reinforced Concrete Abutment Wall

WSDOT Bridge Design Manual M 23-50.19
July 2019

Figure 7.5.1-2 Cantilever Abutments



Mechanical Stabilized Earth (MSE) Wall

U. S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI-10-024
FHWA GEC 011 – Volume I
November 2009

NHI Courses No. 132042 and 132043

Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I

Developed following:

AASHTO LRFD Bridge Design Specifications, 4th Edition, 2007, with 2008 and 2009 Interims.

and

AASHTO LRFD Bridge Construction Specifications, 2nd Edition, 2004, with 2006, 2007, 2008, and 2009 Interims.

Pile/Drilled Shaft Supported Bridge Foundation Behind MSE Abutment Walls

Photo from WSP (Previous AMEC) Project 2013

Photo from Khodair and Hassiotis, 2005

Soil Nail

U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI-14-007
FHWA GEC 007
February 2015

NHI Course No. 132085

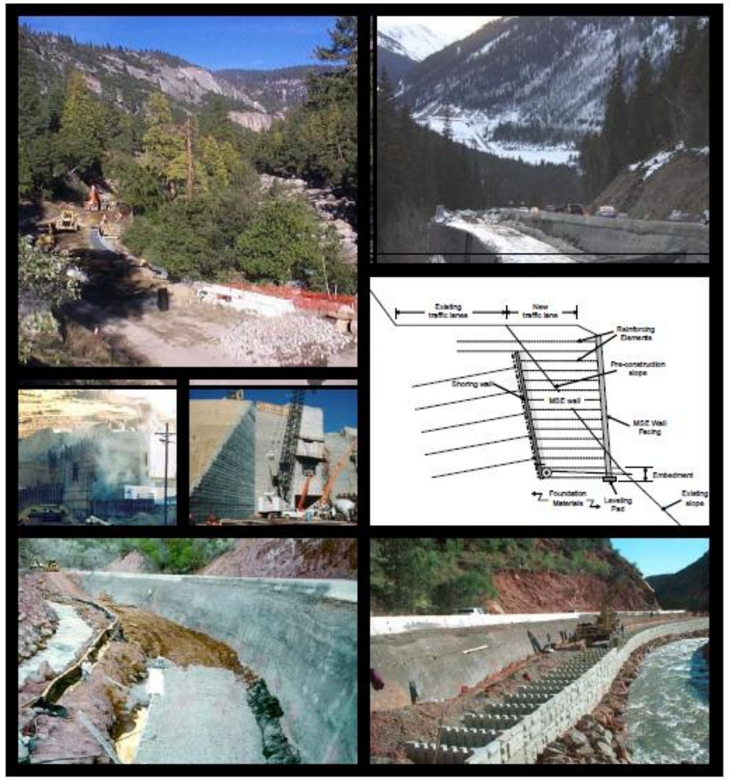
Soil Nail Walls Reference Manual

Developed following:
AASHTO LRFD Bridge Design Specifications, 7th Edition.

Shored MSE (SMSE) Walls

Shored Mechanically Stabilized Earth (SMSE) Wall Systems Design Guidelines

Publication No. FHWA-CFL/TD-06-001 February 2006



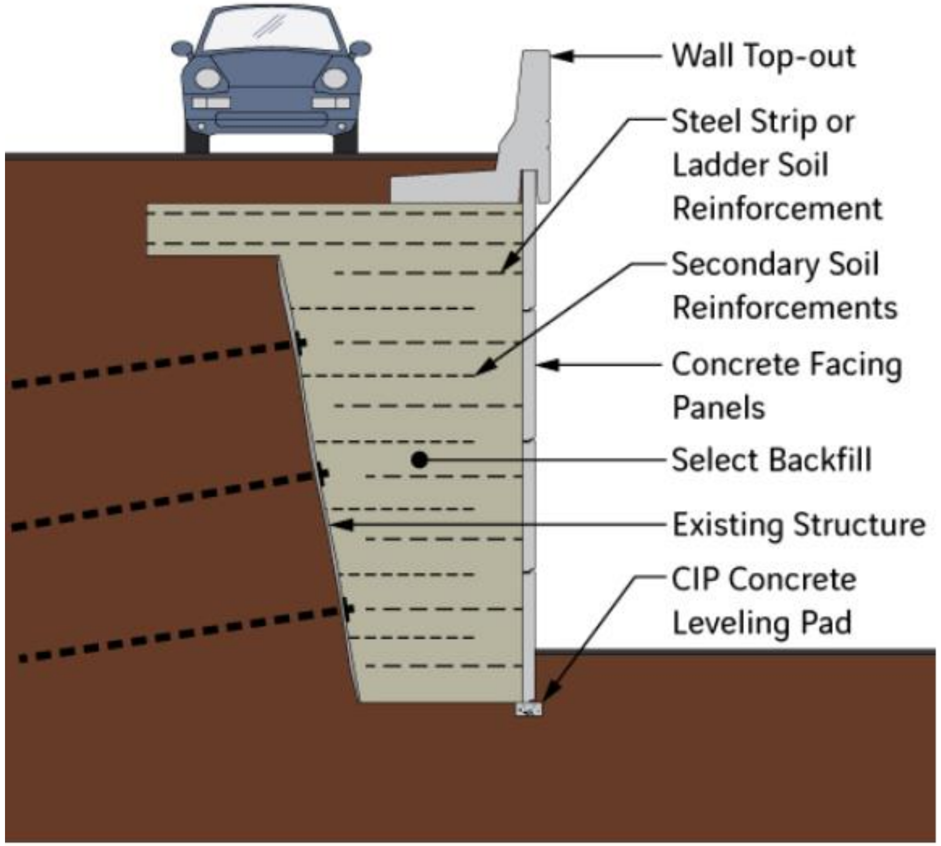
STGEC 2022
Daytona Beach, Florida
October 17-20, 2022

Shored MSE (SMSE) Walls

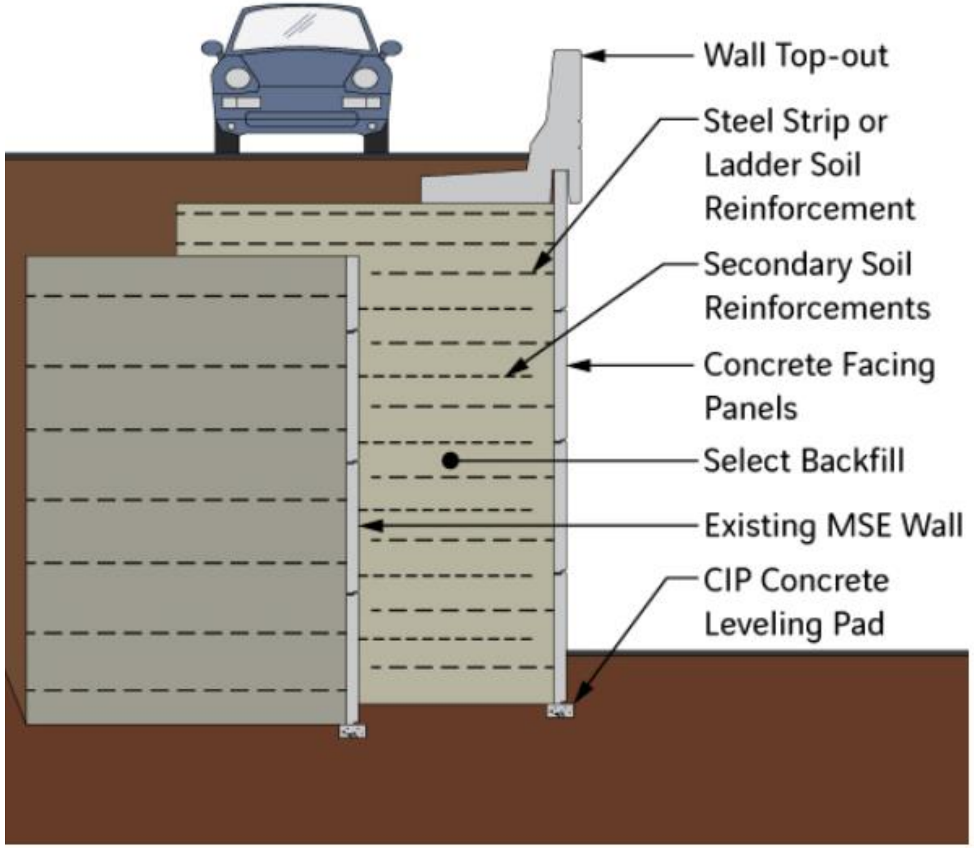
Cut / Fill / Widening

Shored Reinforced Earth® MSE Retaining Walls

(From: https://reinforcedearth.com/products/retaining-walls/special-design/)



Section: Basic shored MSE wall in front of existing soil nail wall.



Section: Basic shored MSE wall in front of existing MSE wall.

Bridge Abutment Walls (Underpass Widening)

"Combo" - Cut Soil Nail Wall/Soldier Pile & Lagging / Anchor Tiebacks/Mechanical Plate Anchors /Precast Panel Facia w/ Flowable Fill

SCDOT North Myrtle Beach Connector Project
(Schnabel Engineering Project, 2007)

FDOT I-10 Scenic Hwy Project
(Schnabel Engineering Project, 2006)

Geosynthetic Reinforced Soil (GRS) Wall

In Memory of *Prof. Jonathan T.H. Wu (1951 - 2020)*
University of Colorado Denver
Director of Reinforced Soil Research Center

Chou, N.N.S., *Wu, J.T.H.*: *Investigating Performance of Geosynthetic-Reinforced Soil Walls*, report no. CDOT-DTD-93-21, Colorado Department of Transportation *(1993)*

GRS Abutments

Combination of gravel and closely spaced layers of geotextile or geogrid; commonly w/o utilizing an approach slab

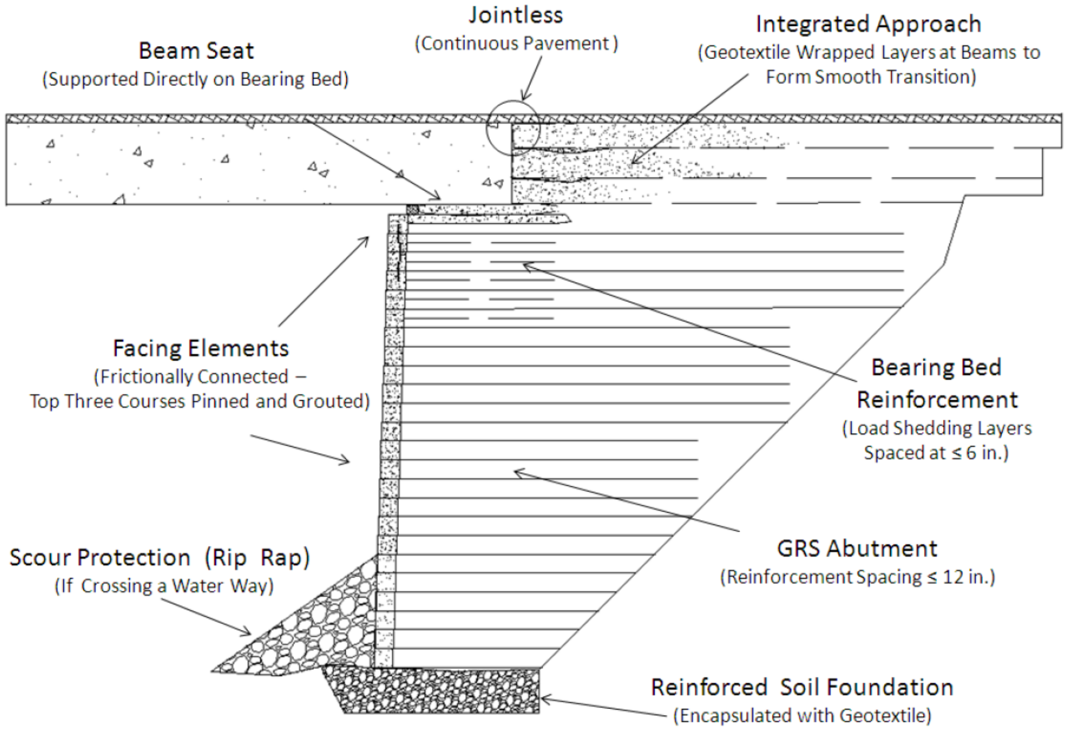


Figure 1. Illustration. Typical GRS-IBS cross section.

Geosynthetic Reinforced Soil (GRS) Wall

Geosynthetic Reinforced Soil
Integrated Bridge System
Interim Implementation Guide

PUBLICATION NO. FHWA-HRT-11-026 JUNE 2012

Integrated Bridge System (GRS-IBS); GRS Abutments

Cost effective; esp. for bridge supported on shallow foundations

*How to **reduce** lateral earth pressures acting on bridge abutment walls?*

STGEC 2022
Daytona Beach, Florida
October 17-20, 2022

Retaining Walls with Lightweight Fill

(Lightweight Fill/Aggregate, Geofoam, etc.)

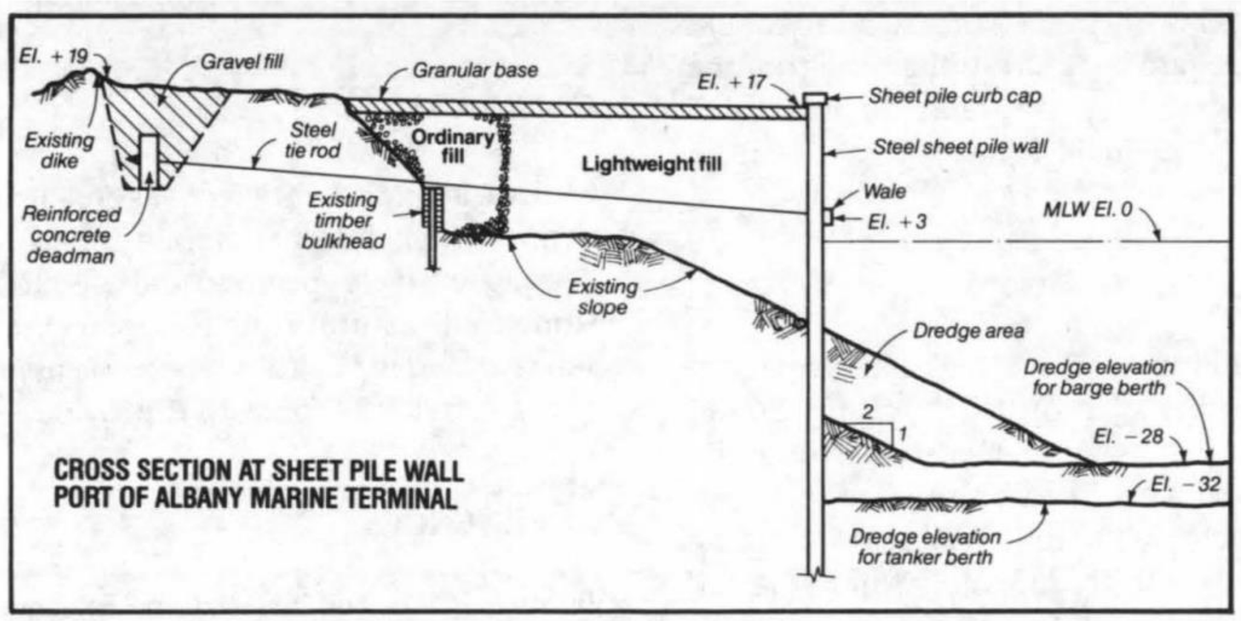


FIGURE 6 Rehabilitation of port of Albany, N.Y., marine terminal.

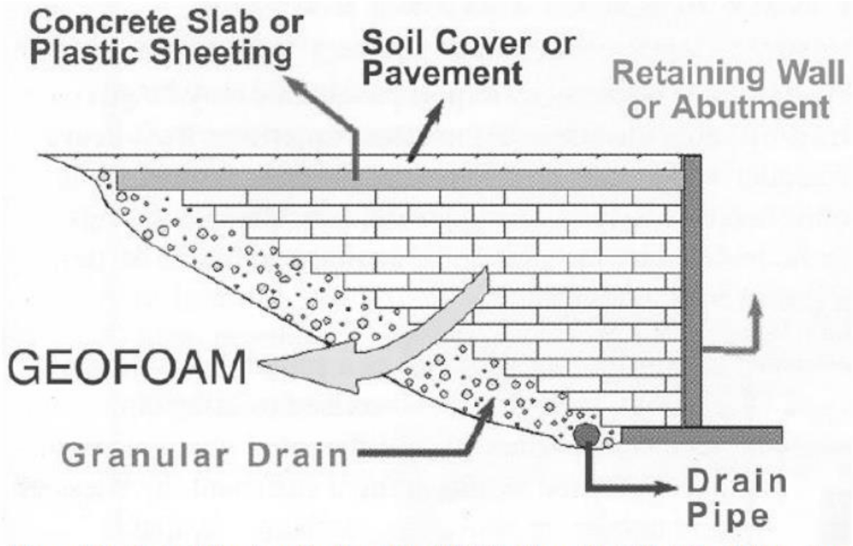
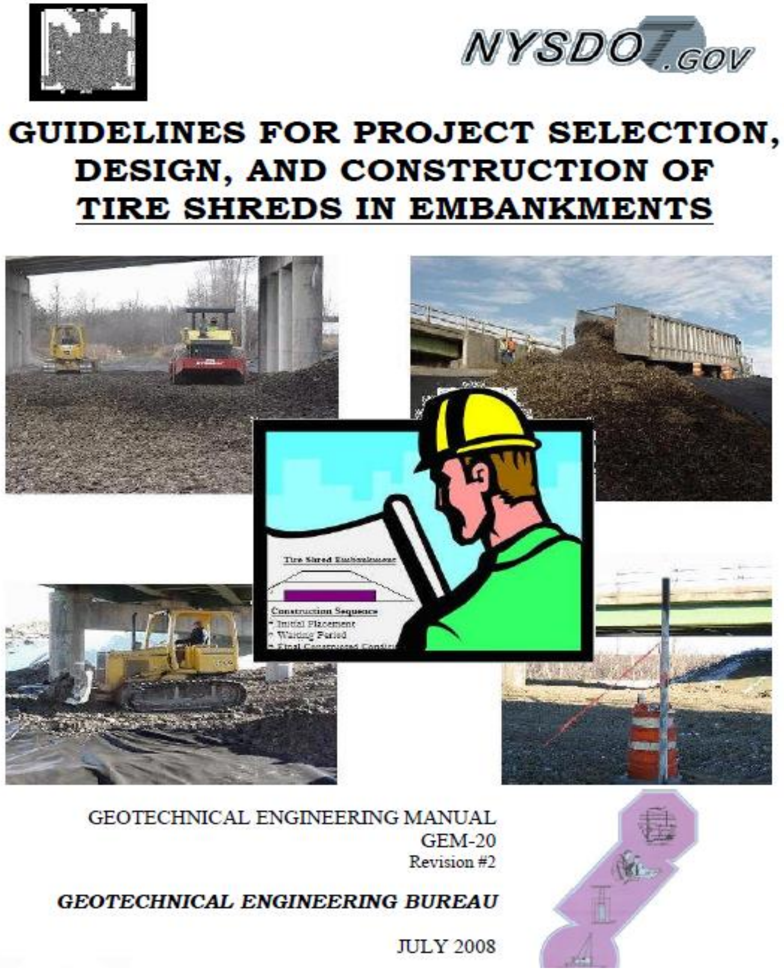


Figure 2.3. Typical Construction Detail for EPS GeoFoam Backfilled Earth Retention Structure (from Negussey 1997)

Resources: https://cee.umass.edu/sites/default/files/cee/full-scale_pilot_study_to_reduce_lateral_stresses_in_retaining_structures_using_geofoam.pdf (2009)
https://onlinepubs.trb.org/Onlinepubs/trr/1993/1422/1422-002.pdf

Retaining Walls with Shredded Tire Fill



NYSDOT.GOV

GUIDELINES FOR PROJECT SELECTION, DESIGN, AND CONSTRUCTION OF TIRE SHREDS IN EMBANKMENTS

GEOTECHNICAL ENGINEERING MANUAL
GEM-20
Revision #2

GEOTECHNICAL ENGINEERING BUREAU

JULY 2008

FINAL REPORT

FIELD STUDY OF A SHREDDED-TIRE EMBANKMENT IN VIRGINIA

Edward J. Hoppe, Ph.D., P.E.
Senior Research Scientist
Virginia Transportation Research Council

W. Grigg Mullen, Ph.D., P.E.
Professor
Virginia Military Institute

April 2004
VTRC 04-R20

SSRG International Journal of Civil Engineering (SSRG – IJCE) – Volume 5 Issue 12 – December 2018

Reduction of Dynamic Earth Pressure on Retaining Wall Backfilled with STC: A Review

[1]Samreen Bano, [2]Dr. Sabih Ahmad

[1]M.tech Student, Department of Civil Engineering, Integral University, Lucknow, Uttar Pradesh, 226026,India.
[2]Associate professor, Department of Civil Engineering, Integral University, Lucknow, Uttar Pradesh, 226026,India.

*How to **relieve (eliminate)** lateral earth pressures acting on bridge abutment walls?*

Reinforced Earth Structures to Relieve Walls of Earth Pressure (Raithel, et al. 2012)

(https://www.kup-geotechnik.com/media/140625_10icg_earthpressure.pdf)

"… reduce the earth pressure … wrap back geotextile reinforced earth structures (GRE). …. earth pressure can be reduced to zero, <u>leaving a gap (4 to 20 inches) in between wall and GRE.</u> ….. horizontal (wall) deformations …maximum around 2 cm for the 10 m high GRE (0.2%H)…."

Figure 8. 14 m high earth pressure relief at an office building using GRE to leave a gap between earth embankment and wall

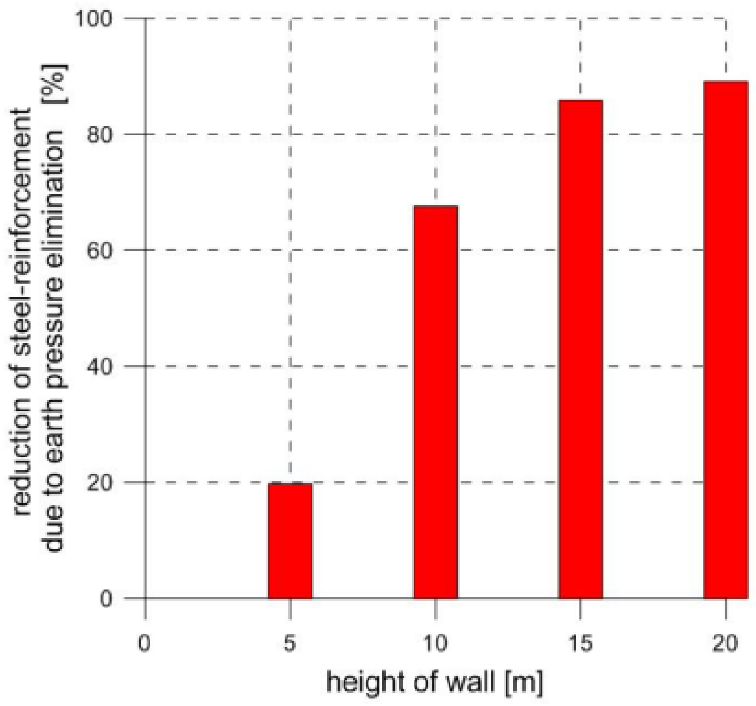
Reinforced Earth Structures to Relieve Walls of Earth Pressure (Raithel, et al. 2012)

(https://www.kup-geotechnik.com/media/140625_10icg_earthpressure.pdf)

Cost-Effectiveness

Reduction of steel-reinforcement

>60% for wall heights >30 feet



SCAN TEAM REPORT
NCHRP Project 20-68D, Scan 19-01

Leading Practices for Detailing Bridge Ends and Approach Pavements To Limit Distress and Deterioration

Supported by the
National Cooperative Highway Research Program

PREPARED BY

Jason DeRuyver, P.E.
Michigan DOT, Chair

Devan Eaton, P.E.
Maine DOT

Romeo Garcia
Federal Highway Administration

Bijan Khaleghi, Ph.D., P.E., S.E.
Washington State DOT

Ted A. Kniazewycz, P.E.
Tennessee DOT

Adam Lancaster, P.E.
Louisiana DOTD

Jill Walsh, Ph.D., P.E.
Saint Martin's University, Subject Matter Expert

SCAN MANAGEMENT

Arora and Associates, P.C.
Lawrenceville, NJ

October 2020

Soil reinforcement can be used to improve the approach embankment. Caltrans' End Bent with Isolated MSE abutment type is shown in **Figure 36**. **Figure 86** shows the 6 inch layer of TPB (treated permeable base) Caltrans uses under the approach slab.

WSDOT: An option to reduce seismic load from approach fill to abutment's wall is to isolate the fill with isolated abutments by providing a six-foot gap between the soil and the abutment wall. **Figure 99** shows an isolated abutment with a separate retaining system to support the embankment. **Figure 100** shows a similar concept but with a fascia wall to provide separation

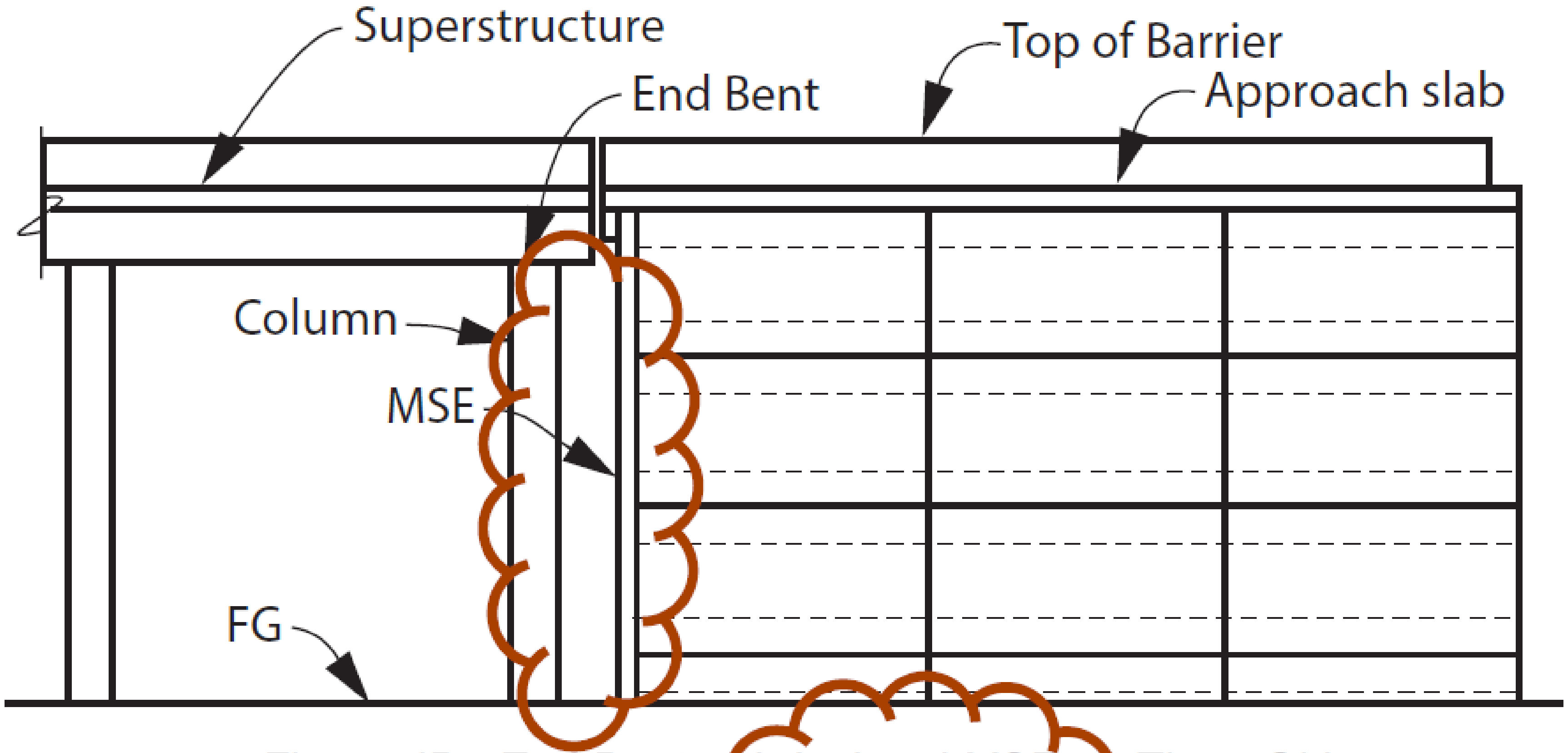


Figure 4B - End Bent with Isolated MSE on Three Sides

Figure 4 - Application of MSE at Bridge Approaches

Design Considerations for Isolated Bridge Abutment

Ct LRFD

MEMO TO DESIGNERS 5-1 • MARCH 2017

"An adequate gap is required to accommodate bridge movements … No special design is required for either the abutment or MSE …"

"The gap … must be wide enough to avoid contact of the two isolated structures due to movements caused by earthquakes."

Question

What is the "adequate gap / wide enough"?

Maximum Gap

WSDOT Bridge Design Manual M 23-50.20
September 2020

Figure 7.5.1-4 Bent-Type Abutment

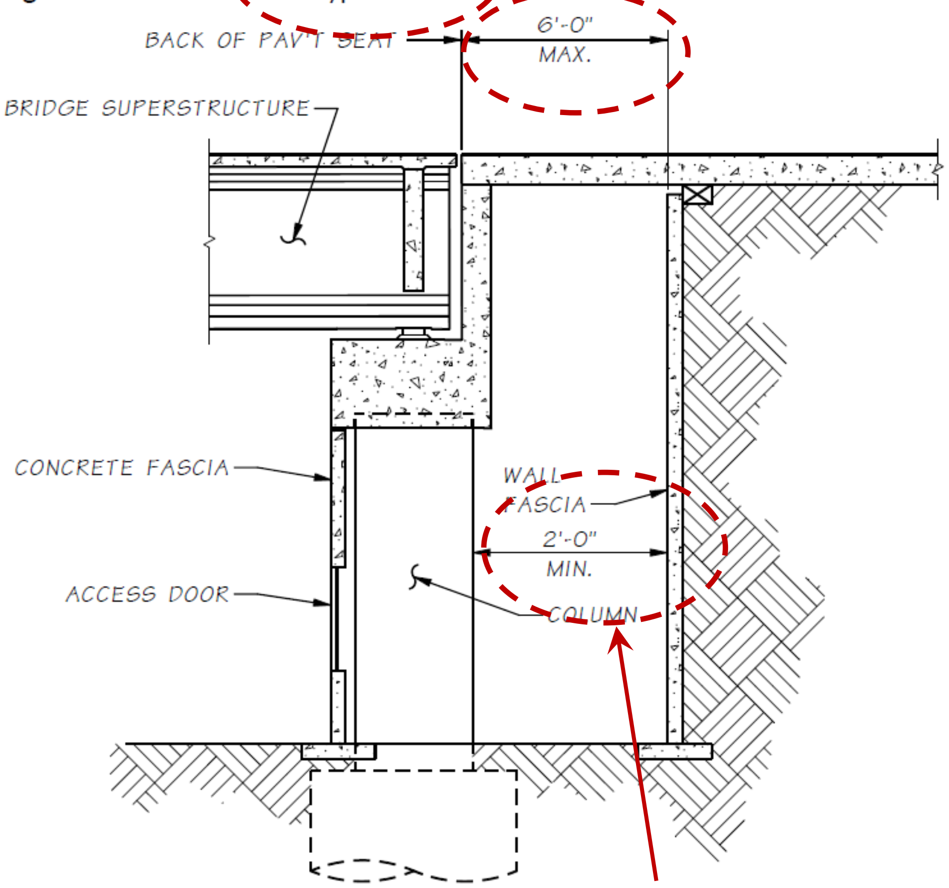
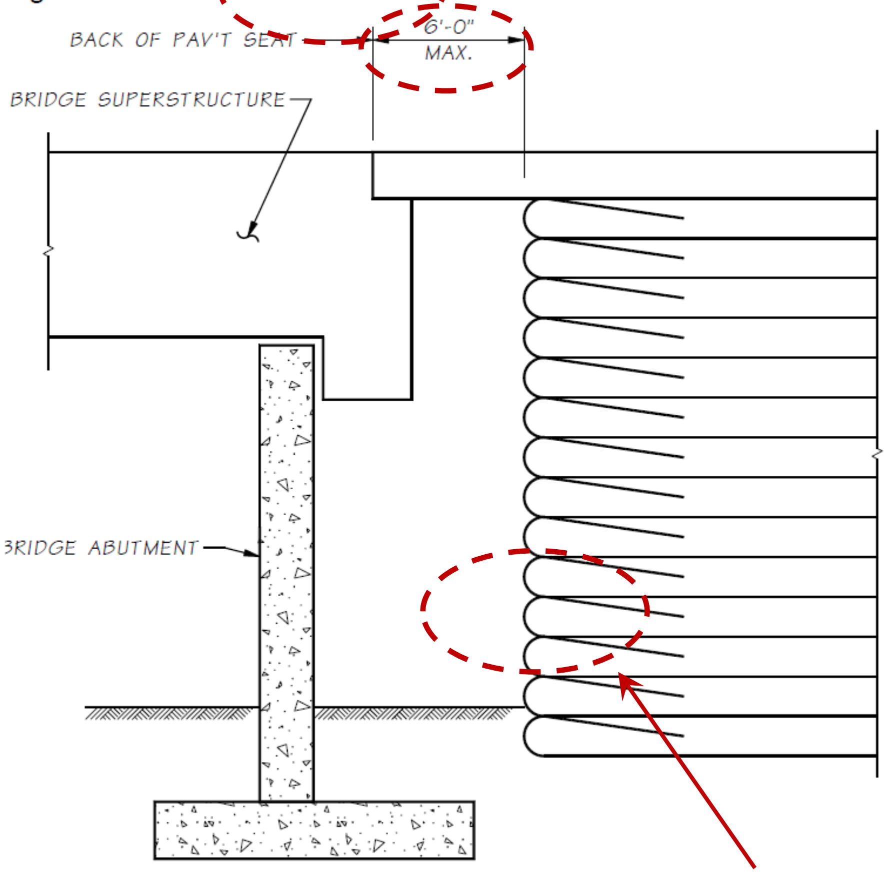


Figure 7.5.1-5 Isolated Abutment



Minimum Gap

GRS

WSDOT Bridge Design Manual M 23-50.20
September 2020

"The **gap** … **shall not be less than 6 inches**. ….. **The approach embankment wall does not require a fascia**."; "**The minimum gap** between the back of the columns, piles, or shafts and the retained structure **shall be 2'-0" to allow for inspection access**."

Question

Why "max. 6-ft clear span (air gap)"?

Figure 7.5.1-4 Bent-Type Abutment

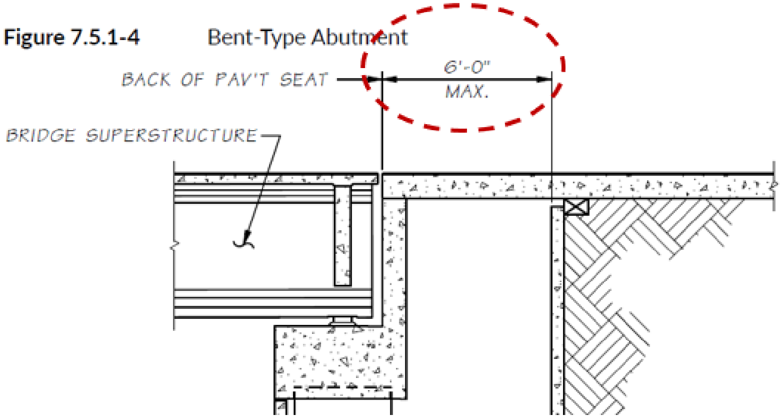
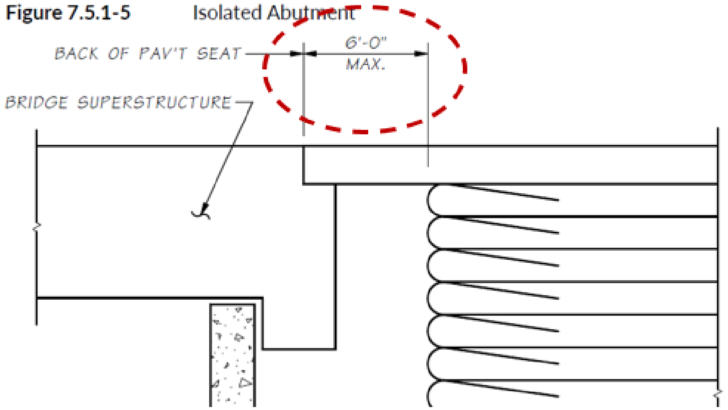


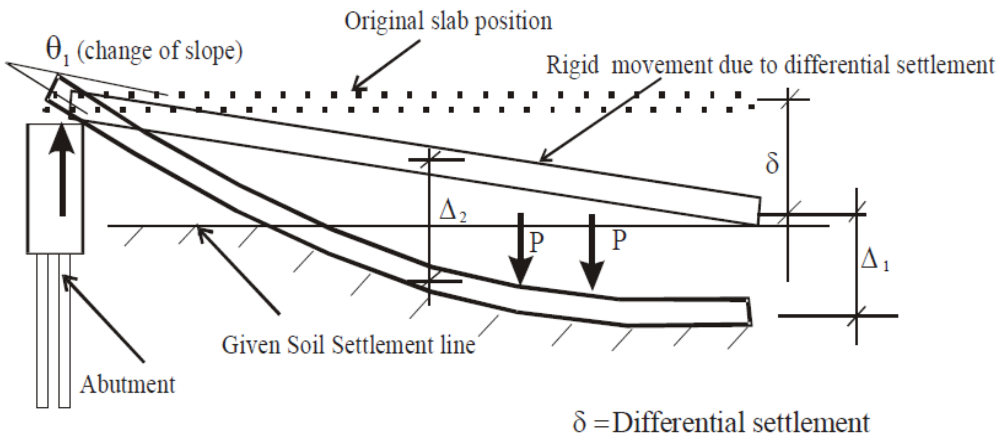
Figure 7.5.1-5 Isolated Abutment



Design Considerations for Isolated Bridge Abutment

Requiring a bridge approach structural slab

- **max. 6'-0" Clear Span (Air Gap)**
- **Optimize slab structural design; consider embankment settlements (static & post-earthquake)**
- **Provide inspection access**



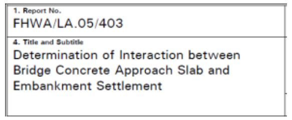

1. Report No.
FHWA/LA.05/403
4. Title and Subtitle
Determination of Interaction between Bridge Concrete Approach Slab and Embankment Settlement

Figure 1

Illustration of approach slab and its interaction with soil

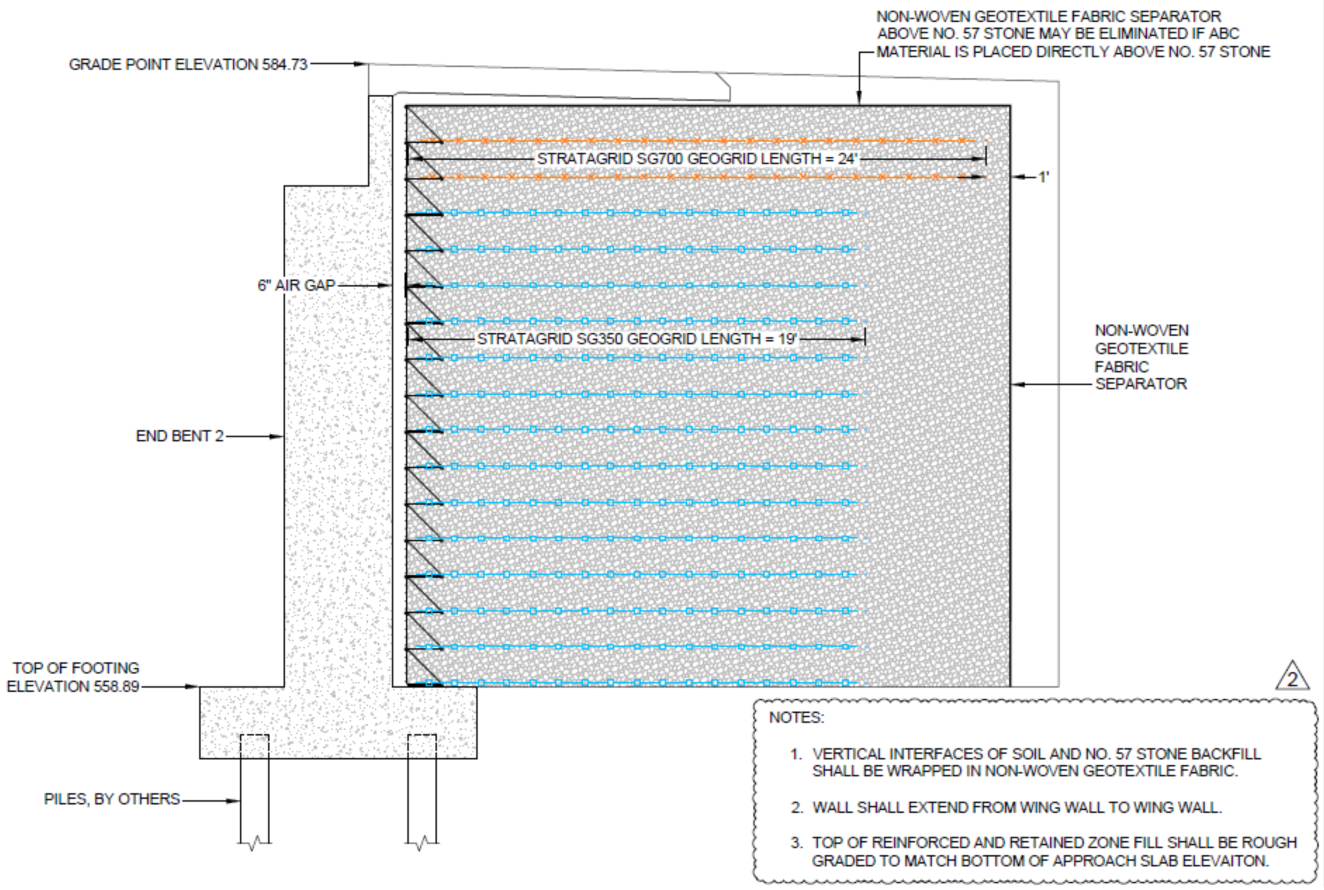
WSDOT BDM (2020)

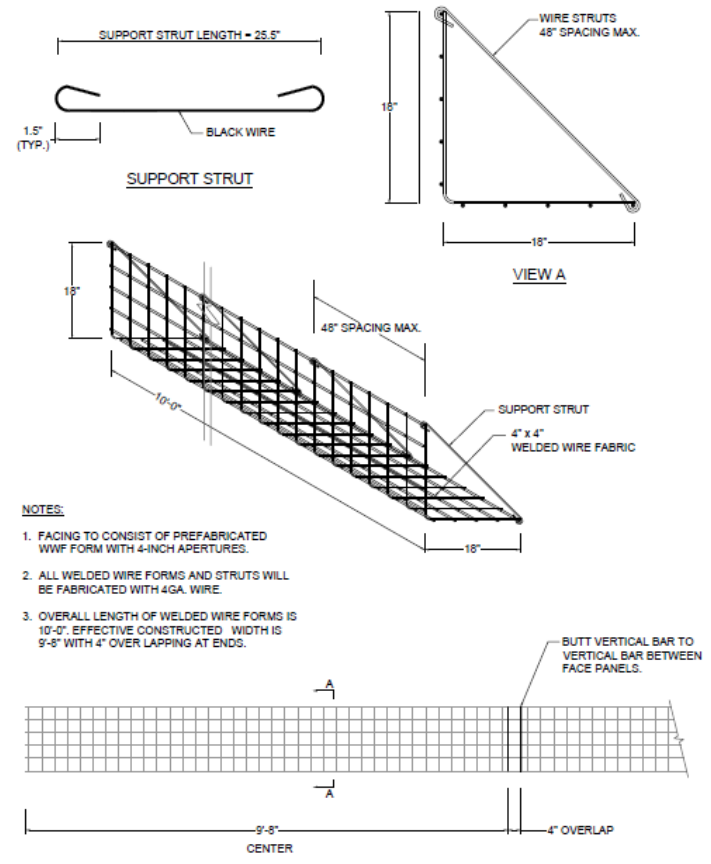
"The approach slab shall be designed as a beam pinned at the back of pavement seat. The approach slab shall support traffic live loads and traffic barrier reactions."

Project Case Study (1)

Charlotte, North Carolina
USA

Isolated Wired Basket Facing Wall w/ 6" Air Gap





(Drawings prepared by ECS for STV/WSP project 2022)

Pile-Supported Bridge Abutment Wall (Constructed First)

(Photo Taken by WSP 2022)

Wired Basket Facing Reinforced Earth Wall (Constructed Next)

(Photo Taken by WSP 2022)

Project Case Study (2)

Seattle, Washington
USA

I-405 Bellevue to Renton Express Toll Lanes Design-Build Project

Client
Washington DOT
Flatiron/Lane JV

Location
King County, Washington

Project Duration
2019-present

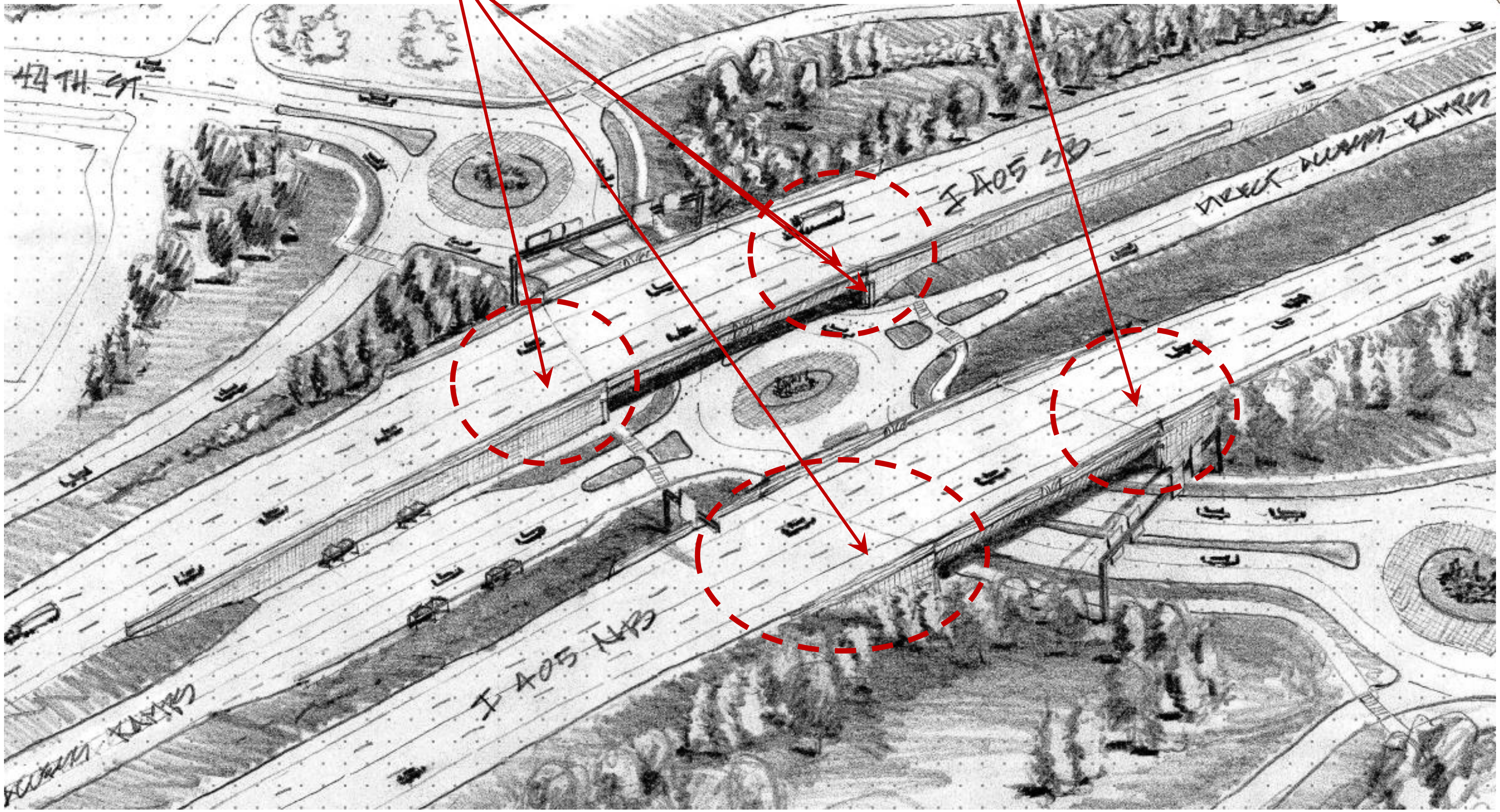
Contract Value
$705 Million

WSP Role: Design Prime Team Member

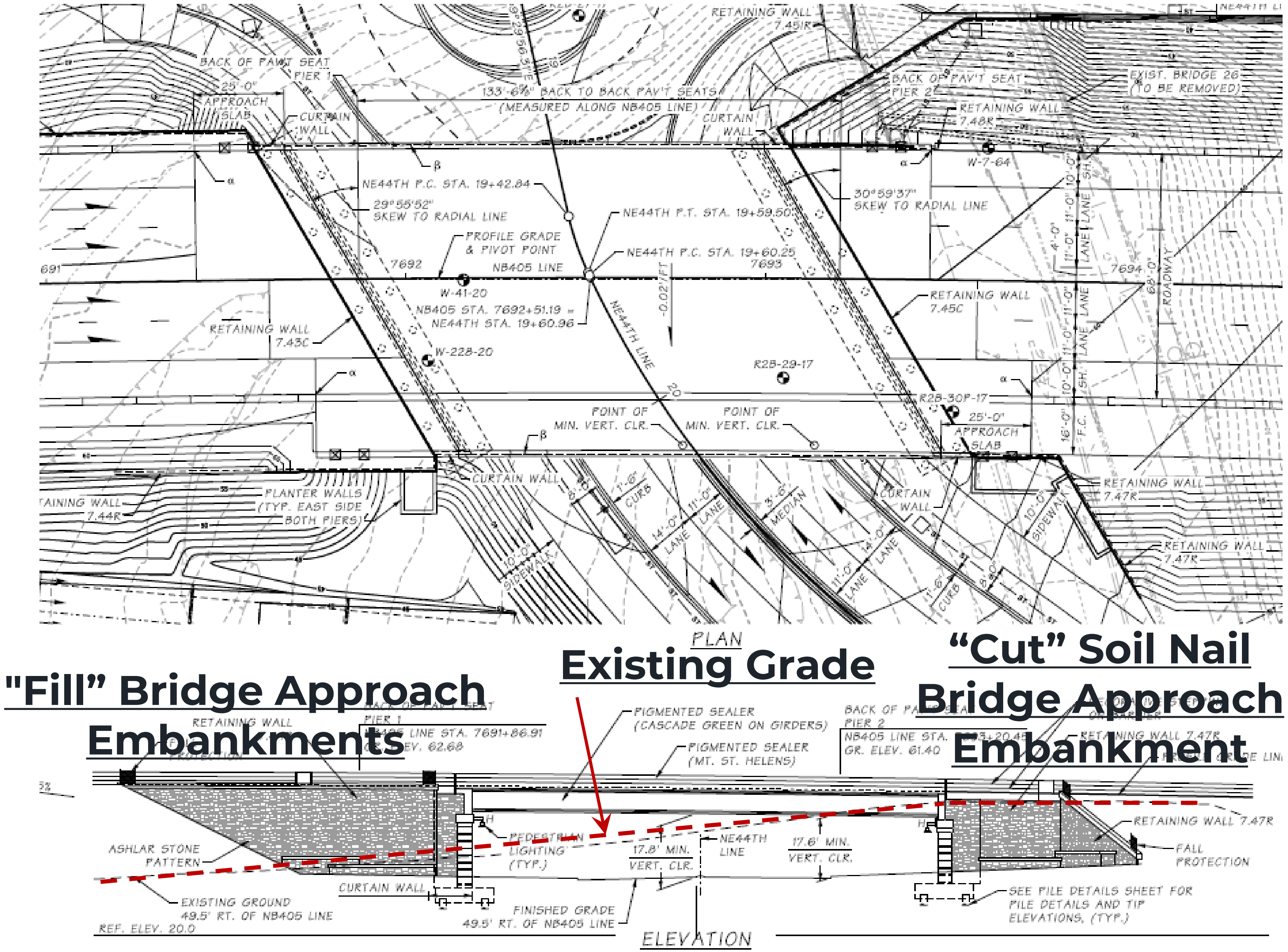
- Geotechnical/Structural/Civil/ Roadway Design Leads
- Environmental (Fish passage and stream restoration)

"Fill" Bridge Approach Embankments

"Cut" Soil Nail Bridge Approach Embankment



(Sketched by WSP 2022)



(Drawings prepared by WSP 2022)

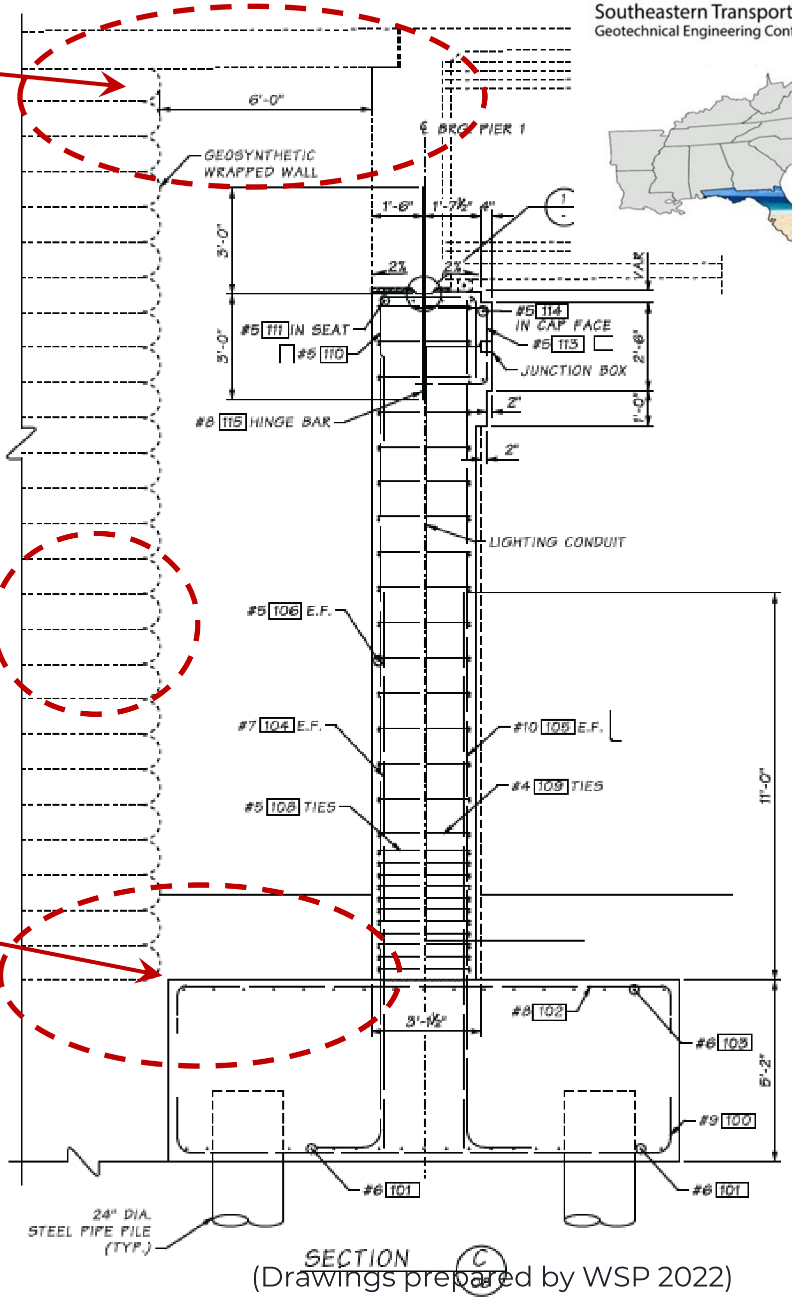
Design Air Gap 6’-0”

Consider long term(static & Post-earthquake) embankment settlements; allow bridge approach slab spanning max. 17'-0" between the back of pavement seat and the bridge abutment wall.

GRS Wall / Wired Basket Wall

Keep Embankment Footprint Outside of Bridge Abutment Wall Pile Cap

Reduce vertical loading on pile; consider lateral pressures acting on the side of pile cap due to surcharge effect.



(Drawings prepared by WSP 2022)

“Cut” Bridge Approach Embankment
Site Preparation

(Photo Taken by WSP 2022)

STGEC 2022
Daytona Beach, Florida
October 17-20, 2022

“Cut” Bridge Approach Embankment

Bridge Foundation Piles Installed First

(Photo Taken by WSP 2022)

"Cut" Bridge Approach Embankment

Bridge Foundation Piles Installed First

(Photo Taken by WSP 2022)

“Cut” Bridge Approach Embankment

Soil Nail Wall Constructed Next

(Photo Taken by WSP 2022)

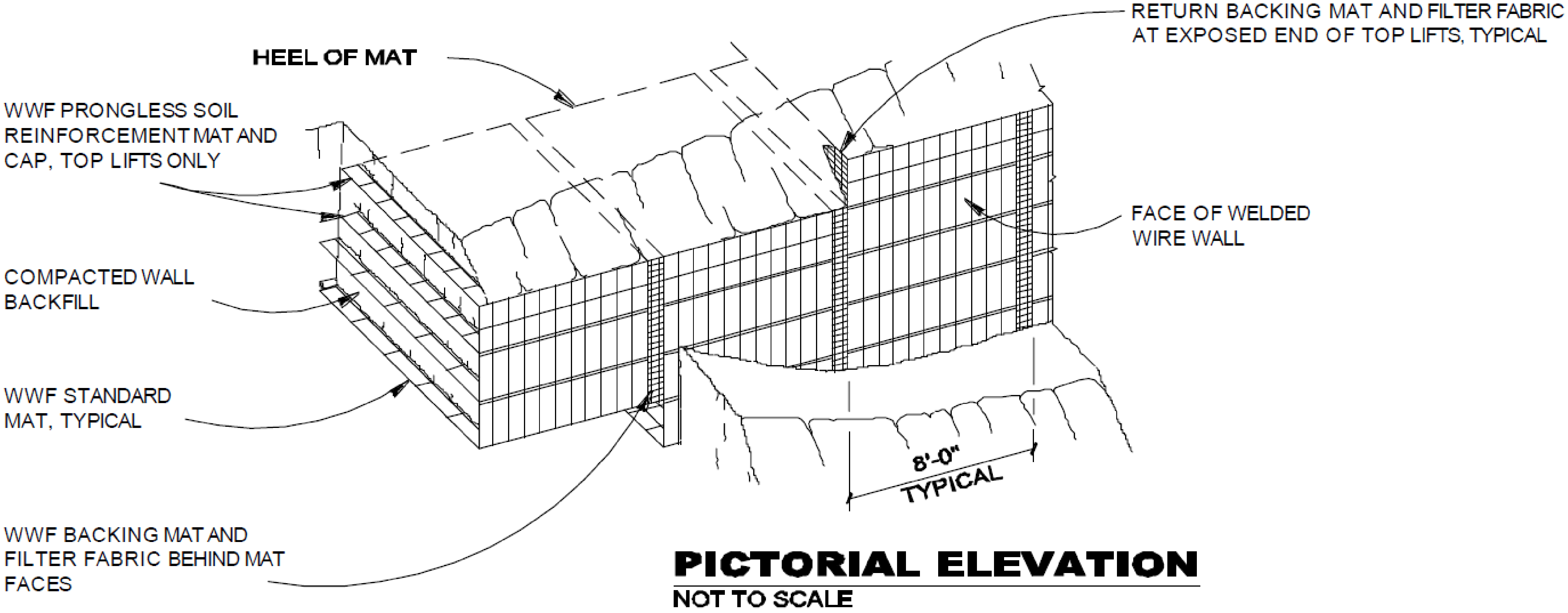
“Fill” Bridge Approach Embankment

Bridge Foundation Piles Installed First

(Photo Taken by WSP 2022)

“Fill” Bridge Approach Embankment

Wired Basket Wall Constructed Next, w/o Structural Facia



(Drawings from Hilfiker 2021)

Isolated Bridge Abutment and Bridge Foundations

Pros

- Eliminate earth pressures acting on bridge abutment wall.
- Reduce compressive loading demand and potential downdrag on foundation piles; esp. for walls w/ greater heights and seismic loading.
- Do not require a fascia for the isolated embankment, though require curtain walls to hide the air gap.
- Construction time efficiency / schedule flexibility

Isolated Bridge Abutment and Bridge Foundations

Cons

- Require the bridge approach slab designed as a structural element; by considering the air gap and long-term embankment settlements (static & post-earthquake).
- Bridge foundation piles may require additional PDA/CAPWAP evaluation to verify design required tension/uplift resistance (subject to seismic loading).

Further Considerations

- Is a single-span bridge with isolated abutments still a single- span bridge for seismic considerations?
- Future inspection access
- Form work / Falsework for approach slab at gap

Thank you

wsp.com

STGEC 2022
Southeastern Transportation
Geotechnical Engineering Conference