Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) for Transportation Bridge Construction

Michael Adams & Jennifer Nicks, Ph.D., P.E.
Federal Highway Administration

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U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank
Highway Research Center

Agenda

- Background and overview
- Materials
- Fundamental design principles
- Construction procedures
- In-service performance
- Research and development
- Q/A and discussion time

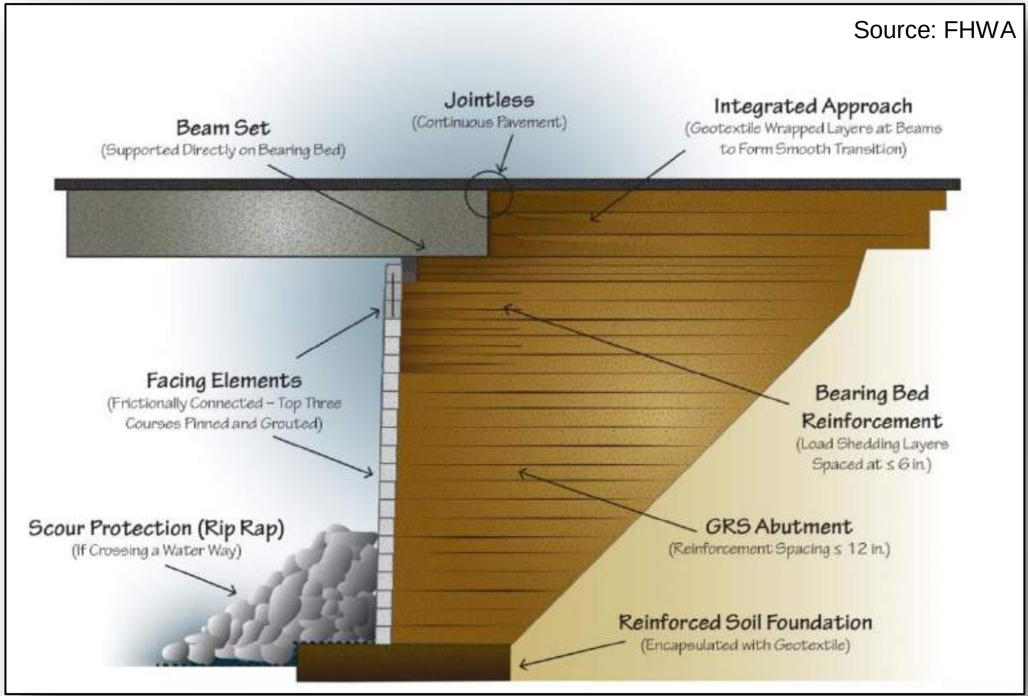
GRS-IBS for Transportation Bridge Construction

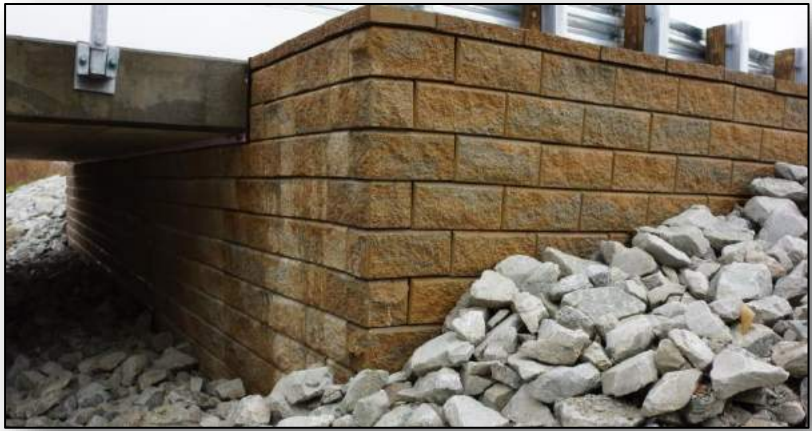
Source: FHWA.

Background and Overview

What is GRS-IBS?

- Accelerated bridge construction technique.
- Utilizes compacted, granular fill and geosynthetic reinforcement in alternating layers.





Source: Hamilton County, IN

Source: Hamilton County, IN

Three Main Components

GRS - Composite Material

Concrete

- Aggregate
- Water
- Cement

GRS

- Aggregate
- Closely-spaced geosynthetics

All images source: FHWA

GRS - Composite Behavior

MSE GRS

S_v = 32” 28” 24” 20” 16” 12” 8” 4”

All images source: FHWA.

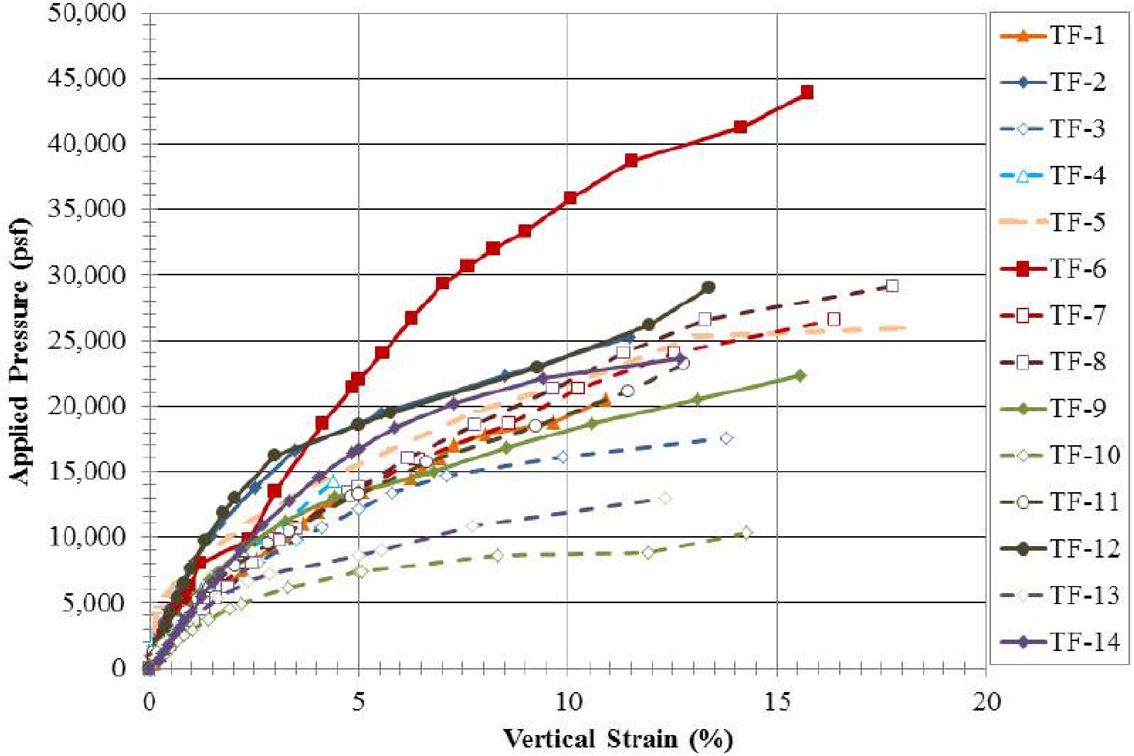
S_v = 16” S_v = 8” S_v = 4”

S_v = vertical reinforcement spacing.

GRS IBS - Composite Design

GRS Abutment

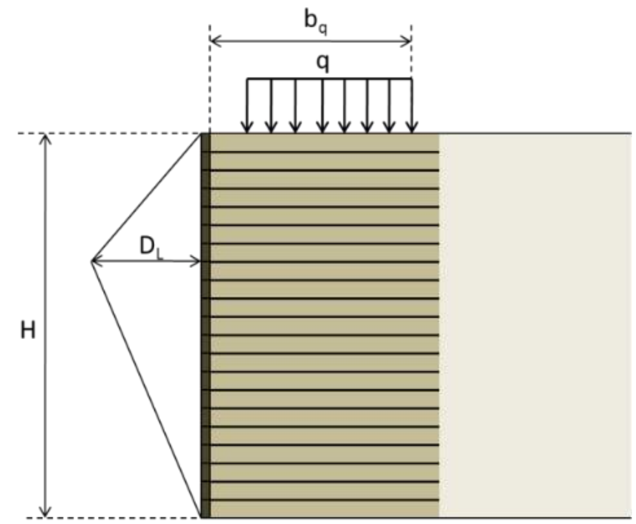
- Geosynthetic reinforcement provides tensile strength and added compressive strength
- Facing, as well as spacing and properties of reinforcement play a role in strength and serviceability



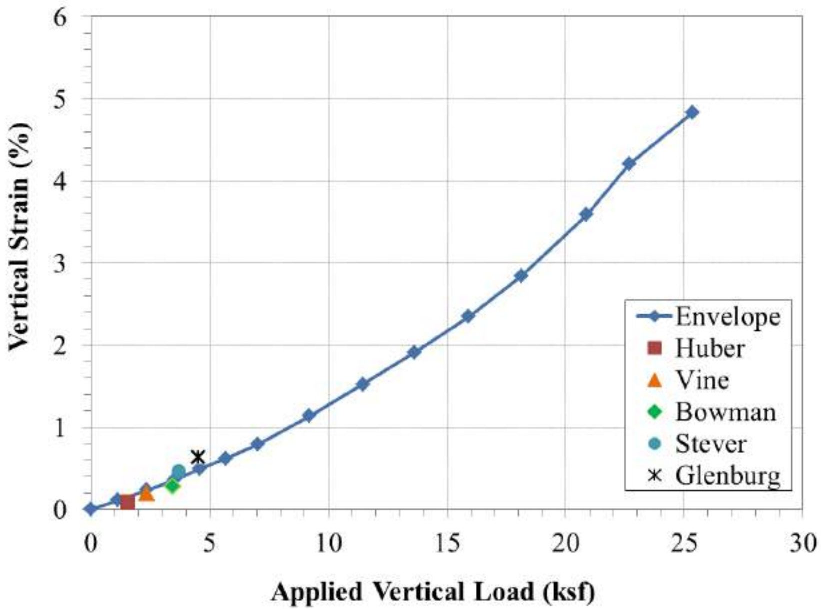
Source: FHWA

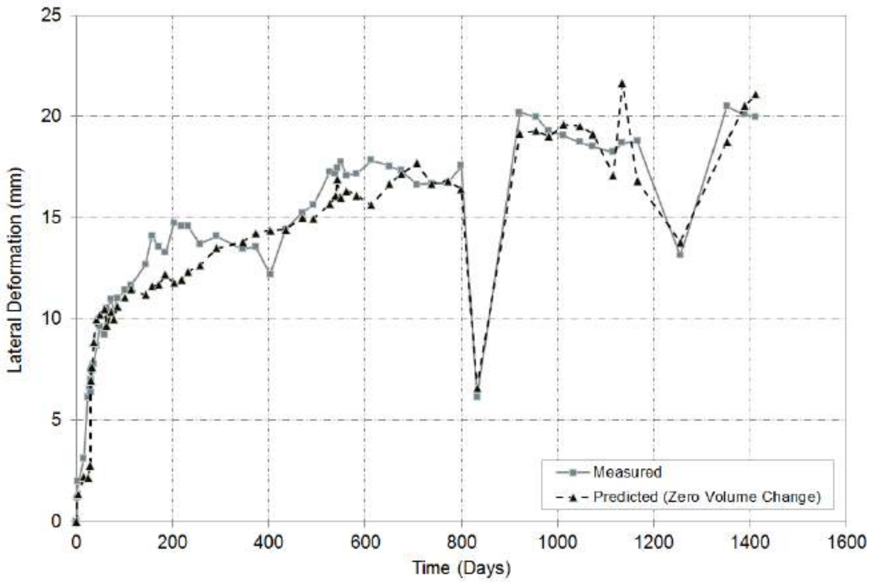
Performance Test Applicability to Bridges

- Predictable settlement
- Assuming zero-volume change, lateral deformation can be estimated



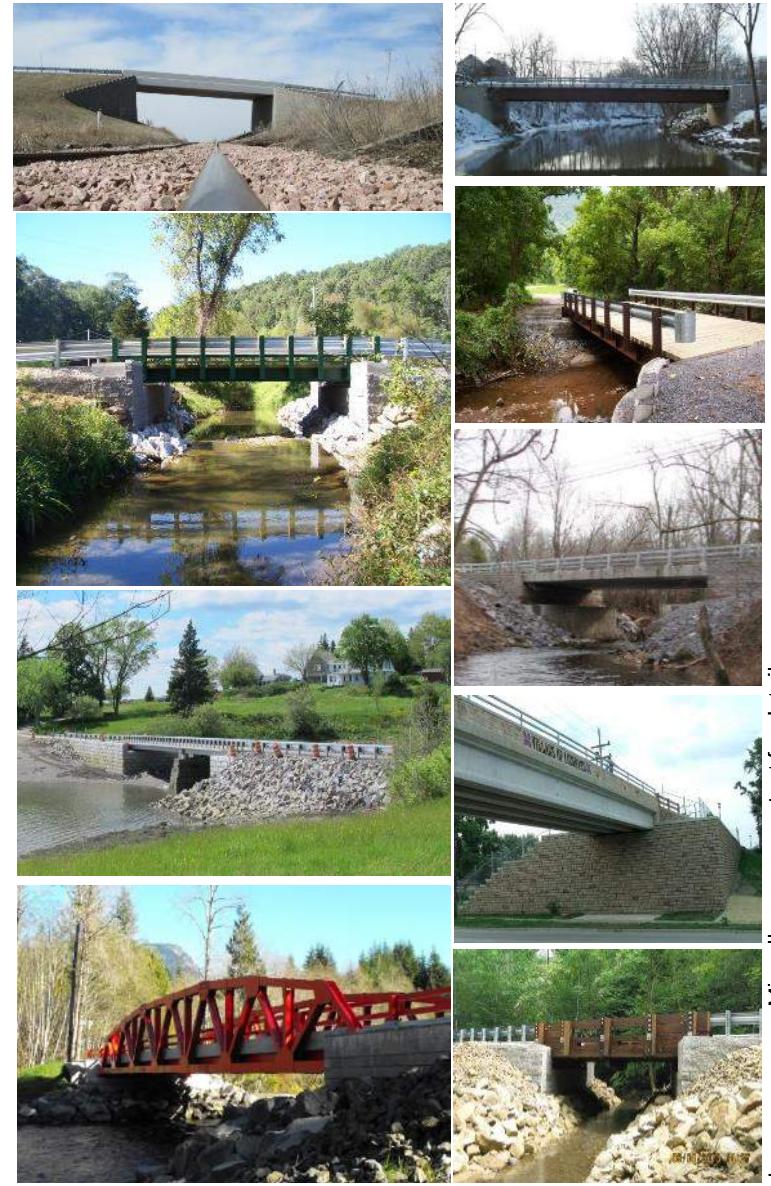
All images source: FHWA





Why Consider the GRS-IBS?

- Up to 60% lower costs
- Accelerated bridge construction
- No specialized labor required
- Use of readily available tools and equipment
- Simple design
- Smooth transition eliminating the “bridge bump”



Images source: Miscellaneous; contact for details.

Potential Alternative or Replacement for:

- Concrete abutments
- Spread footings
- Deep foundations
- Culverts
- True MSE abutments

Source: FHWA

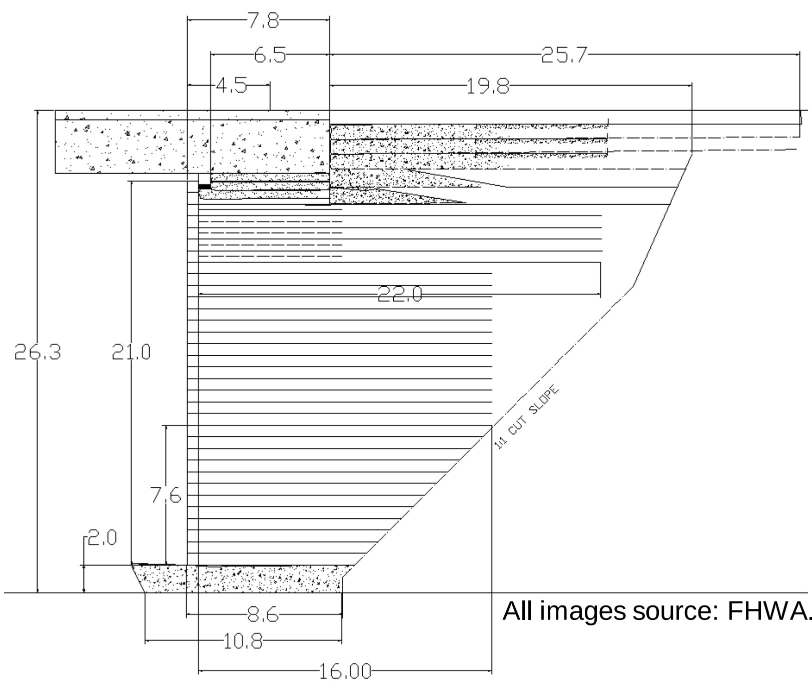
Source: Defiance County, OH

Source: FHWA

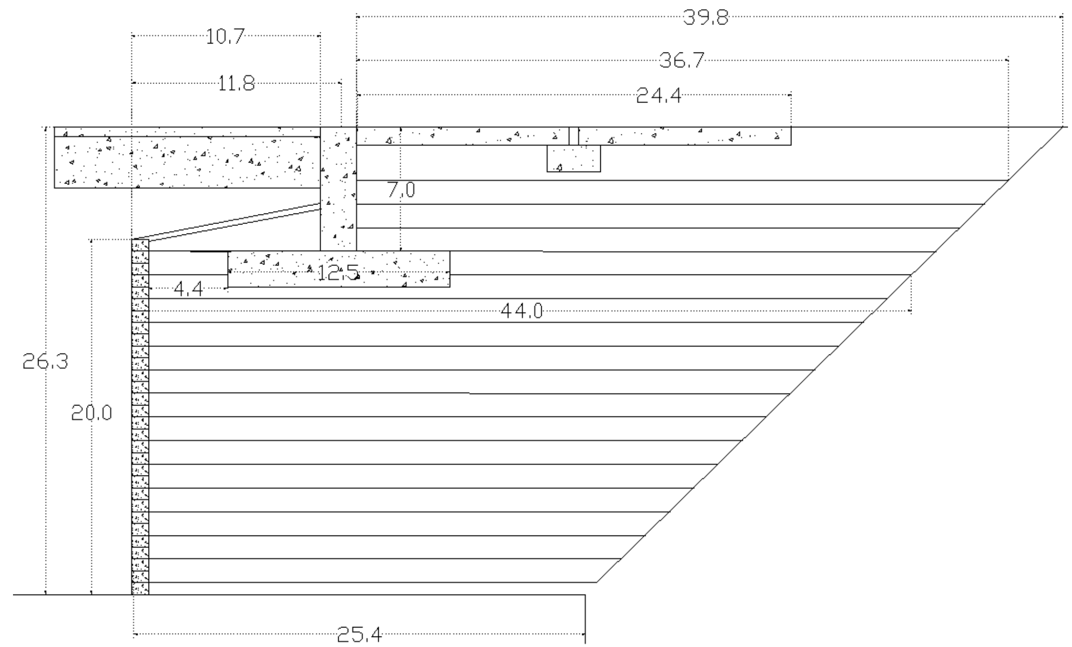
Comparative Design: GRS vs. GMSE Founders Meadows Bridge, Colorado

FHWA-HRT-17-080

AASHTO (2010)



All images source: FHWA.



GRS Material Cost = $185K

GMSE Material Cost = $570K

GRS-IBS for Transportation Bridge Construction

Source: Hamilton County, IN.

Materials

U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center

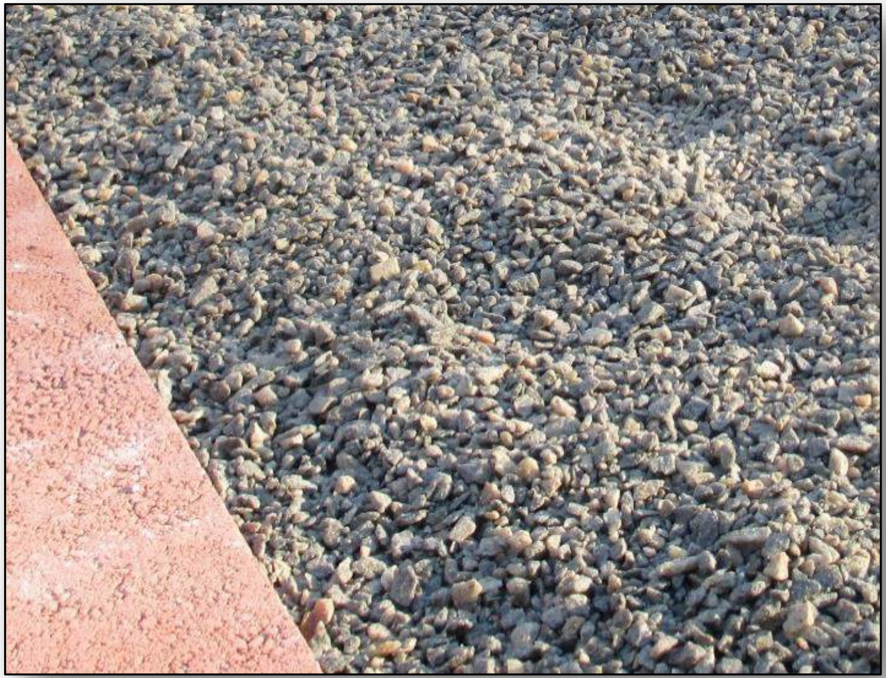
GRS-IBS - Primary Materials

Source: FHWA

Reinforced Fill Materials

Structural Backfill

Open-Graded



Well-Graded

All images source: FHWA

Geosynthetics

Reinforcement

Geogrids

Source: FHWA

Geotextiles

Source: DE DOT

Facing Types

Source: Utah DOT

Source: Scott County, IA

Source: PennDOT

Source: Town of North Haven, ME

Source: Colorado DOT

Facing Blocks

Source: Utah DOT

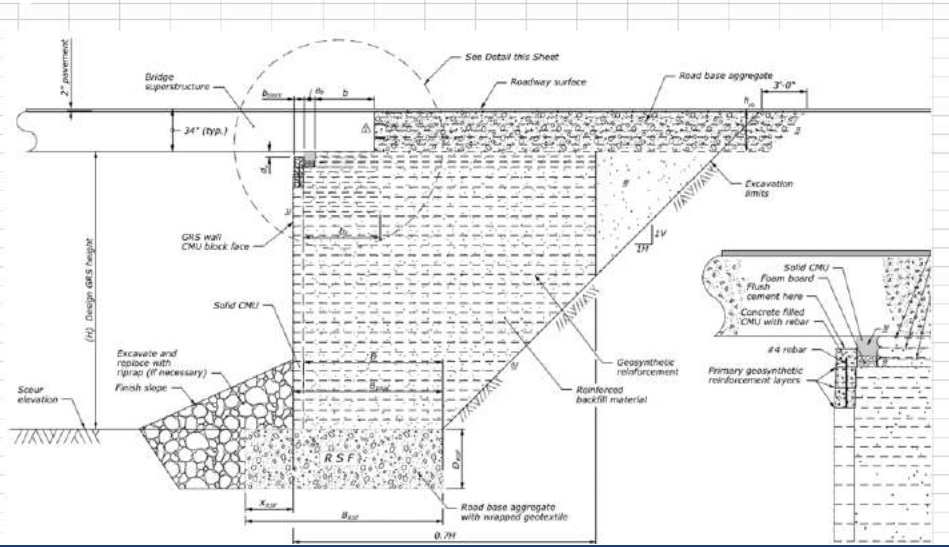
Source: DE DOT

Source: DE DOT

Source: WisDOT

GRS-IBS for Transportation Bridge Construction

2	Abutment Geometry:				Soil Parameters			
3	Abutment Height	H	6.9	ft	Foundation Soils, Friction Angle	ϕ_f'	34	degree
4	Base Width of Wall (including wall facing)	B_{wT}	6.0	ft	Foundation Soils, Cohesion	c'_f	-	psf
5	Reinforcement Spacing	S_v	8	in	Foundation Soils, Unit weight	γ_f	110	pcf
6	Base Width of Wall (not including wall facing)	B	5.00	ft	Foundation Soil Effective Unit Weight	γ'_f	48	lb/ft^3
7	Setback from facing	a_b	1.00	ft	$K_{a,f}$		0.28	
8	Bridge Seat Width	b	2.5	ft	$K_{p,f}$		3.54	
9	Width of Bridge Beam	B_b	28.0	ft	Bearing Capacity Factors (Table 10.6.3.1.2a-1, A	N_c	42.2	
10	Structure depth (road surface to top of block)	H_{bridge}	1.75	ft		N_γ	41.1	
11	Width of Traffic and Roadbase Load Behind Wi	$b_{rb,t}$	1.50	ft		N_q	29.4	
12	Footing Area		70.0	SF	Retained Soils, Friction Angle	ϕ_b'	34	degree
13	Block Parameter:				Retained Soils, Cohesion	c'_b	-	psf
14	Height	H_{block}	8.0	in	Retained Soils, Unit weight	γ_b	110	pcf
15	Length (along face)	L_{block}	18.0	in	$K_{a,b}$		0.28	
16	Depth (front to back)	b_{block}	12.0	in	Reinforced Soils, Friction Angle	ϕ_r'	42	degree
17	Block Weight	W_{block}	80	lbs	Reinforced Soils, Cohesion	c'_r	-	psf
18	Number of Reinforcement Layers	N_{sv}	10		Reinforced Soils, Unit weight	γ_r	125	pcf
19	Reinforced Soil Foundation				Maximum Diameter of Reinforced Fill	d_{max}	0.75	in
20	Depth of Reinforced Soil Foundation	D_{RSF}	1.5	ft	$K_{a,r}$		0.20	
21	Distance of RSF in front of Abutment	X_{RSF}	1.5	ft	$K_{p,r}$		5.04	
22	Base Width of Reinforced Soil Foundation	B_{RSF}	7.5	ft	Road Base Unit Weight	γ_{rb}	135	pcf
23	Load and Resistance Factors				Reinforced Soil Foundation, Friction Angle	ϕ_{rsf}'	40	degree
24	Dead Load Max	$\gamma_{DC\,MAX}$	1.25		Reinforced Soil Foundation Unit Weight	γ_{rsf}	125	pcf
25	Dead Load Min	$\gamma_{DC\,MIN}$	0.9		Bridge Loads			
26	Horizontal Active Earth Pressure Max	$\gamma_{EH\,MAX}$	1.5		Bridge dead load per abutment	Q_{DL}	25,000	lbs
27	Horizontal Active Earth Pressure Min	$\gamma_{EH\,MIN}$	0.9		Bridge live load per abutment	Q_{LL}	30,000	lbs
28	Vertical Earth Pressure Max	$\gamma_{EV\,MAX}$	1.35		Dead load pressure per abutment	$q_{DL,e}$	357	psf
29	Vertical Earth Pressure Min	$\gamma_{EV\,MIN}$	1		Live load pressure per abutment	$q_{LL,0}$	429	psf
30	Live Load Surcharge	[illegible]	1.75		Geosynthetic Reinforcement			



Source: FHWA.

Fundamental Design Principles

and assumptions

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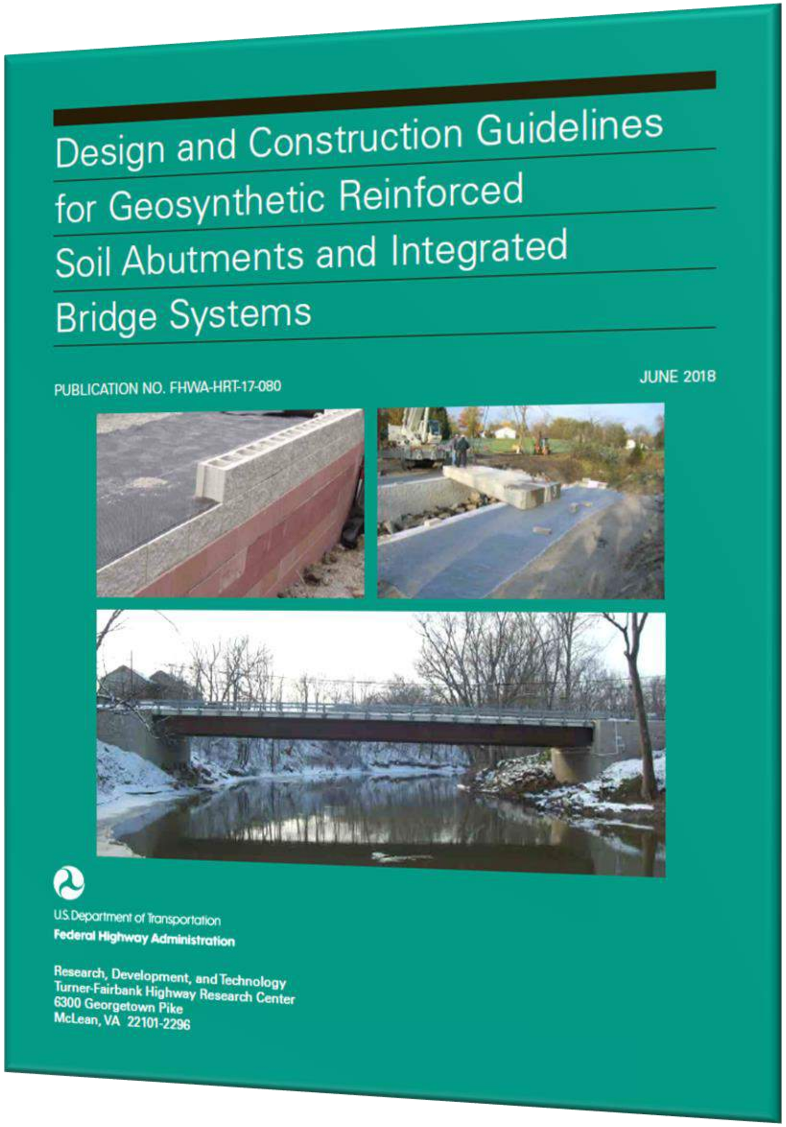
Design Process

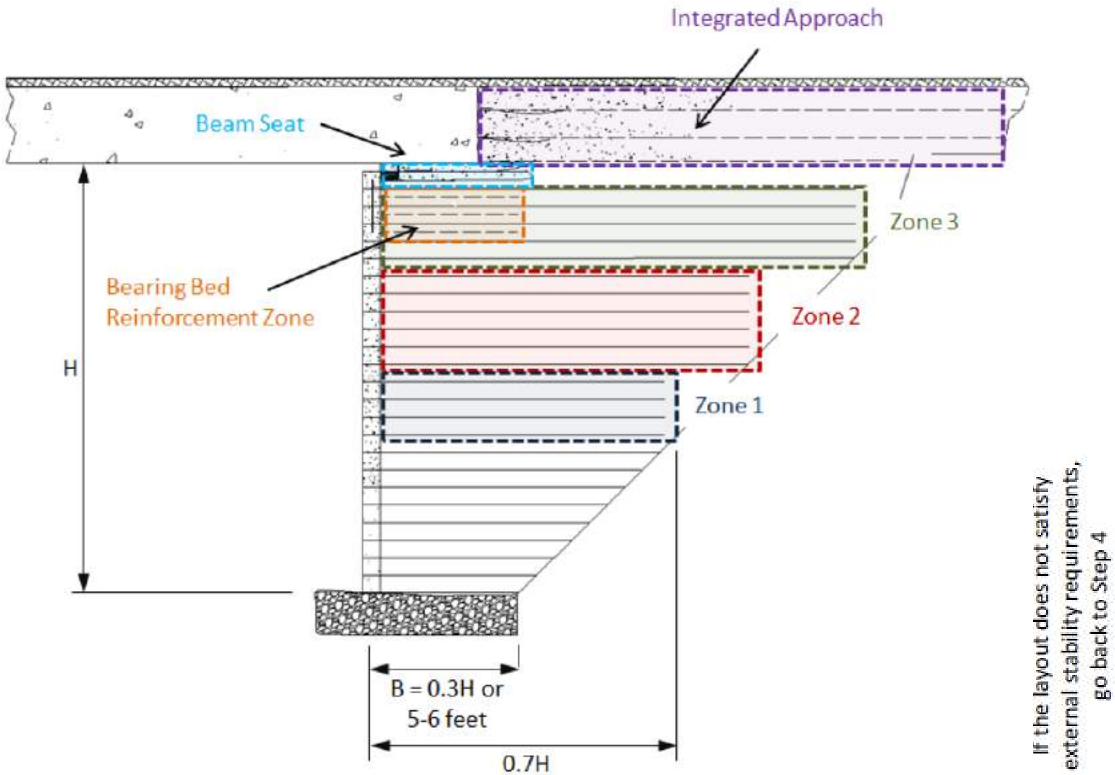
- Step-by-step process outlined in FHWA guidance:

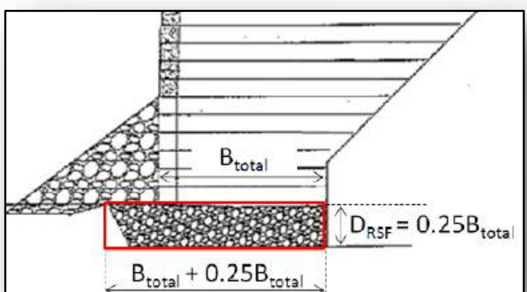
  FHWA-HRT-17-080
- Different from conventional MSE design
- Empirical and analytical design procedures
- Design examples included

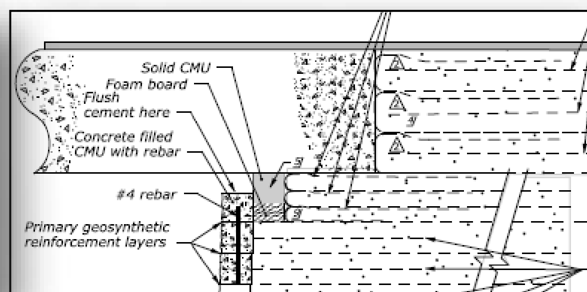


Source: FHWA

Design Steps







1. ESTABLISH PROJECT REQUIREMENTS
Geometry, Performance Criteria, etc.

↓

2. PERFORM A SITE EVALUATION
Soil and Hydraulic Conditions, Topography Groundwater, etc.

↓

3. EVALUATE PROJECT FEASIBILITY
Cost, Logistics, Technical Requirements, etc.
Channel Stability and Scour Depths (if a water crossing)

↓

4. DETERMINE GRS-IBS LAYOUT
Height, Excavation Depth, Reinforcement Length and Spacing, etc.

↓

5. CALCULATE LOADS
Dead, Live, and Earthquake Loads, etc.

↓

6. CONDUCT EXTERNAL STABILITY ANALYSIS
Direct Sliding, Bearing Resistance, and Global Stability

If the layout does not satisfy external stability requirements, go back to Step 4

↓

7. CONDUCT INTERNAL STABILITY ANALYSIS
Bearing Resistance, Deformations, Reinforcement Strength

If the layout does not satisfy internal stability requirements, go back to Step 4

↓

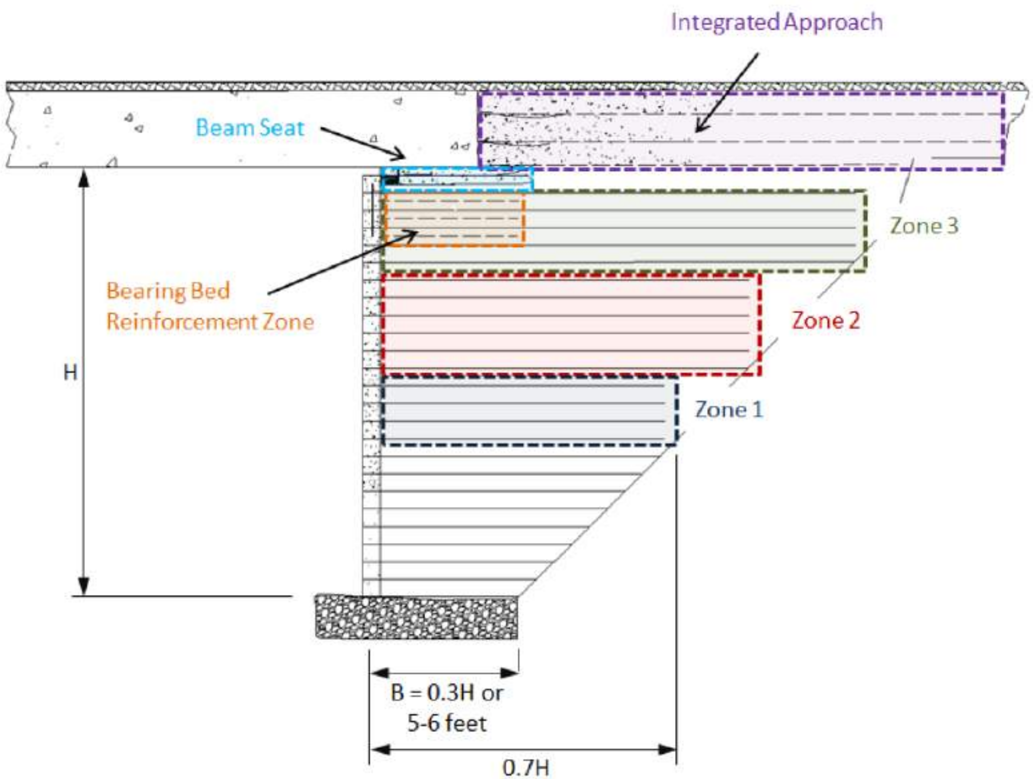
8. IMPLEMENT DESIGN DETAILS
Wing Walls, Guard Rails, Utilities, etc.

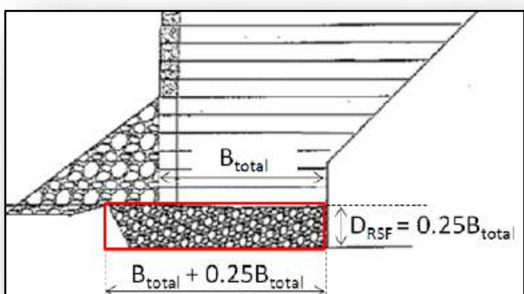
↓

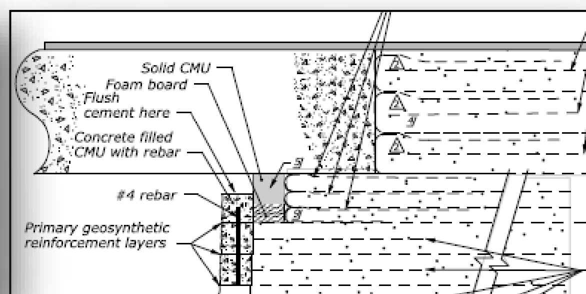
9. FINALIZE GRS-IBS DESIGN
Design Plans, Construction Specifications, etc.

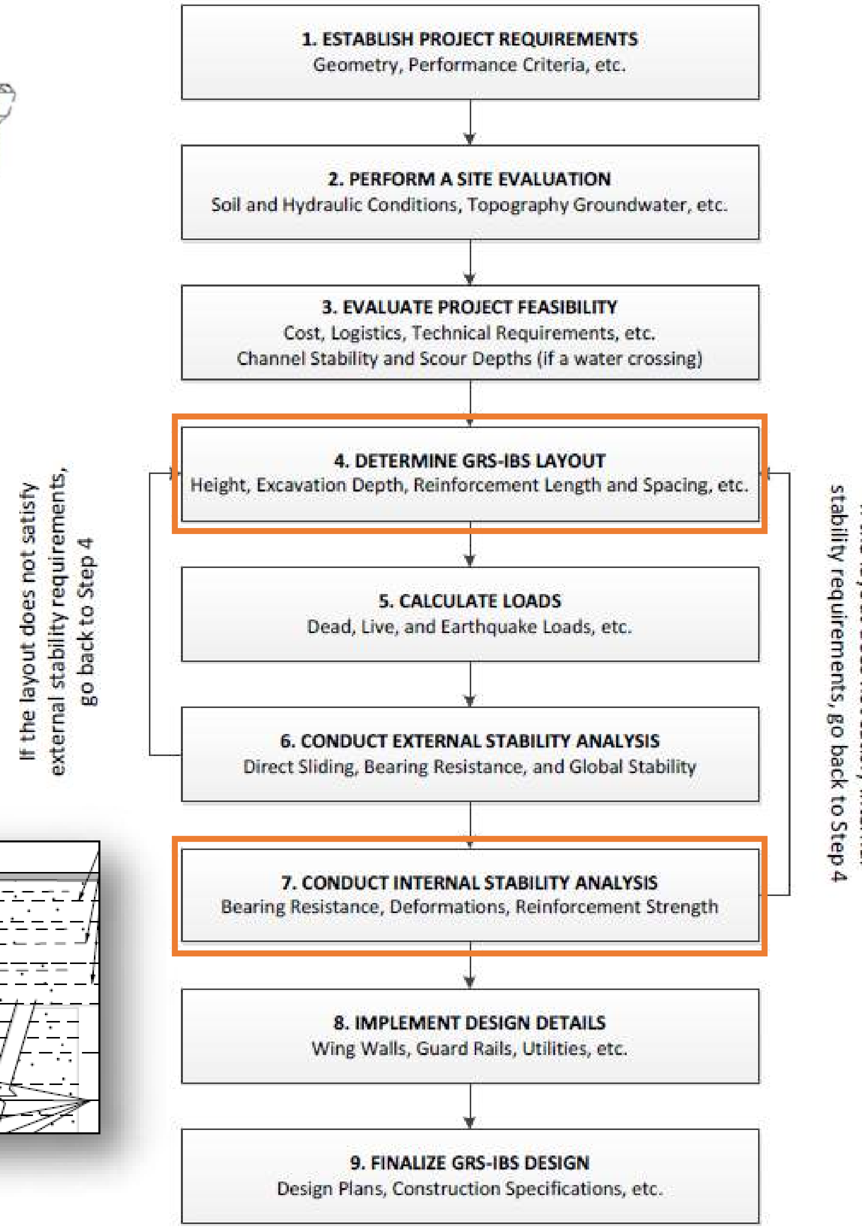
All images source: FHWA

Design Steps









All images source: FHWA

GRS IBS - Design Considerations

- Use of shallow foundations
  - Serviceability (e.g., settlement)
  - Scour of abutments at water crossings
- Facing durability and aesthetics
- Seismic performance

Design Spreadsheet for GRS IBS in LRFD

	A	B	C	D	E	F	G	H
1								
2	Abutment Geometry:				Soil Parameters			
3	Abutment Height	H	6.9	ft	Foundation Soils, Friction Angle	ϕ_f'	34	degree
4	Base Width of Wall (including wall facing)	B_{wf}	6.0	ft	Foundation Soils, Cohesion	c'_f	-	psf
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12	Footing Area		70.0	SF	Retained Soils, Friction Angle	ϕ_b'	34	degree
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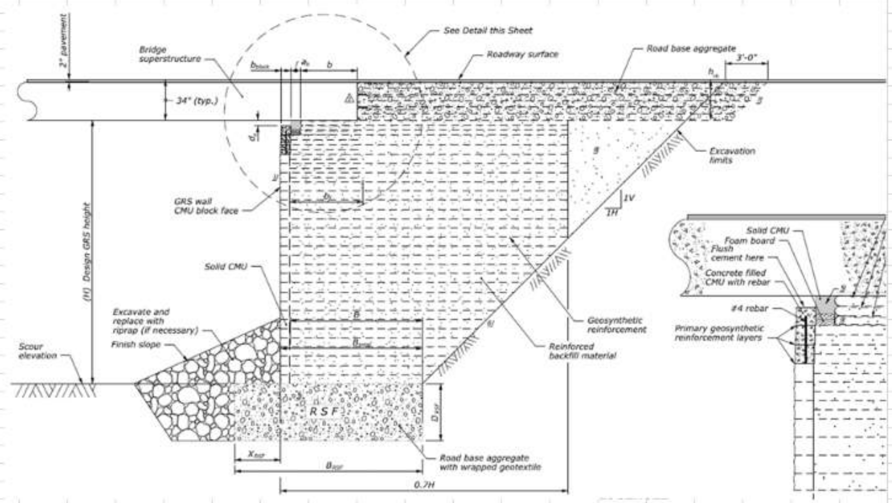
30	Live Load Surcharge	γ_{LS}	1.75		Geosynthetic Reinforcement			
31	Horizontal Active Earth Pressure Min	$\gamma_{passive\ MIN}$	0.5		Ultimate Reinforcement Strength	T_f	4,800	lb/ft
32	Capacity Resistance	ϕ_{cap}	0.45		Ultimate Reinforcement Strength, Factored	T_{ff}	1,920	lb/ft
33	Reinforcement Resistance	ϕ_{reinf}	0.40		Reinforcement Strength at 2%	$T_{\varepsilon=2\%}$	383	lb/ft
34	Soil-Sliding Resistance	ϕ_τ	1.00		Number of bearing bed reinforcement (3 min)		3	layers
35	Bearing Capacity Resistance	ϕ_{bc}	0.65		Length of bearing bed reinforcement (min)		5.42	ft



Source: FHWA

GRS-IBS for Transportation Bridge Construction

Source: FHWA.

Construction Procedures

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Federal Highway Administration

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Construction of GRS-IBS

- Equipment and Tools
- Excavation
- Reinforced Soil Foundation (RSF)
- Block placement
- Geosynthetic placement
- Fill Placement
- Top of wall details
- Placement of Superstructure
- Approach construction
- Rip Rap Installation
- Instrumentation

Equipment

All images source: Unknown

Equipment

All images source: FHWA

Tools

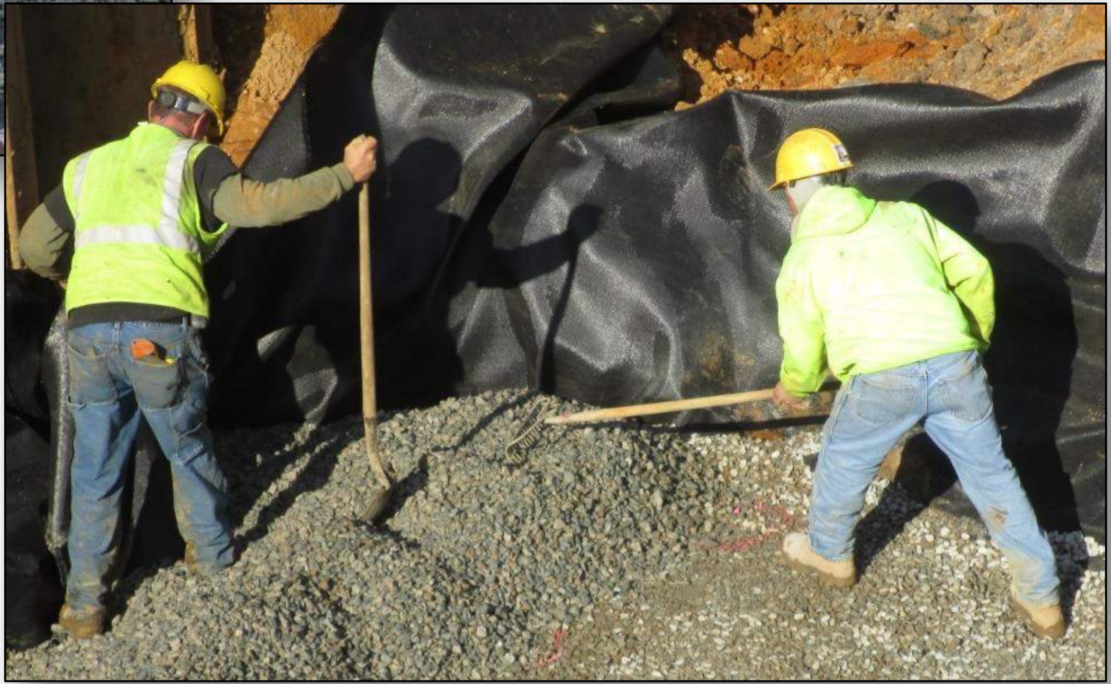
Source: Defiance County, OH

Source: Defiance County, OH

Hand Tools

All images source: Defiance County, OH

- Levels
- String Lines
- Shovels
- Rakes/spreaders



Hand Tools

All images source: Defiance County, OH

- Rubber Mallet
- Block Tongs

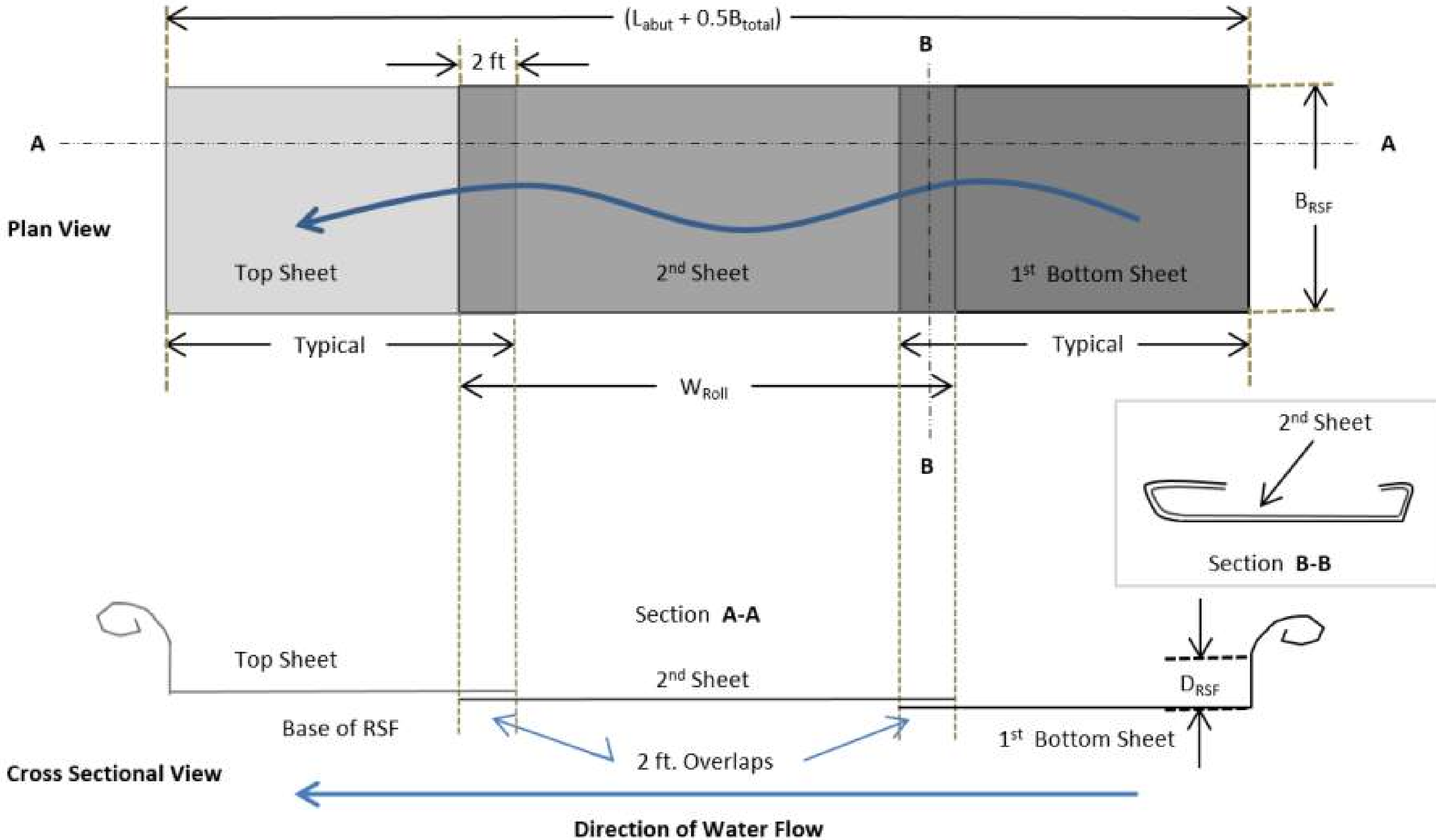
RSF Excavation

Source: PennDOT

RSF Excavation

Source: Defiance County, OH

RSF - Reinforcement Schedule



Source: FHWA.

RSF Excavation

All images source: Defiance County, OH

Reinforced Soil Foundation

Source: DE DOT

Reinforced Soil Foundation

Source: DE DOT

Reinforced Soil Foundation

Source: DE DOT

Reinforced Soil Foundation

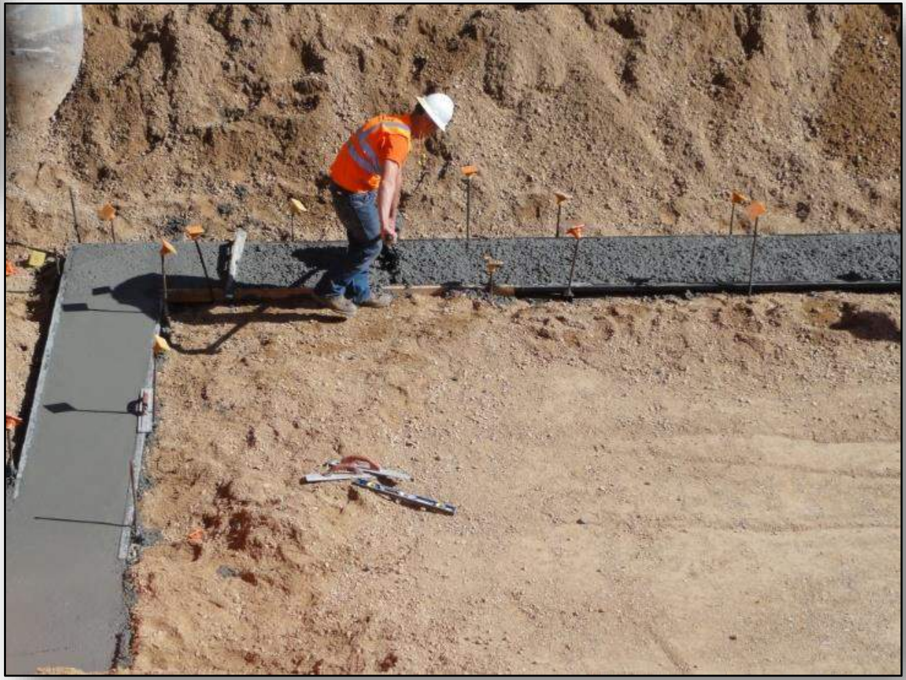
Source: DE DOT

Block Placement - *(First Row)*

The first course is the most important.

All images source: DE DOT

Wall with Concrete Leveling Pad



All images source: UT DOT

Block Placement

All images source: UT DOT

Block Placement

Source: DE DOT

Source: UT DOT

Source: UT DOT

Block Placement *(corners details)*

Source: Defiance County, OH

Source: WisDOT

Images source: Defiance County, OH

Source: Defiance County, OH

Source: St. Lawrence County, NY

Source: MNDOT

Geosynthetic Placement

Reinforcement Type

Biaxial

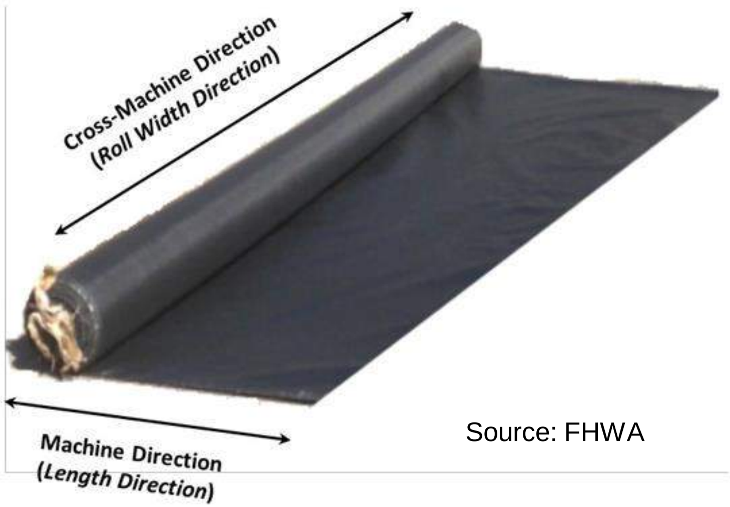
Source: DE DOT

Uniaxial

Source: IL DOT

Geosynthetic Placement

Source: Utah DOT



Source: FHWA

Roll out geosynthetic with strong direction perpendicular to abutment face.

Source: Utah DOT

Geosynthetic Placement

All images source: Defiance County, OH

Geosynthetic Placement

No overlaps or tying of geosynthetic

Source: DE DOT

Source: WisDOT

Source: DE DOT

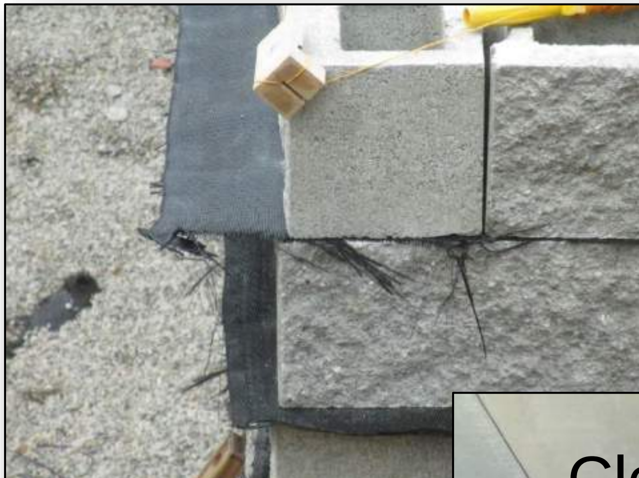
Geosynthetic Placement

Pull reinforcement taut to remove wrinkles
No overlaps, especially at the face

Source: DE DOT

Geosynthetic Placement

Trim geosynthetic at block facing



Source: DE DOT

Source: DE DOT

Source: Utah DOT

Fill Placement


Source: DE DOT


Source: WisDOT

Fill Placement

Source: Defiance County, OH

Source: WisDOT

Fill Placement

Source: Defiance County, OH

Source: DE DOT

Fill Compaction

All images source: WisDOT

Fill Compaction

Source: WisDOT

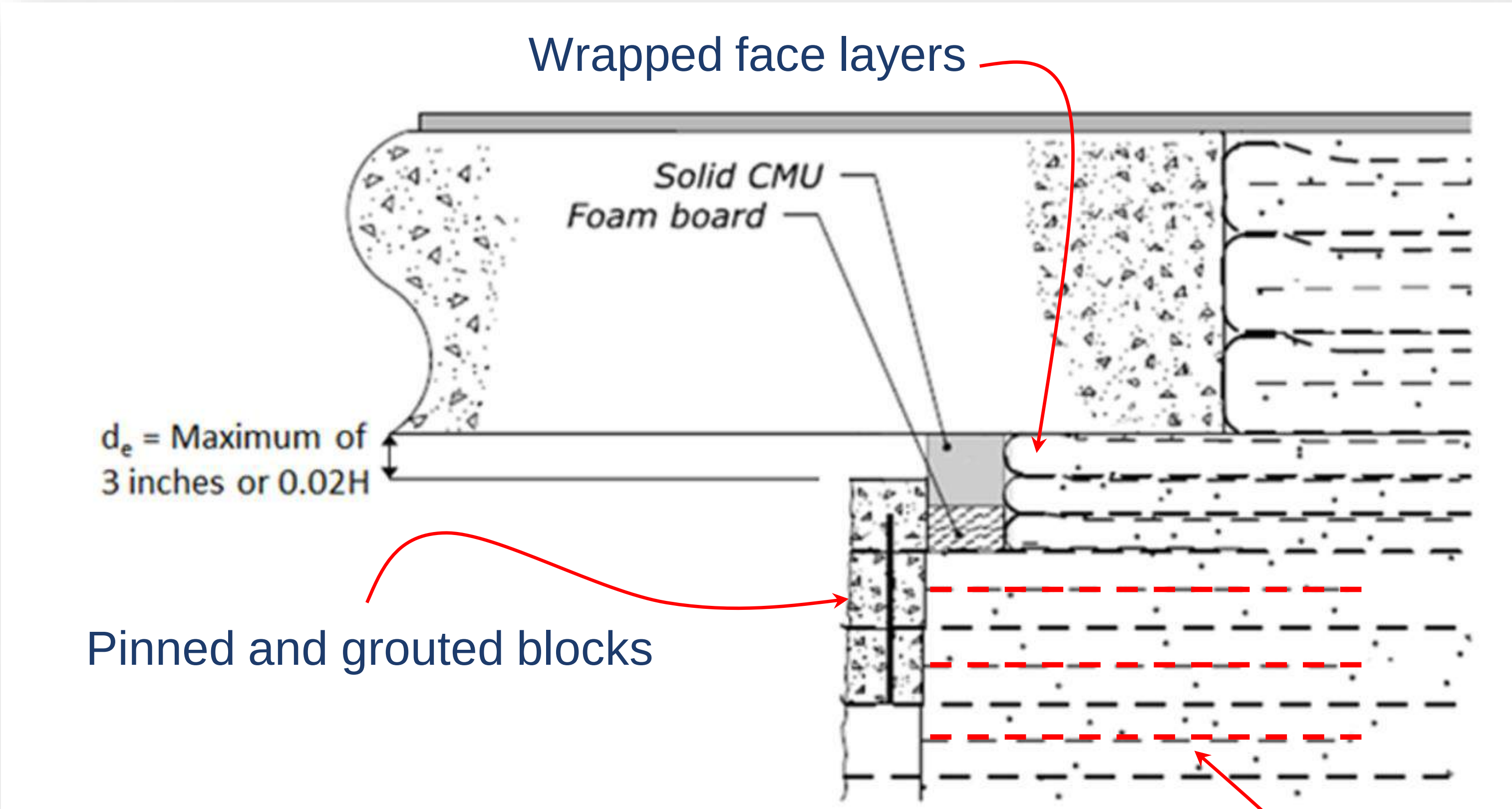
Source: Utah DOT

Fill Compaction

Source: Defiance County, OH

Source: WisDOT

Top of wall details



Source: FHWA

Bearing bed reinforcement layers

Top of wall details

All images source: Defiance County, OH

Top of wall details (set back distance)



All images source: Defiance County, OH

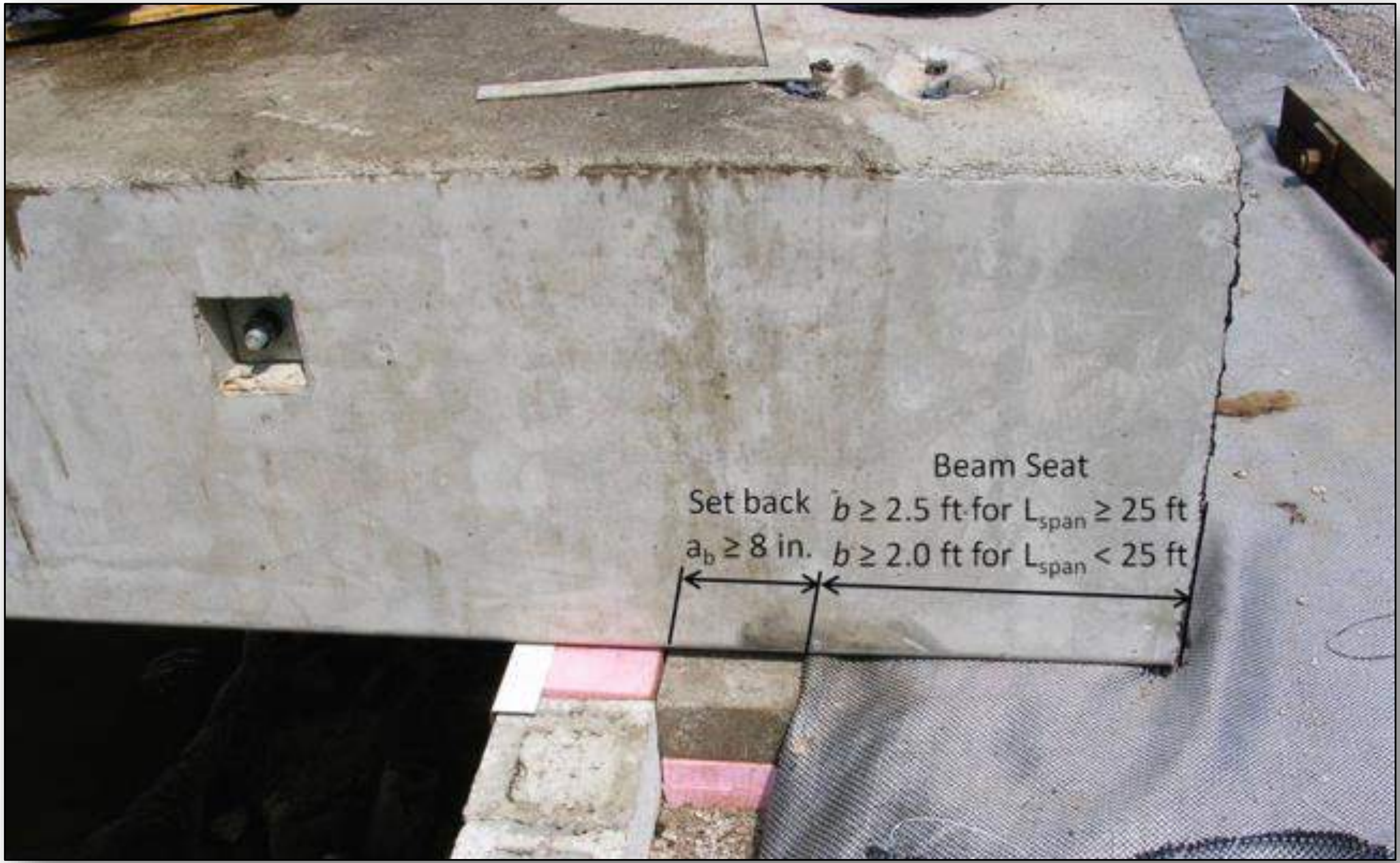
Top of wall details

All images source: Defiance County, OH

Top of wall details

All images source: Defiance County, OH

Placement of Superstructure



Source: FHWA

Placement of Superstructure

All images source: FHWA

Placement of Superstructure

All images source: Defiance County, OH

Approach Construction

All images source: FHWA

Approach Construction

All images source: PennDOT

Approach Construction

Source: FHWA

Approach Construction

All images source: Defiance County, OH

Rip Rap Installation

All images source: Defiance County, OH

Scour Apron

Source: NCDOT

Performance

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Federal Highway Administration
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Instrumentation

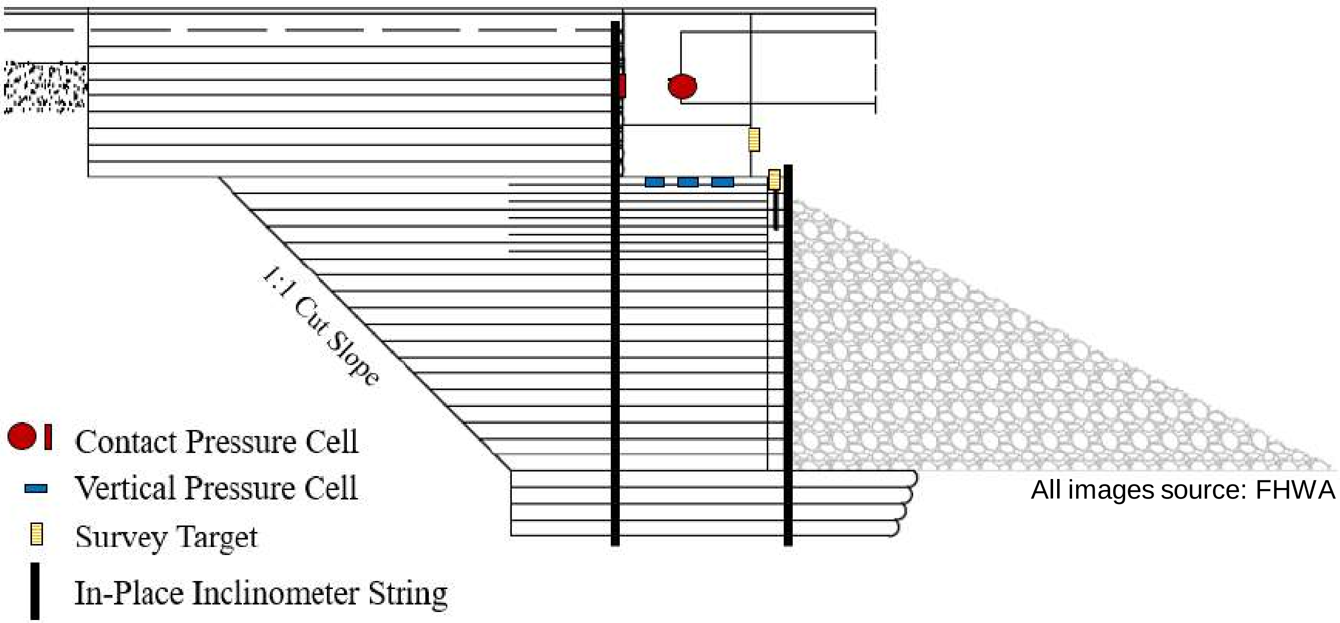
Source: FHWA

Instrumentation

All images source: FHWA

Instrumentation & 5-Yr Performance Monitoring of a GRS-IBS

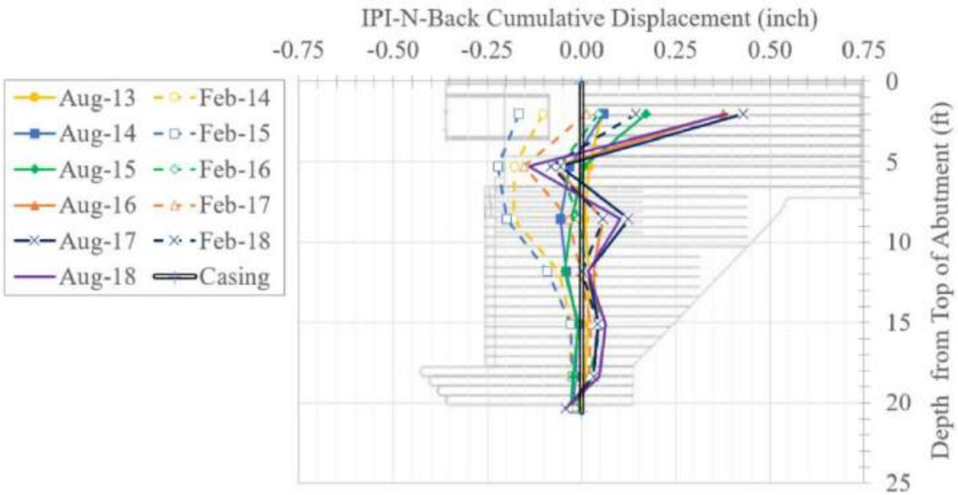
FHWA-HRT-20-040

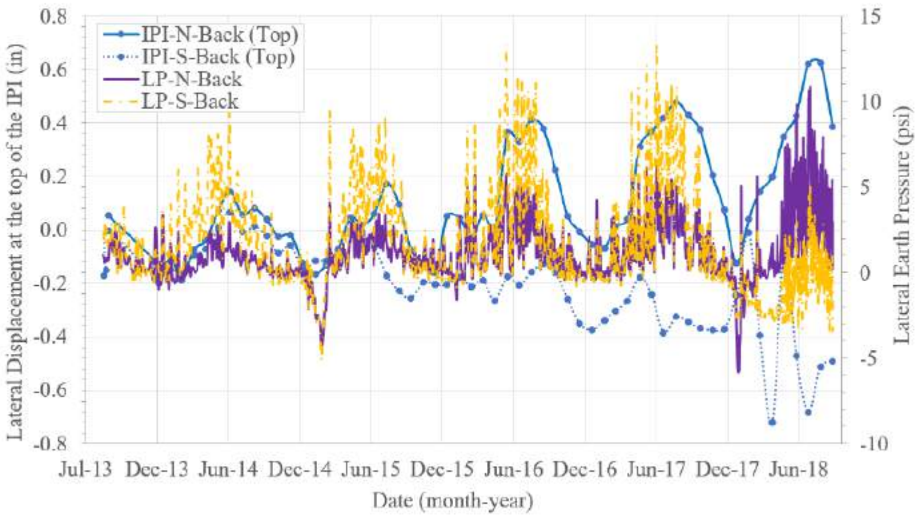


All images source: FHWA

Instrumentation & 5-Yr Performance Monitoring of a GRS-IBS

FHWA-HRT-20-040

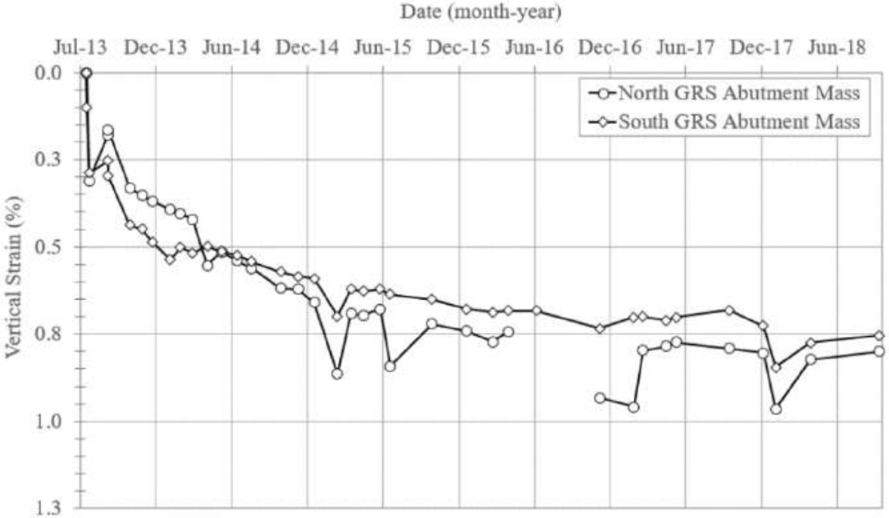


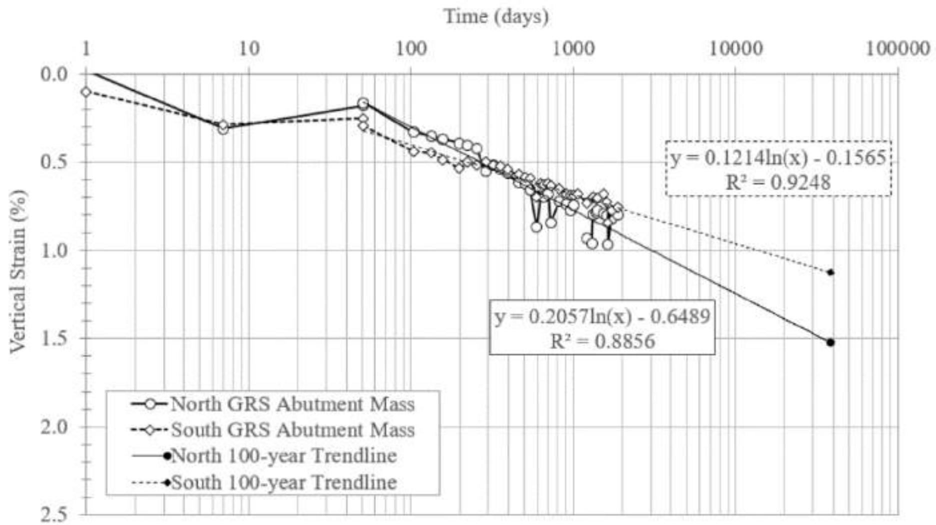


All images source: FHWA

Instrumentation & 5-Yr Performance Monitoring of a GRS-IBS

FHWA-HRT-20-040





All images source: FHWA

GRS-IBS Long-Term Monitoring Projects

- Tiffin River, OH (2009)
- St. Lawrence County, NY (2013)
- Sheffield, MA (2014)

Source: Defiance County, OH

Source: St. Lawrence County, NY

Source: MassDOT

GRS-IBS for Transportation Bridge Construction

Source: FHWA.

Research and Development

U.S. Department of Transportation
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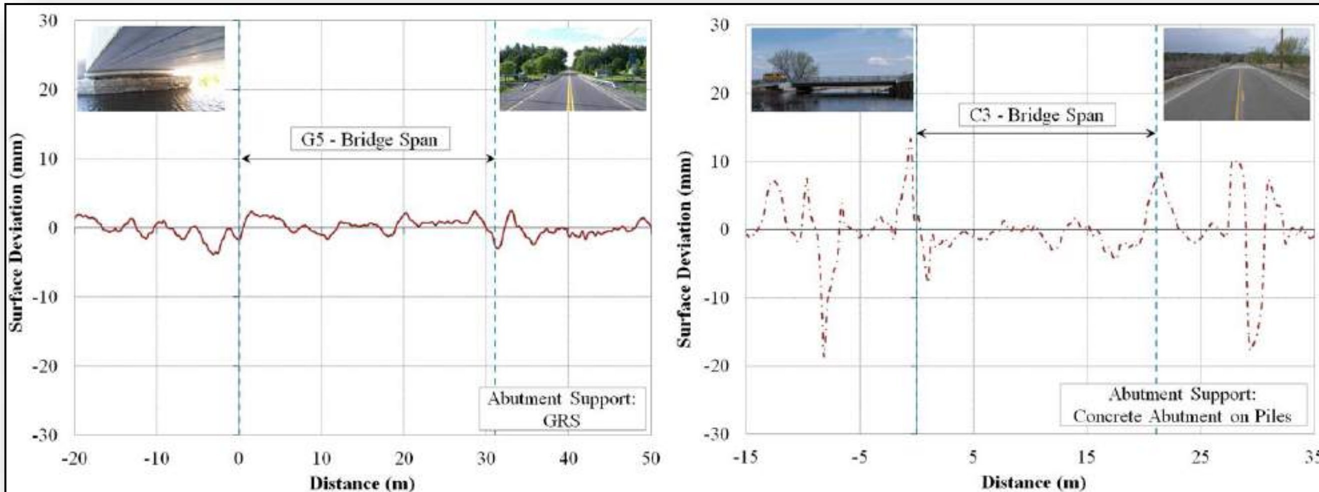
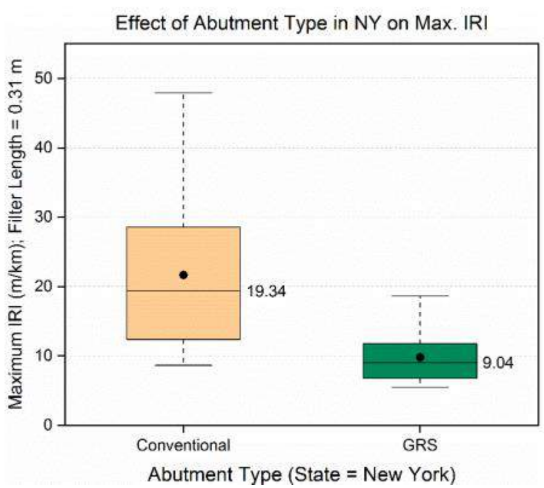
Bridge Approach Profiles

Comparison between GRS and conventional abutment

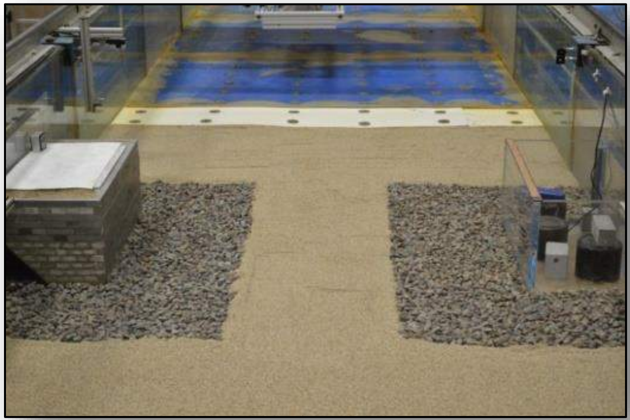


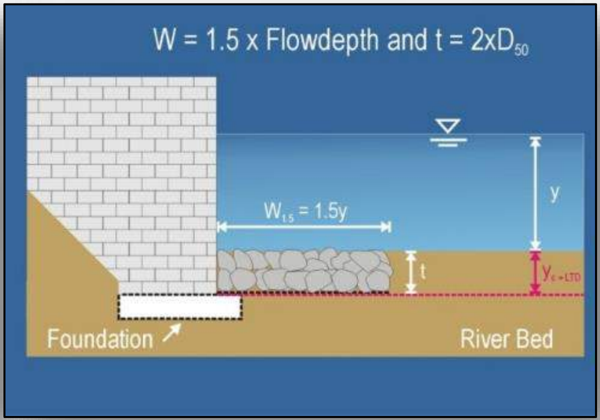
All images source: FHWA

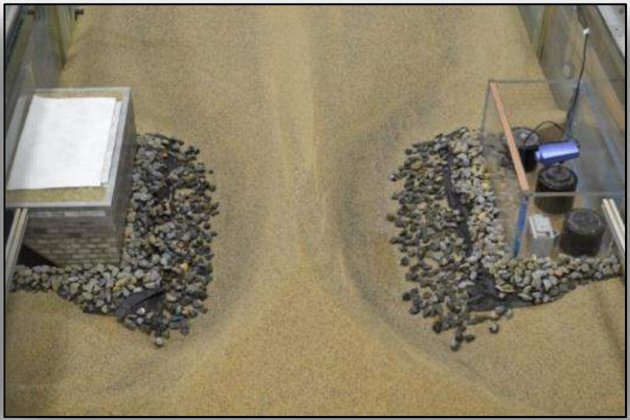


FHWA-HRT-21-037

Shallow Foundation Scour Study







All images source: FHWA

Long-Term Performance Monitoring of GRS Mini-Piers and Mini-Abutments at TFHRC

- Secondary settlement
- Open- vs. well-graded backfill
- Reinforcement strength
- Thermal interaction

- Secondary settlement
- Plane strain conditions (L/b)
- Shape effect
- Lateral pressure distributions

All images source: FHWA

Questions?

Thank You For Attending!

Michael Adams
mike.adams@dot.gov
Jennifer Nicks, Ph.D., P.E.
jennifer.nicks@dot.gov

Federal Highway Administration

U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank
Highway Research Center

Contact Information

Michael Adams, P.E.
Research Geotechnical Engineer
Office of Infrastructure Research and Development
Federal Highway Administration
mike.adams@dot.gov

Timothy D. Stark, Ph.D., P.E.
Professor of Civil & Environmental Engineering
University of Illinois at Urbana-Champaign
Technical Director
Fabricated Geomembrane Institute
tstark@Illinois.edu

Jennifer Nicks, Ph.D., P.E.
Research Geotechnical Engineer
Office of Infrastructure Research and Development
Federal Highway Administration
jennifer.nicks@dot.gov

Jennifer Miller, M.S.
Coordinator
Fabricated Geomembrane Institute
University of Illinois at Urbana-Champaign
fabricatedgeomembrane@gmail.com

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