U.S. Department of Transportation
Federal Highway Administration

innovation ingenuity invention imagination
Every Day Counts

GEOSYNTHETIC REINFORCED SOIL INTEGRATED BRIDGE SYSTEM

Michael Adams, Daniel Alzamora, Jennifer Nicks

EDC

- Taking effective, proven and market–ready technologies and getting them into widespread use

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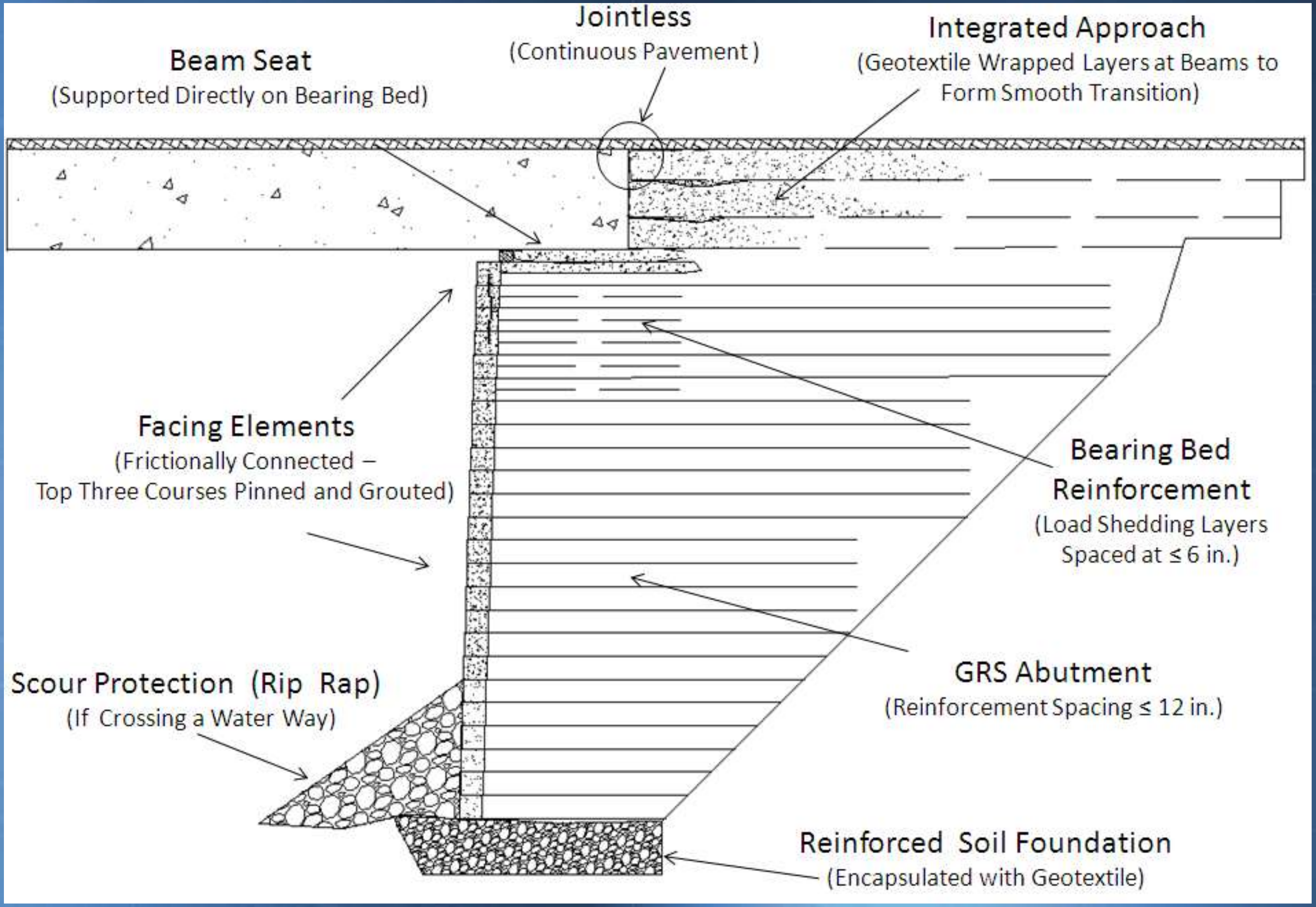
Definitions

- GRS - Geosynthetic Reinforced Soil
  - An engineered fill of closely spaced (< 12") alternating layers of compacted granular fill material and geosynthetic reinforcement
- IBS - Integrated Bridge System
  - A fast, cost-effective method of bridge support that blends the roadway into the superstructure using GRS technology

Cross-Section of GRS-IBS



Summary of Benefits

- Reduced construction cost (25 - 60%)
- Reduced construction time
- Construction less dependent on weather conditions
- Flexible design - easily field modified for unforeseen site conditions (e.g. obstructions, utilities, different site conditions)
- Easier to maintain (fewer bridge parts)
- QA/QC Advantages

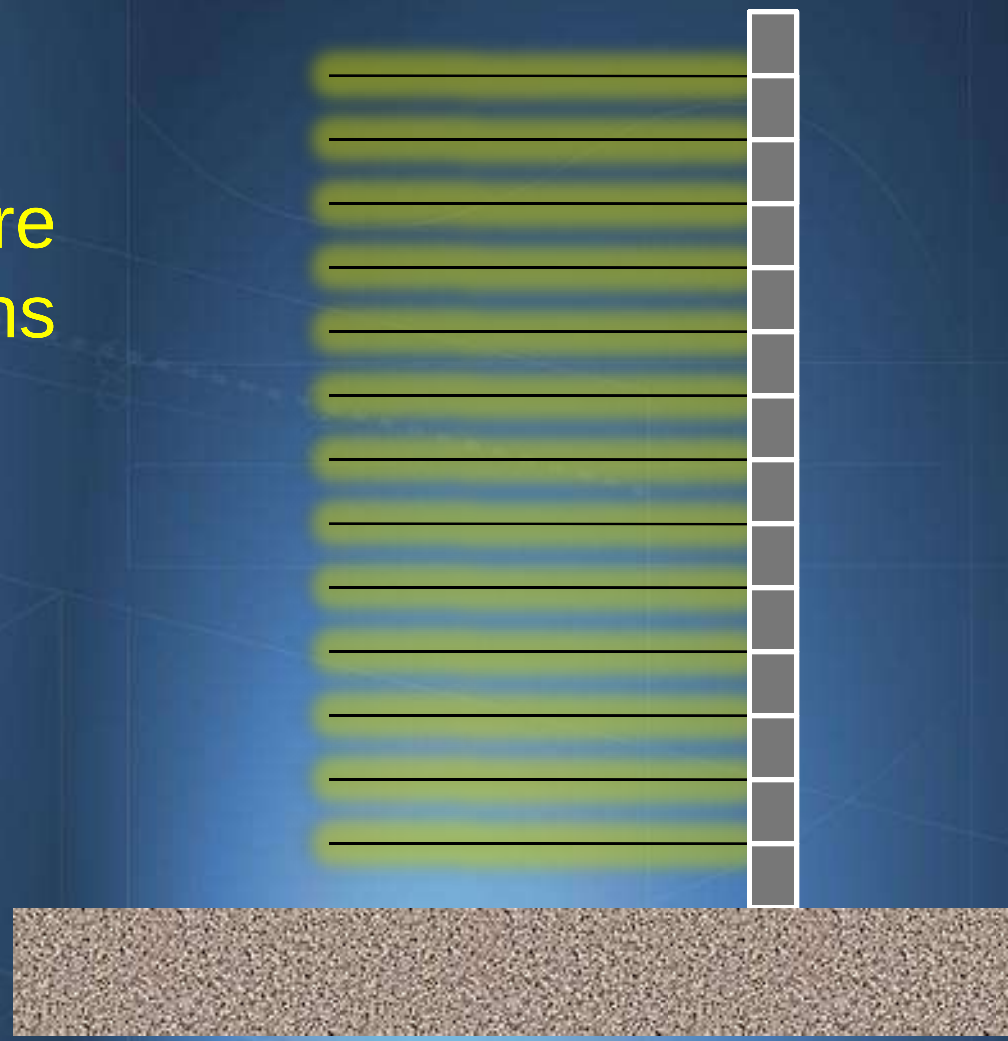
Site Selection

- Single span (currently 140 ft)
- 30 ft abutment height
- Grade separation
- Water crossings with low scour potential
- Steel or concrete superstructures
- New or replacement structures

Composite Behavior

GRS

- Composite Structure
- Friction Connections
- Close Spacing



Performance Tests

Before

After

Performance Test
2400 lb/ft @ 8” Spacing

Before

After


0.5 ksf
(25 kPa)

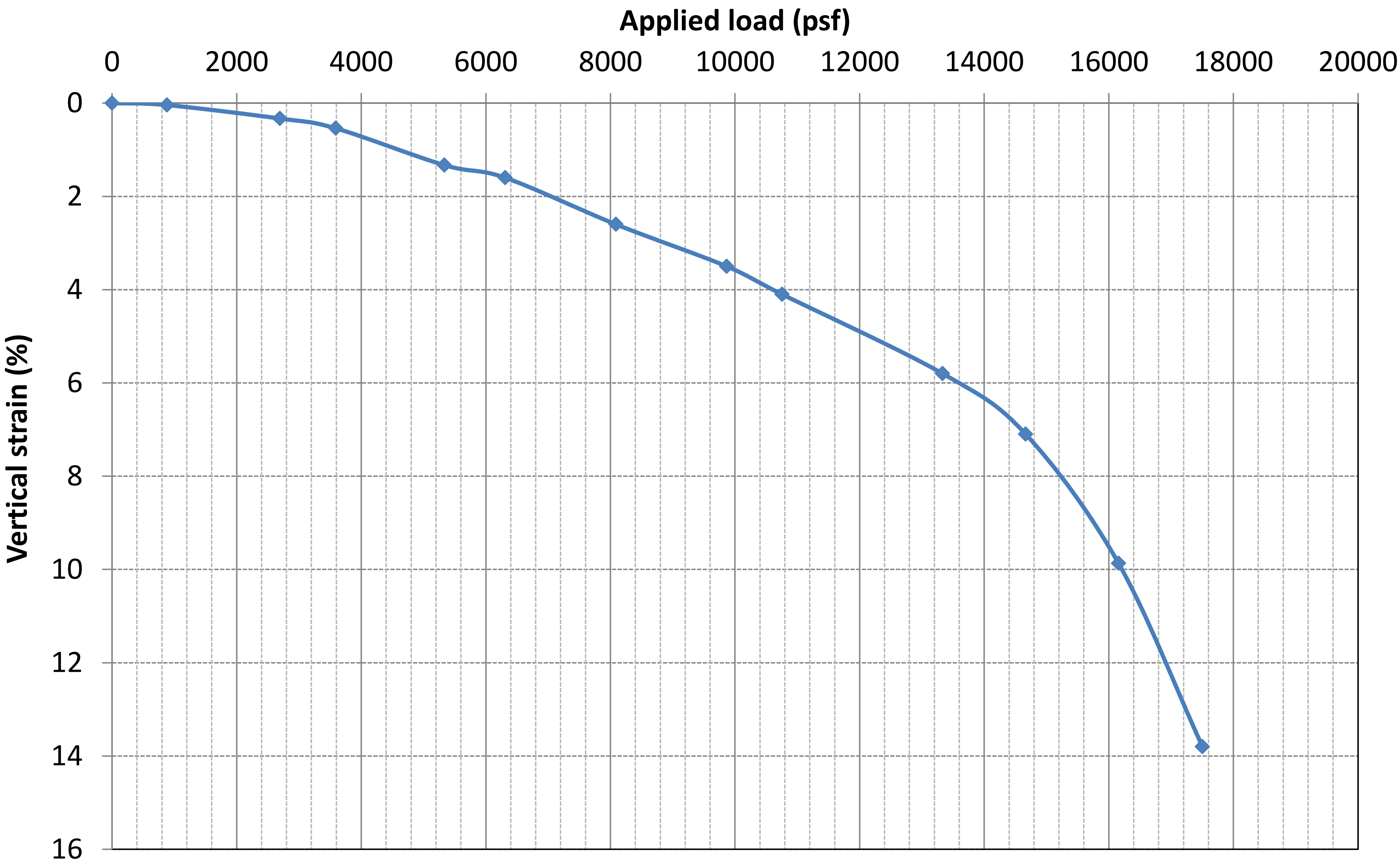

4.1 ksf
(196 kPa)

6.8 ksf
(326 kPa)


10.3 ksf
(493 kPa)

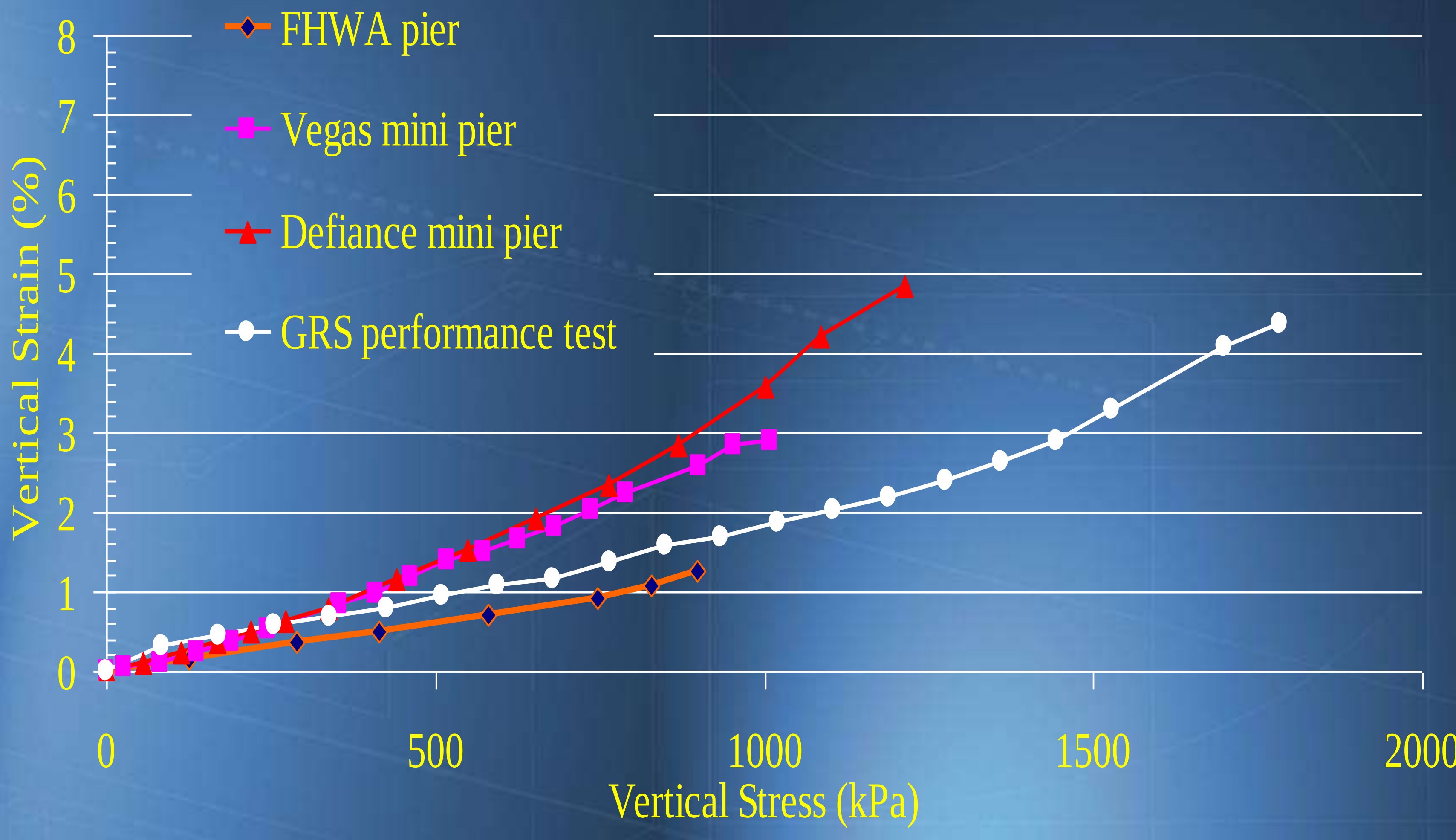
13.9 ksf
(666 kPa)


18.1 ksf
(867 kPa)

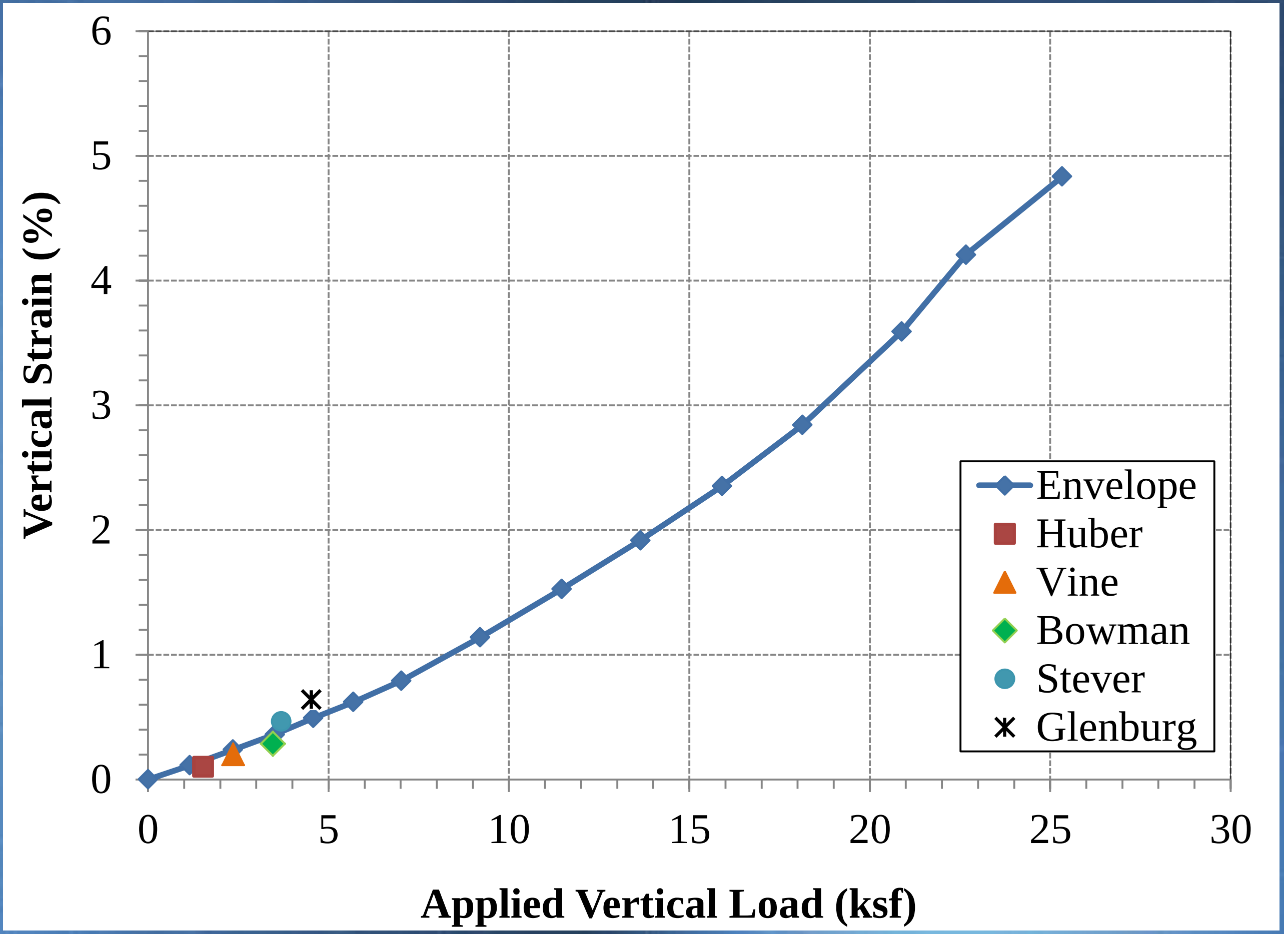


Applied load (psf)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Vertical strain (%)
0
2
4
6
8
10
12
14
16

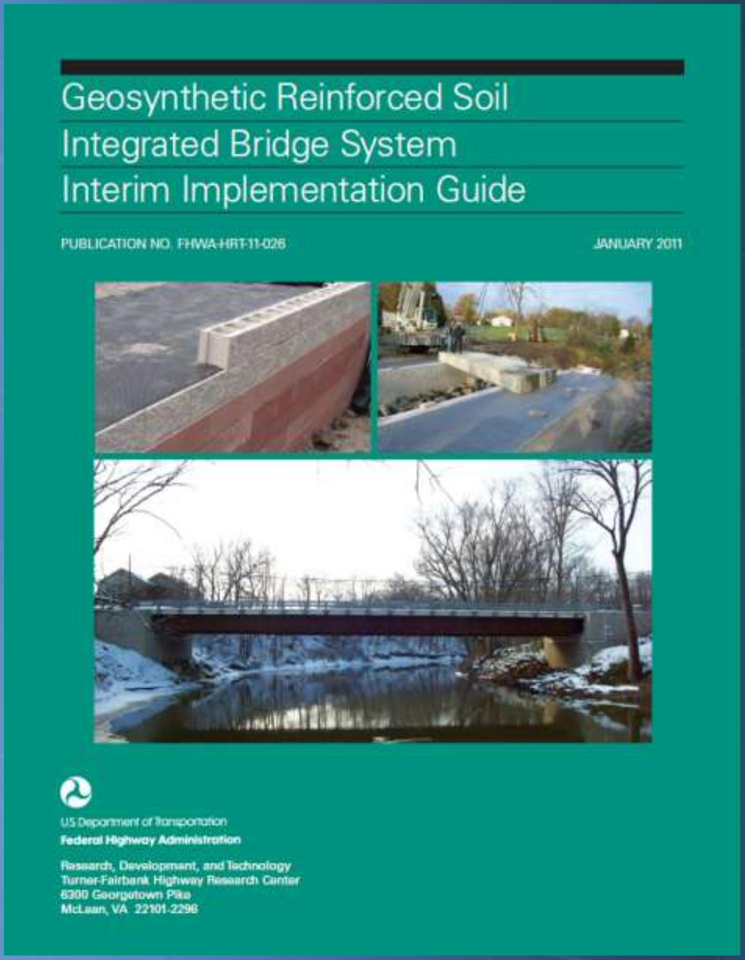
Performance Test Results

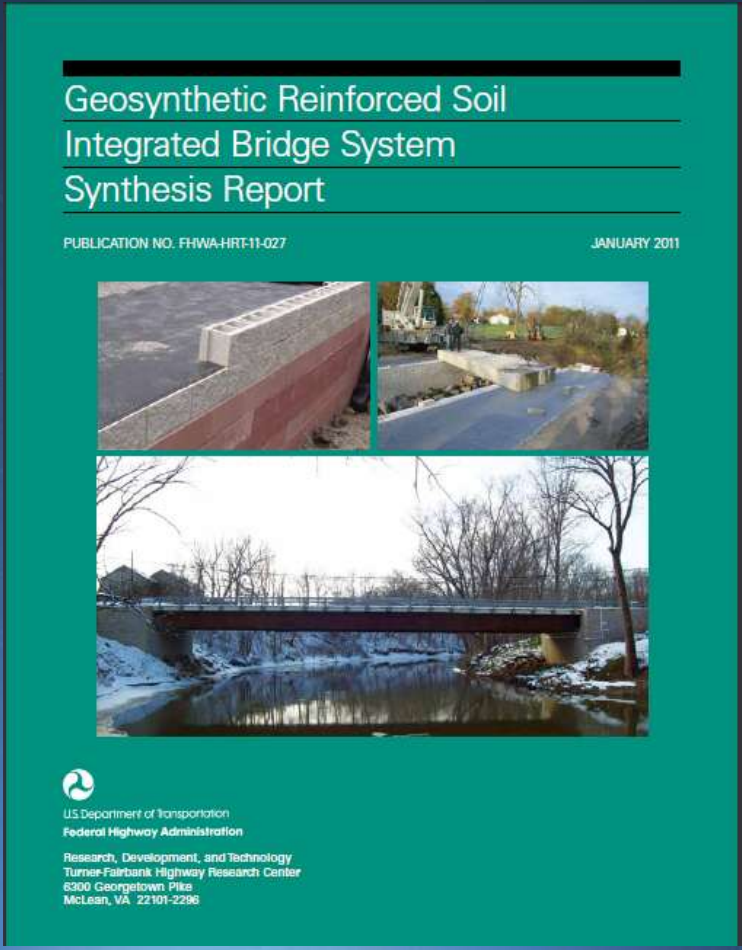


Vertical Deformation *Continued*



GRS IBS Reports





STATE	PROJECT	SHEET NUMBER
	FHWA GRS-IBS	A

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GRS-IBS
DESIGN DRAWINGS
2011

INDEX TO SHEETS

GENERAL NOTES

PURPOSE: These example plan Sheets A through D were prepared to illustrate the typical contents of a set of drawings necessary for a GRS-IBS project. Presented in these plans are the assumptions for the bridge and GRS-IBS systems with typical wall heights (H) ranging from 10 to 24 feet. Two conditions were prepared for the quantity estimate Sheet B: "poor soil conditions" and "favorable soil conditions". INTENDED USE: These plans are not associated with a specific project. All dimensions and properties should be confirmed and/or revised by the Engineer of Record prior to use. Project specifications should be prepared to supplement this plan set.

DESIGN

DESIGN LOADS AND SOIL PROPERTIES

Combined load: Superstructure (qLL + qB) 2 TSF maximum (service load, allowable stress design). Roadway live load surcharge: 250 psf uniform vertical

Road Base unit weight = 140 pcf, thickness = 34-inches

"Poor" Soil Conditions:

Retained backfill: Unit weight= 125 pcf, friction angle= 34°, cohesion = 0 psf, (Cohesion ≥ 200 psf assumed for temporary back slope cut conditions during construction.)
d_{max} ≥ 1.0 Inches
Reinforced fill: Unit weight=115 pcf, friction angle = 38°, cohesion = 0 psf
RSF backfill: Unit weight = 140 pcf, friction angle = 38°, cohesion = 0 psf
Foundation soil: Unit weight = 125 pcf, friction angle = 30°, cohesion = 0 psf

"Favorable" Soil Conditions:

Retained backfill: Unit weight = 125 pcf, friction angle = 40°, cohesion = 100 psf
d_{max} ≥ 0.5-inches
Foundation soil: Unit weight = 125 pcf, friction angle = 40°, cohesion = 100 psf
Reinforced fill: Unit weight = 120 pcf, friction angle = 42°, cohesion =0 psf
RSF backfill: Unit weight = 120 pcf, friction angle = 42°, cohesion = 0 psf

DESIGN SPECIFICATIONS

1. *Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide, FHWA-HRT-11-026, January 2011.*
2. *Design methods follow the ASD design methods presented in Chapter 4 of the reference Manual. No seismic design assumed.*
3. *Conduct a subsurface investigation in accordance with "Soils and Foundations", FHWA-NHI-06-088 (2006) and "Subsurface Investigations", FHWA-NHI-01-031, (2006).*
4. *Design factor of safety against sliding is ≥ 1.5; Factor of safety against bearing failure is ≥ 2.5.*
5. *A global stability analysis must be performed for each site. Factor of safety against global failure is to be ≥ 1.5.*
6. *Performance criteria: tolerable vertical strain = 0.5% of wall height (H): tolerable lateral strain = 1.0% of b and a_b (bearing width and setback)*
7. *Settlement below the RSF is assumed to be negligible. No differential settlement between abutments is assumed.*
8. *Sliding checks were conducted at the top and bottom of the RSF to meet the minimum factors of safety in the reference manual.*
9. *Road base thickness (h_{rb}) assumes a 32-inch structure and 2-inch pavement thickness.*

CONSTRUCTION SPECIFICATIONS

1. *Site Layout/Survey: Construct the base of the GRS abutment and wingwalls within 1.0 inch of the staked elevations. Construct the external GRS abutment and wingwalls to within ±0.5 inches of the surveyed stake dimensions.*
2. *Excavation: Comply with Occupational Safety and Health Administration (OSHA) for all excavations.*
3. *Compaction: Compact backfill to a minimum of 95 percent of the maximum dry density according to AASHTO-T-99 and ± 2 percent optimum moisture content In the bearing reinforcement zone, compact to 100 percent of the maximum dry density according to AASHTO-T-99. Only hand-operated compaction equipment is allowed within 3-feet of the wall face. Reinforcement extends directly beneath each layer of CMU blocks, covering ≥ 85% of the full width of the block to the front face of the wall.*
4. *Geosynthetic Reinforcement Placement: Pull the geosynthetic taught to remove any wrinkles and lay flat prior to placing and compacting the backfill material. Splices should be staggered at least 24-inches apart and splices are not allowed in the bearing reinforcement zone. No equipment is allowed directly on the geosynthetic. Place a minimum 6-inch layer of granular fill prior to operating only rubber-tired equipment over the geosynthetic at speeds less than 5 miles per hour with no sudden braking or sharp turning.*
5. *RSF Construction: The RSF should be encapsulated in geotextile reinforcement on all sides with minimum overlaps of 3.0 feet to prevent water infiltration. Wrapped corners need to be tight without exposed soil. Compact backfill material in lifts less than 6-inches in compacted height. Grade and level the top of the RSF prior to final encapsulation, as this will serve as the leveling pad for the CMU blocks of the GRS abutment.*
6. *GRS Wall Face Alignment: Check for level alignment of the CMU block row at least every other layer of the GRS abutment. Correct any alignment deviations greater than 0.25 inches.*
7. *Beam Seat Placement: Generally, the thickness of the beam seat is approximately 8 to 12 inches and consists of a minimum of two 4-inch lifts of wrapped-face GRS. Place precut 4-inch thick foam board on the top of the bearing bed reinforcement butt against the back face of the CMU block. Set half-height or full height (depending on wall height and required clear space) solid CMU blocks on top of the foam board. Wrap two approximately 4-inch lifts across the beam seat. Before folding the final wrap, it may be necessary to grade the surface aggregate of the beam seat slightly high, to about 0.5 inches, to aid in seating the superstructure and to maximize contact with the bearing area.*
8. *Superstructure Placement: The crane used for the placement of the superstructure can be positioned on the GRS abutment provided the outrigger pads are sized for less than 4,000 psf near the face of the abutment wall. Greater loads could be supported with increasing distance from the abutment face if checked by the Engineer of Record. An additional layout of geosynthetic reinforcement can be placed between the beam seat and the concrete or steel beams to provide additional protection of the beam seat. Set beams square and level without dragging across the beam seat surface.*
9. *Integrated Approach Placement: Following the placement of the superstructure, geotextile reinforcement layers are placed along the back of the superstructure, built in maximum lift heights of 6-inches (maximum vertical spacing of reinforcement ≤ 6-inches). The top of the final wrap should be approximately 2-inches below the top of the superstructure to allow at least 2-inches of aggregate base cover over the geosynthetic to protect it from hot mix asphalt.*

REINFORCING STEEL

Provide reinforcing steel conforming to ASTM A615, GR. 60.

CMU BLOCK

In colder climates, freeze-thaw test (ASTM C1262-10) should be concluded to assess the durability of the CMU and ensure it follows the standard specification (ASTM C1372). Additives can be used to reduce efflorescence at the face of the blocks if they are at locations subject to de-icing chemicals.

Compresive strength = 4,000 psi minimum
Water absorption limit = 5 %
H_{block} = 7⅝" L_{block} = 15⅝" b_{block} = 7⅝"
Note: In many construction applications CMU blocks are placed with a ⅜" mortar joint to create an in place nominal dimension of 8" x 8" x 16".

REINFORCED BACKFILL GRADATION

Reinforced Backfill Gradation – See Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide, Table 1 or Table 2. Consider GRS CMU minimal dimensions to be the same.

GEOSYNTHETIC REINFORCEMENT TENSILE PROPERTIES

Required ultimate tensile strength = 4,800 lb/ft by (ASTM D 4595 (geotextiles) or ASTM D 6637 (geogrids))
Tensile strength at 2% strain = 1,370 lb/ft

POLYSTYRENE FOAM BOARD

Provide polystyrene foam board conforming to AASHTO M230, type VI.

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GRS-IBS
COVER SHEET

NO.	DATE	BY	REVISIONS	NO.	DATE	BY	REVISIONS
	03/25/11		Rev. 0		04/04/11		Rev. 1
	03/28/11						

DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	PROJECT TEAM LEADER	BRIDGE DRAWING	DATE	DRAWING NO.
FHWA	C. TUTTLE	R. BARROWS, B. COLLINS, M. DODSON, M. ELIAS A. ALZAMORA, J. NICKS	NTS	M. ADAMS	1 of 4	04/2011	

STATE	PROJECT	SHEET NUMBER
	FHWA GRS-IBS	8

GRS-IBS Poor Soil Condition Quantites Per Abutment 1/

HEIGHT (H) (FT)	ROAD BASE h_{rb} THICKNESS (IN)	GEOSYNTHETIC REINFROCEMENT (SQYD) 6/	CMU BLOCK HOLLOW (EA)	CMU BLOCK SOLID (EACH)	#4 REBAR (FT)	GRS BACKFILL (CUYD)	RSF FILL (CUYD)	FOAM BOARD (SQFT) 2/	ROAD BASE AGGREGATE (CUYD)	CONCRETE BLOCK WALL FILL (CUYD)
10.42	34	1200	710	349	652	287	52	18	54	1.4
12.32	34	1700	950	365	698	399	73	18	63	1.5
14.31	34	2100	1165	373	721	509	94	18	68	1.6
16.22	34	2700	1455	389	766	655	123	18	77	1.7
18.21	34	3200	1700	397	789	793	154	36	82	1.7
20.12	34	4000	2030	413	835	973	187	36	92	1.8
22.1	34	4600	2305	421	858	1139	220	36	96	1.9
24.01	34	5600	3280	437	904	1354	267	36	106	2

GRS-IBS ABBUTMENT Favorable Soil Condition Quantities Per Abutment 1/

HEIGHT (H) (FEET)	ROAD BASE h_{rb} THICKNESS (IN)	GEOSYNTHETIC REINFROCEMENT (SQYD) 6/	CMU BLOCK HOLLOW (EACH)	CMU BLOCK SOLID (EACH)	#4 REBAR (FEET)	GRS BACKFILL (CUYD)	RSF FILL (CUYD)	FOAM BOARD (SQFT) 2/	ROAD BASE AGGREGATE (CUYD)	CONCRETE BLOCK WALL FILL (CUYD)
10.42	34	1000	720	349	652	176	24	18	54	1.4
12.32	34	1400	950	365	698	242	26	18	63	1.5
14.31	34	1700	1165	373	721	305	27	18	68	1.6
16.22	34	2200	1455	389	766	394	29	18	77	1.7
18.21	34	2700	1700	397	789	483	35	36	82	1.7
20.12	34	3400	2030	413	835	606	43	36	92	1.8
22.1	34	4000	2305	421	858	715	50	36	96	1.9
24.01	34	4800	3280	437	904	865	60	36	108	2

GRS-IBS Poor Soil Condition DESIGN DIMENSIONS

WALL HEIGHT (H)	WINGWALL LENGTH, L_{ww}	d_e 7/	a_b	b	b_r	B_{total}	B	B_{RSF}	D_{RSF}	X_{RSF}	ABUT WIDTH	WINGWAL L HEIGHT
(FT)	(FT)	(IN)	(IN)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)
10.42	15.63	3	7.6	2.5	3.83	9.5	8.86	11.88	2.38	2.38	37.76	14.00
12.32	18.23	3	7.6	2.5	3.83	11.0	10.36	13.75	2.75	2.75	37.76	15.89
14.31	19.53	4	7.6	2.5	3.83	12.5	11.86	15.63	3.13	3.13	37.76	17.79
16.22	22.14	4	7.6	2.5	3.83	14.0	13.36	17.50	3.50	3.50	37.76	19.70
18.21	23.44	5	7.6	2.5	3.83	15.5	14.86	19.38	4.00	3.88	37.76	21.60
20.11	26.04	5	7.6	2.5	3.83	17.0	16.36	21.25	4.25	4.25	37.76	23.51
22.10	27.34	6	7.6	2.5	3.83	18.5	17.86	23.13	4.63	4.63	37.76	25.42
24.01	29.95	6	7.6	2.5	3.83	20.0	19.36	25.00	5.00	5.00	37.76	27.83

GRS-IBS Favorable Soil Condition DESIGN DIMENSIONS

WALL HEIGHT (H)	WINGWALL LENGTH, L_{ww}	d_e 7/	a_b	b	b_r	B_{total}	B	B_{RSF}	D_{RSF}	X_{RSF}	ABUT WIDTH	WINGWALL HEIGHT
(FT)	(FT)	(IN)	(IN)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)	(FT)
10.42	15.63	3	7.6	2.5	3.83	6.0	5.36	7.50	1.50	1.50	37.76	14.00
12.32	18.23	3	7.6	2.5	3.83	6.0	5.36	7.50	1.50	1.50	37.76	15.89
14.31	19.53	4	7.6	2.5	3.83	6.0	5.36	7.50	1.50	1.50	37.76	17.79
16.22	22.14	4	7.6	2.5	3.83	6.0	5.36	7.50	1.50	1.50	37.76	19.70
18.21	23.44	5	7.6	2.5	3.83	6.5	5.86	8.13	1.63	1.63	37.76	21.60
20.11	26.04	5	7.6	2.5	3.83	7.0	6.36	8.75	1.75	1.75	37.76	23.51
22.10	27.34	6	7.6	2.5	3.83	7.5	6.86	9.38	1.88	1.88	37.76	25.42
24.01	29.95	6	7.6	2.5	3.83	8.0	7.36	10.00	2.00	2.00	37.76	27.83

FOOTNOTES:

1/ The estimated materials quantities correspond to the dimensions on the accompanying plan sheets. Deviation from the dimensions on the plan sheets will void the quantities.

2/ Foam board thickness is 4-inches (typ.).

3/ Wingwall length = B total + H + 3-feet.

4/ CMU block assumptions: solid blocks at the base of the GRS abutment from estimated scour elevation to 100-year flood event elevation (5-feet assumed here): solid blocks in setback location to beam seat (1-row assumed): hollow blocks for remaining wall height and guardrail height: concrete-filled blocks assumed 3 rows deep below bearing pad and at the top of the wall of guardwall and at all corners: wet cast coping at the top row of exposed CMU at abutment wall and wingwall: flush concrete fill in the CMU's at the top of the abutment wall under the beam seat below the clear zone. See Sheet C and D for illustrations of these details.

5/ Maximum vertical spacing of reinforcement = height of 1 CMU block (H_{block}) in reinforced backfill zone. Maximum vertical spacing of reinforcement ≤ 6-inches in bearing bed zone and integrated approach.

6/ No overlaps in geosynthetics measured for quantities.

7/ Design clear space (d_e) rounded up to the nearest 1.0 inch.

8/ Geosynthetic reinforcement quantity includes RSF and IBS geotextile quantities.

ABREVIATIONS:

a_b = Set back distance between back of facing element and beam seat

B = Base length of reinforcement not including the wall face

b = Bearing width for bridge, beam seat

B_b = Width of the bridge

b_{block} = Width of CMU

b_r = Length of bearing bed reinforcement

B_{RSF} = Width of RSF

B_{total} = Total width at base of GRS abutment including the wall facing

CMU = Concrete masonry unit

d_e = Clear space from top of wall to bottom of superstructure.

d_{max} = Maximum partical diameter in reinforced backfill

D_{RSF} = Depth of RSF below bottom of wall elevation

GRS = Geosynthetic Reinforced Soil

H = Wall height measured from top of RSF to top of beam seat

H_{block} = Height of CMU

h_{rb} = Height of road base (equals height of super structure and pavement thickness)

IBS = Integrated Bridge System

L = Length of geosynthetic reinforcement

L_{abut} = Abutment width

L_{block} = Length of CMU

L_{ww} = Wingwall length.

RSF = Reinforced soil foundation

X_{RSF} = Length of RSF in front of the abutment wall face

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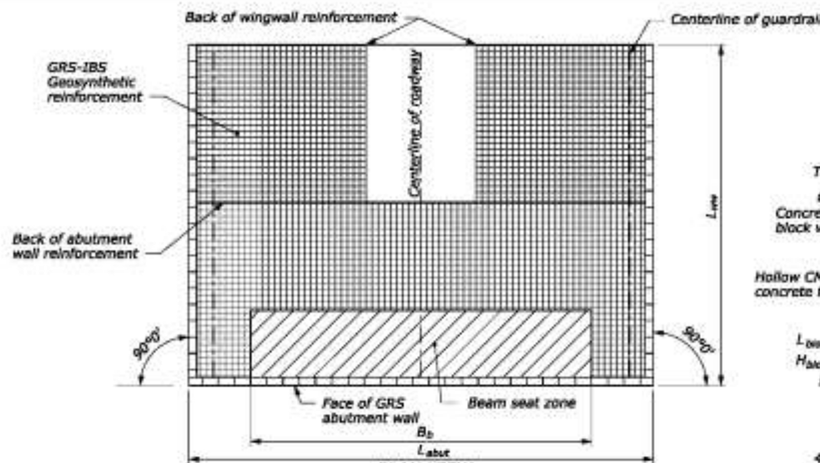
GRS-IBS

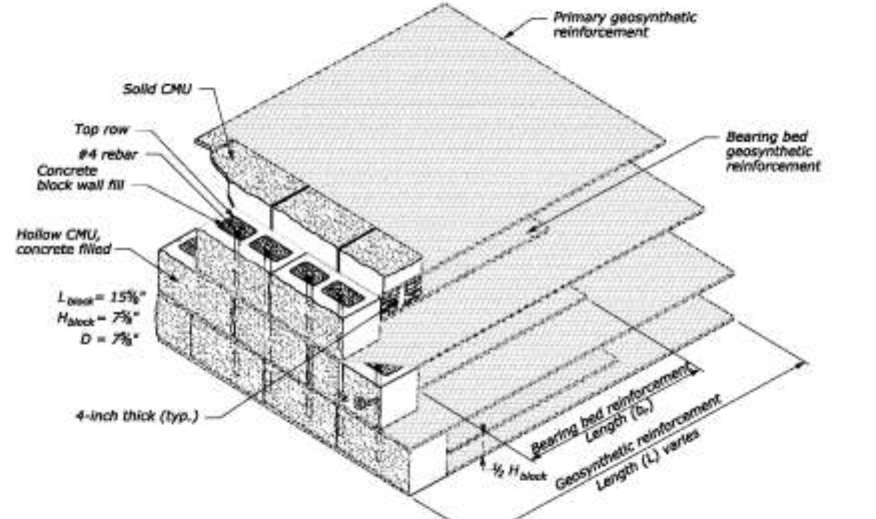
DESIGN DIMENSION QUANTITIES

NO.	DATE	BY	REVISIONS	NO.	DATE	BY	REVISIONS	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	PROJECT TEAM LEADER	BRIDGE DRAWING	DATE	DRAWING NO.
	03/25/11		Rev. 0					FHWA	C. TUTTLE	R. BARROWS, B. COLLINS, M. DODSON, M. ELIAS A. ALZAMORA, J. NICKS	NTS	M. ADAMS	2 of 4	04/2011	
	03/29/11														

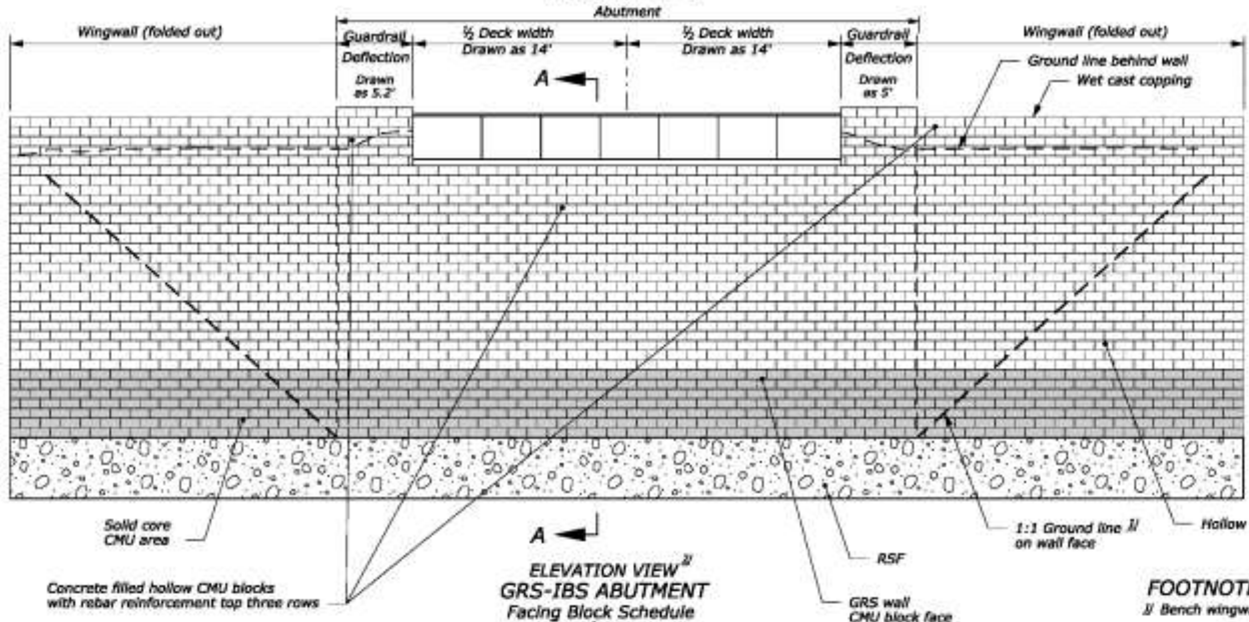
STATE	PROJECT	SHEET NUMBER
	FHWA GRS-IBS	C



PLAN VIEW
GRS-IBS ABUTMENT
Facing Block Schedule
SCALE: ⅛" = 1'-0"



TYPICAL BEAM SEAT
(ISOMETRIC VIEW)



ELEVATION VIEW 2/
GRS-IBS ABUTMENT
Facing Block Schedule
SCALE: ⅛" = 1'-0"

NOTE:

1. Insert #4 rebars into the top 3 rows of CMU's and corner CMU's and fill with concrete.
2. Adjust length and angle of wingwalls for site specific conditions and quantities in Sheet B accordingly.
3. If RSF is not used beneath the wingwalls, then additional independent retaining wall calculations should be performed to determine the stability of the wingwalls.
4. Superelevation of the roadway is assumed to have a crest at the centerline of the roadway, which corresponds to the maximum design clear space (d).
5. No skew angle of the bridge to the stream channel is assumed.
6. No angular distortion between abutments is assumed.
7. Solid core CMU's placed up to the riprap height (5 feet typ.).
8. CMU blocks are staggered, including corners, so there are no vertical joints greater than 1 CMU block height.
9. Guardrail type and location to be designed by others in accordance with required safety standards.

FOOTNOTE:

1/ Bench wingwall as necessary.

2/ Wingwalls folded out for elevation view.

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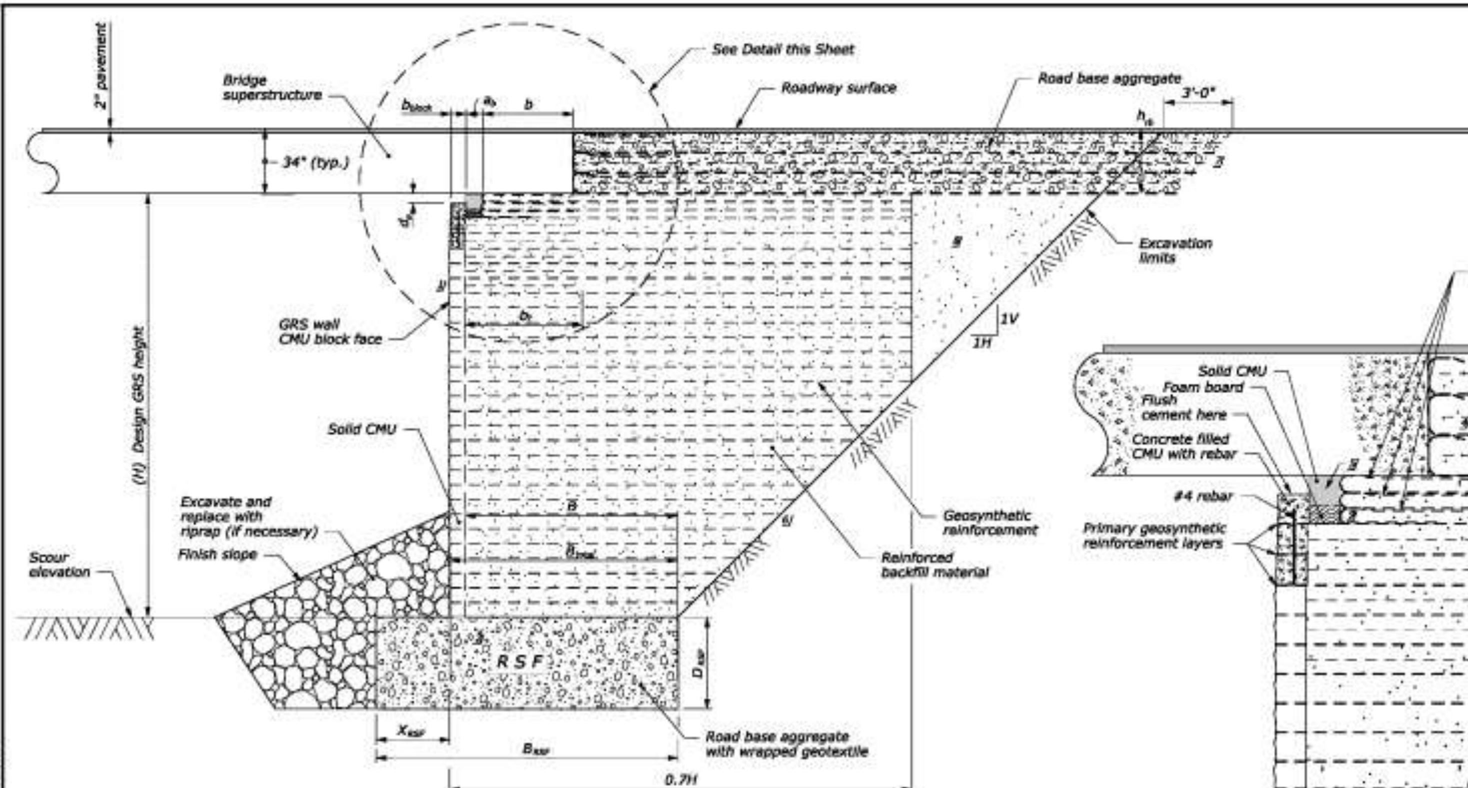
GRS-IBS
PLAN AND ELEVATION
FACING BLOCK SCHEDULE

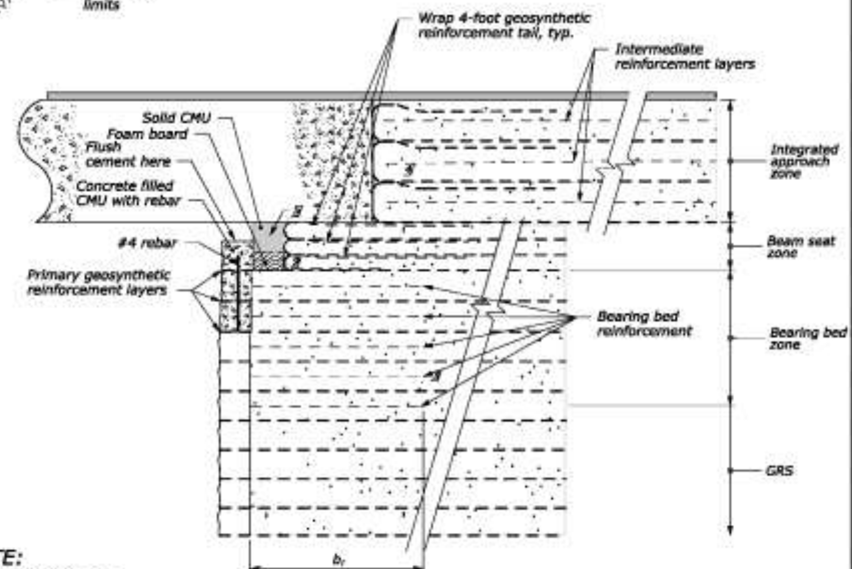
NO.	DATE	BY	REVISIONS	NO.	DATE	BY	REVISIONS	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	PROJECT TEAM LEADER	BRIDGE DRAWING	DATE	DRAWING NO.
	03/25/11		Rev. 0		04/04/11		Rev. 1	FHWA	C. TUTTLE	R. BARROWS, B. COLLINS, M. DODSON, M. ELIAS A. ALZAMORA, J. NICKS	AS SHOWN	M. ADAMS	3 of 4	04/2011	
	03/29/11														

STATE	PROJECT	SHEET NUMBER
	FHWA GRS-IBS	D



SECTION A-A

Vertical Scale: 3/16" = 1'-0"
Horizontal Scale: NTS



DETAIL

(Beam seat and integrated approach Detail)
Vertical Scale: 3/8" = 1'-0"
Horizontal Scale: NTS

LEGEND:

- Reinforced backfill material
- Road base aggregate
- Pavement
- Riprap
- Hollow concrete masonry unit (CMU)
- Colored solid concrete masonry unit (CMU)
- Concrete filled concrete masonry unit (CMU)

NOTE:

1. Insert #4 rebars in to the top 3 rows of CMU's and corner CMU's and fill with concrete.
2. Strike CMU concrete fill flush with top of CMU's under bridge girders slope to drain.
3. On the top row of CMU's create a mortar capping approx. 3/8-inch thick.
4. Typical sections represent a wall height (H) equal to 18.21-feet.

FOOTNOTE:

1/ Vertical wall face batter = 0°.

2/ Solid CMU's behind riprap.

3/ Minimum of 5 layers of bearing bed reinforcement.

4/ Primary wrap reinforcement vertical spacing for the integrated approach is a maximum of 12-inches.

5/ Full height block is typical in front of bearing seat but a half height block and a special foam board thickness may be required in some applications.

6/ Short term back slope ratio per OSHA Safety Regulations (29CFR, Part 1926, Subpart P, excavation). Shoring may be required if the short term back slope will be open more than 30 days or if the required short term back slope ratio specified cannot be obtained.

7/ Extend integration zone layers past cut slope.

8/ Insure that high quality fill is placed in this area.

9/ The first beam seat reinforcement layer length is a maximum of 6-feet with a conventional 4-foot tail.

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GRS-IBS

DETAILS

NO.	DATE	BY	REVISIONS	NO.	DATE	BY	REVISIONS	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	PROJECT TEAM LEADER	BRIDGE DRAWING	DATE	DRAWING NO.
	03/25/11		Rev. 0		04/04/11		Rev. 1	FHWA	C. TUTTLE	R. BARROWS, R. COLLINS, M. DODSON, M. ELIAS, A. ALZAMORA, J. NICKS	AS SHOWN	M. ADAMS	4 of 4	04/2011	
	03/29/11														

CONSTRUCTION
Youtube Video

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User Perspective

Defiance County, Ohio


Construction Costs:
80’x32’-$266,000 - 2005
Open to Traffic:
47 days

Construction Costs:
28’x20’-$68,000 - 2008


Construction Costs
28’x20’-$88,000 - 20

Construction Costs:
32’x10’-$51,000 - 2010

Construction Costs:
28’x20’-$70,000 - 2010

Construction Costs:
28’x20’-$65,000 - 2010


Construction Costs:
28’x32’-$85,000 - 2010


Construction Costs:
36’x20’-$71,000 - 2010

Construction Cost:
140’x40’-$620,000 - 2009

User Perspective

St. Lawrence County, NY

CR 12 - 40’x33’- Material Cost $160,000
Construction costs $240,000


CR 24 - 47’x33’- Material Cost $110,500

CR 31 - 56’x33’- Material Cost $165,000

CR 35 - 67’x33’- Material Cost $180,500
Construction Cost $310,000

CR 38 - 63’x32’- Material Cost $175,000

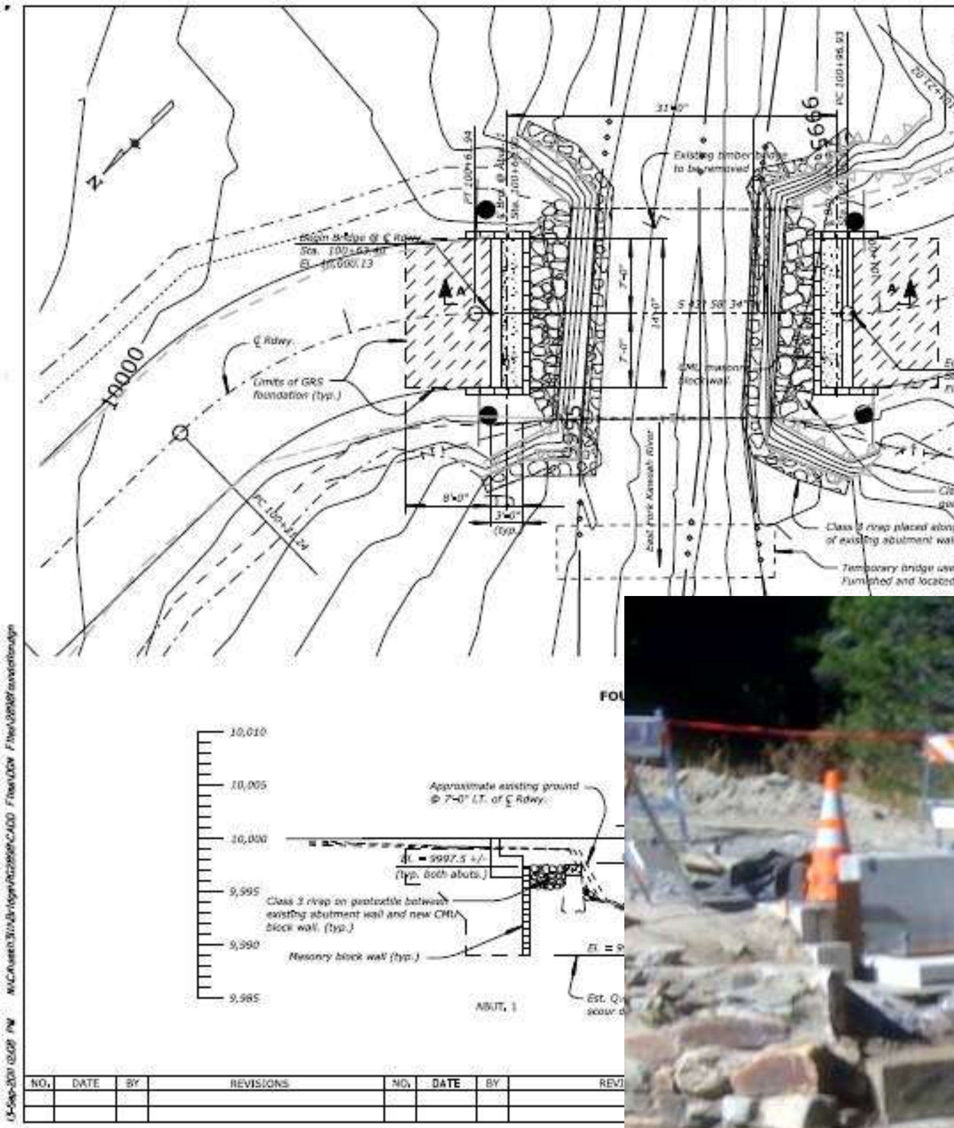
User Perspective
Huston Township, Pennsylvania


10/27/2011 17:28

User Perspective
Ottawa County , Oklahoma


User Perspective
National Park Service

Disney Bridge in Sequoia NP



Strawberry Creek
Great Basin National Park - NV

U.S. Department of Transportation

Federal Highway Administration

Every Day Counts

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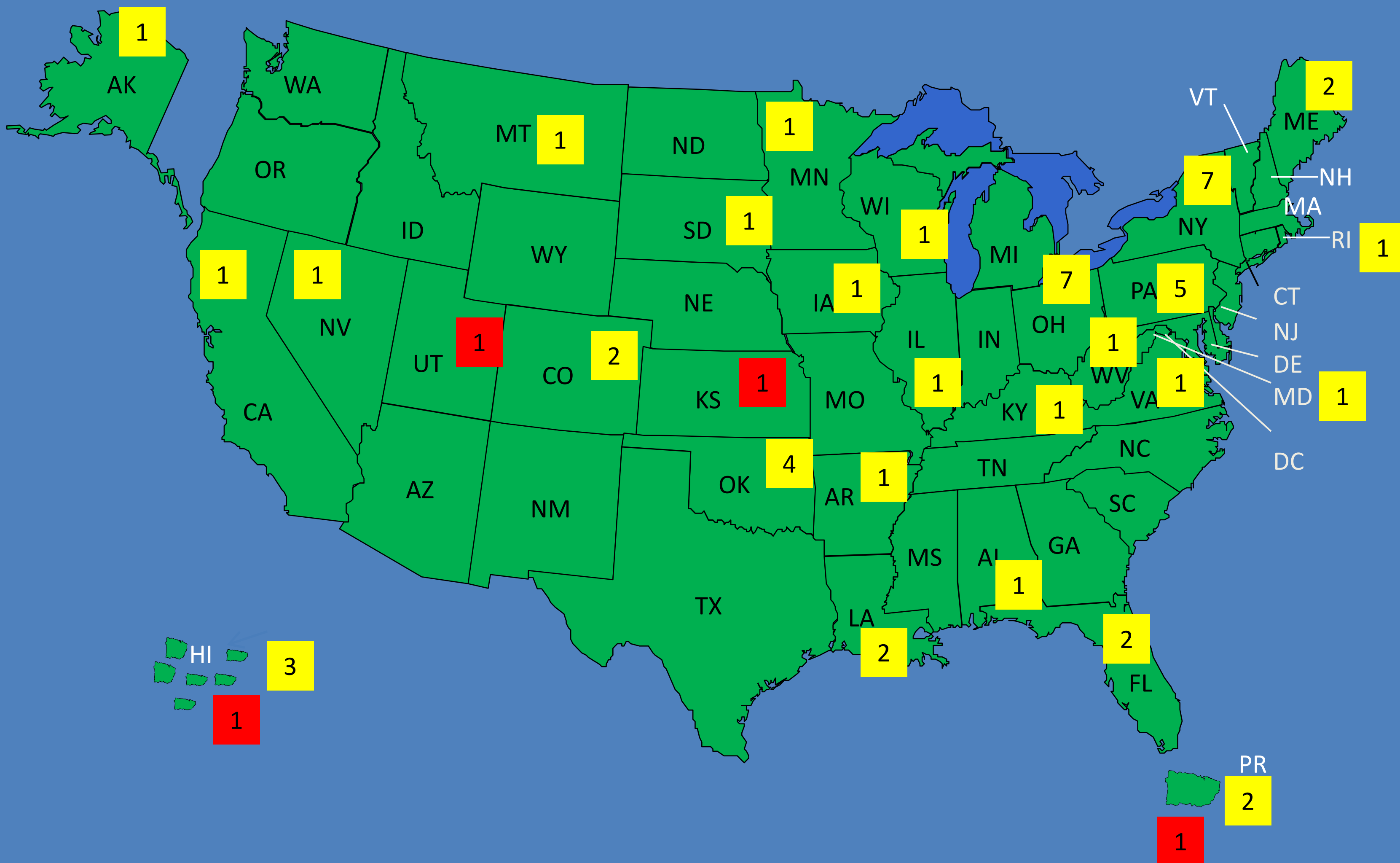
PROGRESS TOWARD 2012 EDC GRS IBD GOALS

2012 Deployment Goals

- December 2012:
  - 30 bridges have been designed and/or constructed using GRS-IBS on the NHS within 20 states
  - 75 bridges have been designed and/or constructed using GRS-IBS off the NHS

State DOT Deployment

Total of 56 project in 28 states at some stage of development from conceptual to construction



U.S. Department
of Transportation

Federal Highway
Administration

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