

Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) Concepts & Background

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& State Geotechnical Engineer**



GRS-IBS

- Introduction to the concept
- Research Performed
- Design Guide
- Design Method
- Construction
- FDOT Implementation
- Developmental Specification 549
- Developmental Standard 6025



Acknowledgement

Thank-you to Daniel Alzamora, Jennifer Nicks and Michael Adams with Federal Highway (FHWA) for allowing me to draw from their experience and training materials including many of the slides in this presentation.



FHWA's EDC Web Site

www.fhwa.dot.gov/everydaycounts

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



FHWA's EDC Web Site

www.fhwa.dot.gov/everydaycounts/technology/grs_ibs/

Ancient Secrets, Modern Science: Geosynthetic Reinforced Soil (GRS) Integrated Bridge System (IBS)



FHWA's EDC Web Site

http://www.fhwa.dot.gov/everydaycounts/technology/grs_ibs/multimedia.cfm

Multimedia:
Videos,
Webinars
& Pictures

FHWA > Every Day Counts > Accelerating Technology > GRS-IBS > Multimedia

GRS-IBS Multimedia

Videos

Welcome to the Every Day Counts (EDC) Exchange – a series of information exchanges intended to introduce you to FHWA's EDC Initiatives. The videos that you are about to view include introductions to the initiative as well as specific projects and examples of successful application of the initiative.

Part 1 – Introductory remarks by:

- Warren Schaeffer, P.E., P.S. – DeLancey County (Or)
- Engineer
- G. Randy Albert, P.E. – PennDOT Municipal Service Supervisor

Part 2 – National Question and Answer Session

Part 3 – Presentations by:

- Brian P. Keiserleber, P.E. – Buchanan County (IA)
- Engineer
- Toby Bogart, P.E. – St. Lawrence County (NY)
- Superintendent of highways

Part 4 – National Question and Answer Session

Photos



Start to Finish
10 Days

GRS-IBS

- Introduction
- Description
- The Three Main Components of GRS
- Quickfacts
- Case Studies
- Multimedia
- FAQs
- Publications
- Helpful Resources
- Training

<< Return to ABC site

GRS-IBS BROCHURE

- Download Brochure
- Printable/Foldable

EDC INNOVATION BOX

Share your ideas on how to Shorten Project Delivery or Accelerate Technology and Innovation Deployment

RELATED LINKS

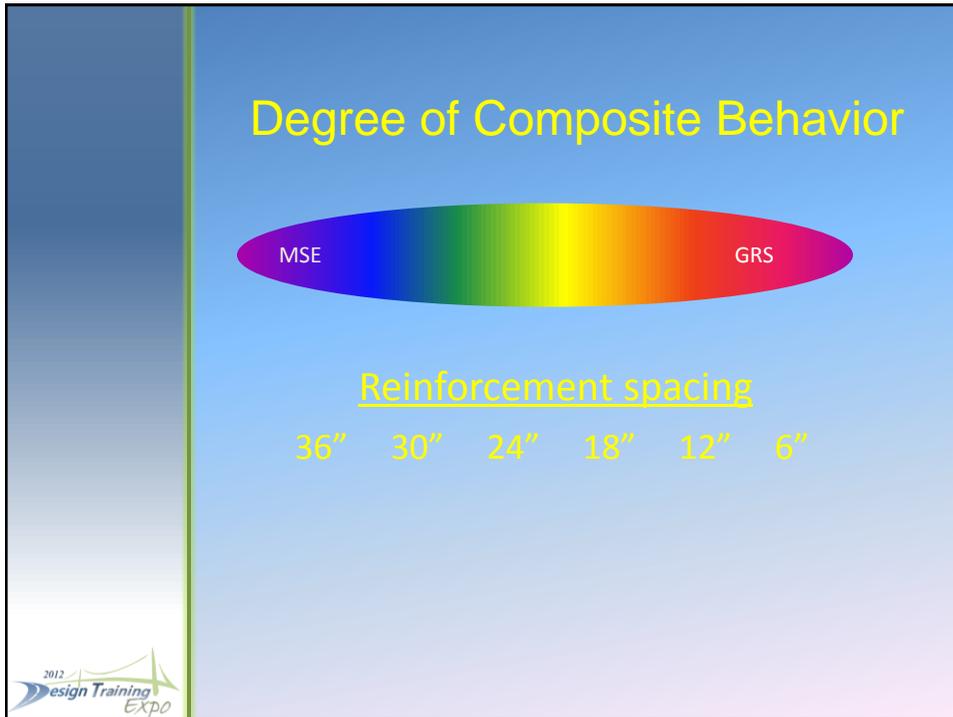
- Geotechnical

To learn more about this EDC initiative, contact your local FHWA Division Office



GRS – IBS





GRS Fundamentals

Why Do This?

- FHWA & States with experience report:
 - Reduced construction cost (25 - 60%)
 - Reduced construction time
 - 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
 - Smooth Transition

2012 Design Training Expo

GRS FUNDAMENTALS



GRS Fundamentals

Definitions

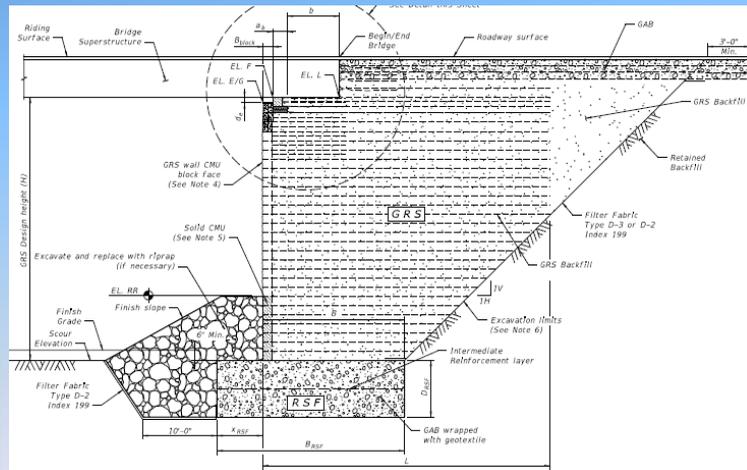
- **GRS - Geosynthetic Reinforced Soil**
 - An engineered, well compacted granular fill with closely spaced (< 12") layers of geosynthetic reinforcement
- **IBS - Integrated Bridge System**
 - A fast, cost-effective method of bridge support blending the roadway into the superstructure using GRS technology



Cut-away of a GRS Mass



Cross-Section of GRS-IBS



Site Selection

- Simple span (currently ≤ 140 ft)
 - Single or Multiple Span Bridges
- ≤ 30 ft abutment height
- Grade separation
- 9 fps Water Velocity (or higher?)
- Cost Effective to Excavate for RSF Below Scour Elevation?



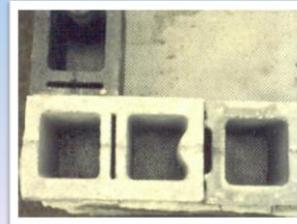
Site Selection

- Tolerable Settlements
- Steel or concrete superstructures
- New or replacement structures
- On or Off System
- Approval Needed for Interstate or Multi-Land Roadways



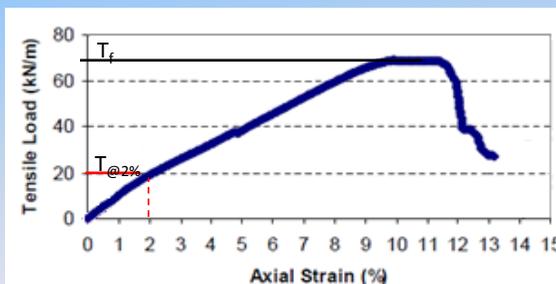
Facing Elements

- Split face CMU Block
 - Dimensions: 7-5/8" x 7-5/8" x 15-5/8" (nominal 8x8x16)
 - Readily available
 - Inexpensive
 - Compatible with the frictional connection to the reinforcement
- Material Specifications:
 - Compressive strength \geq 4,000 psi
 - Water absorption limit: 5%



Geosynthetic Reinforcement

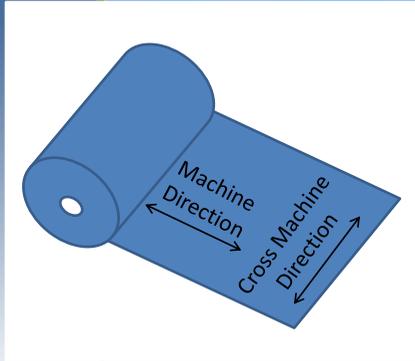
- Geosynthetic reinforcement material can include:
 - HDPE, PP, or PET Geogrids
 - PP or PET Woven geotextiles
- Ultimate Strength: $T_{ult} = 4800$ lb/ft (both directions)
- Strength at 2% Strain ($T_{2\%}$): Tensile Load @ 2% ϵ



Geosynthetic Reinforcement

Continued

- Cross Machine vs. Machine Direction



- Uniaxial (strength in one direction)
- Biaxial (strength in both directions)

Granular Backfill

- Well graded
 - Spec 204
Graded Aggregate
 - $\phi \geq 38^\circ$
- Open graded
 - #57
 - #67
 - #89
 - $\phi \geq 38^\circ$



FHWA Research: Performance Testing and Monitoring



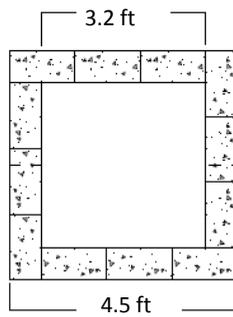
GRS Fundamentals

Performance Tests

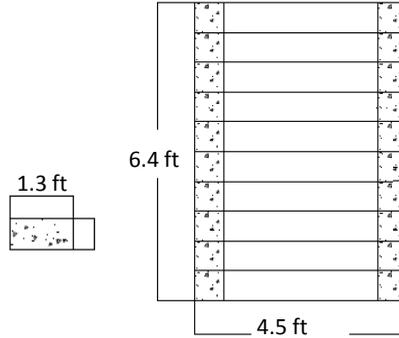
- Also known as “Mini-Pier” experiments
- Provides material strength properties of a particular GRS composite
- Procedure involves axially loading the GRS mass to measure lateral and vertical deformation



Performance Tests *Continued*



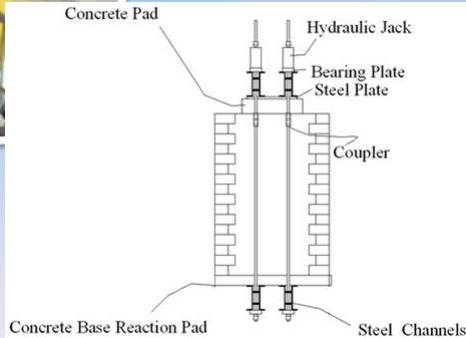
Top View



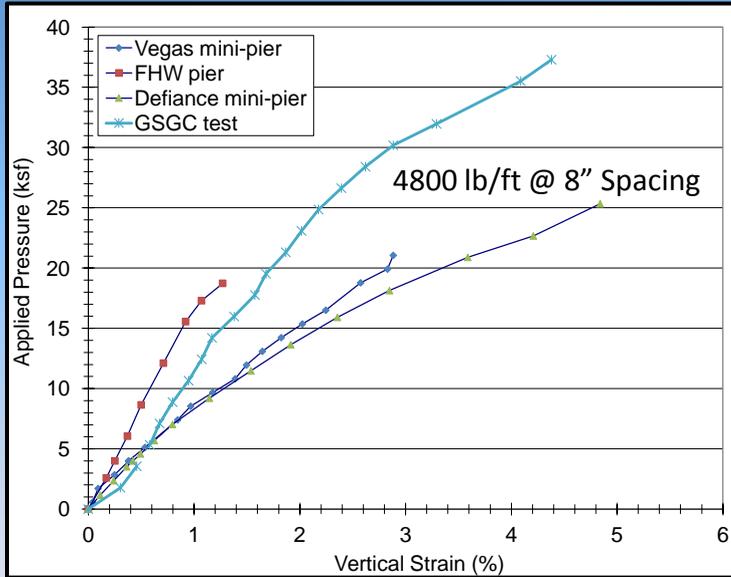
Side View



Performance Tests *Continued*



Performance Test Results



GRS Fundamentals

Performance Tests *Continued*

Before



After

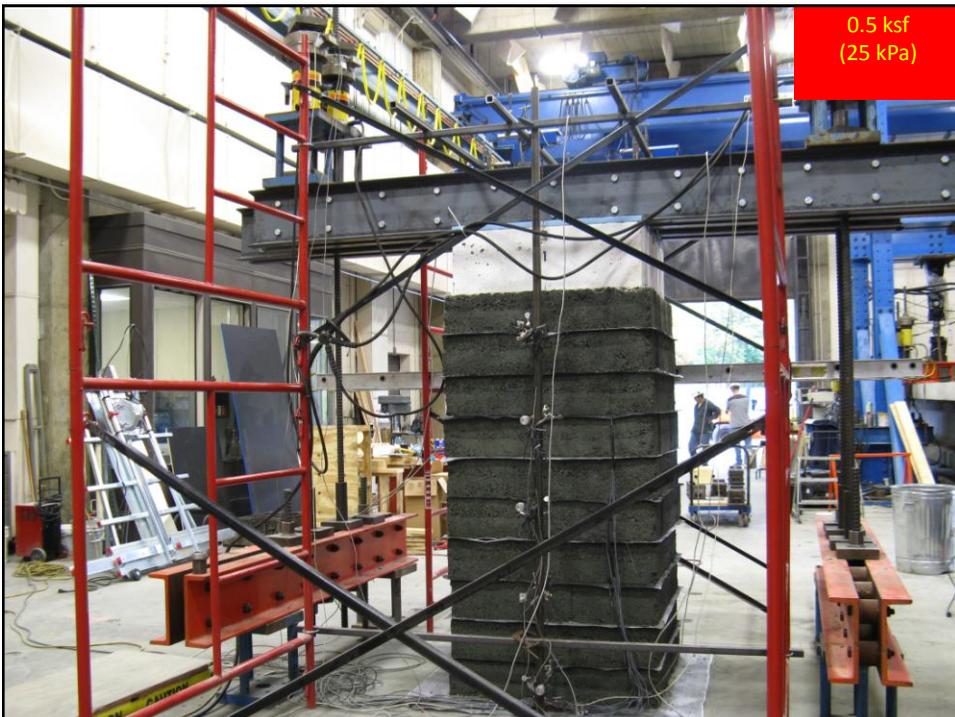


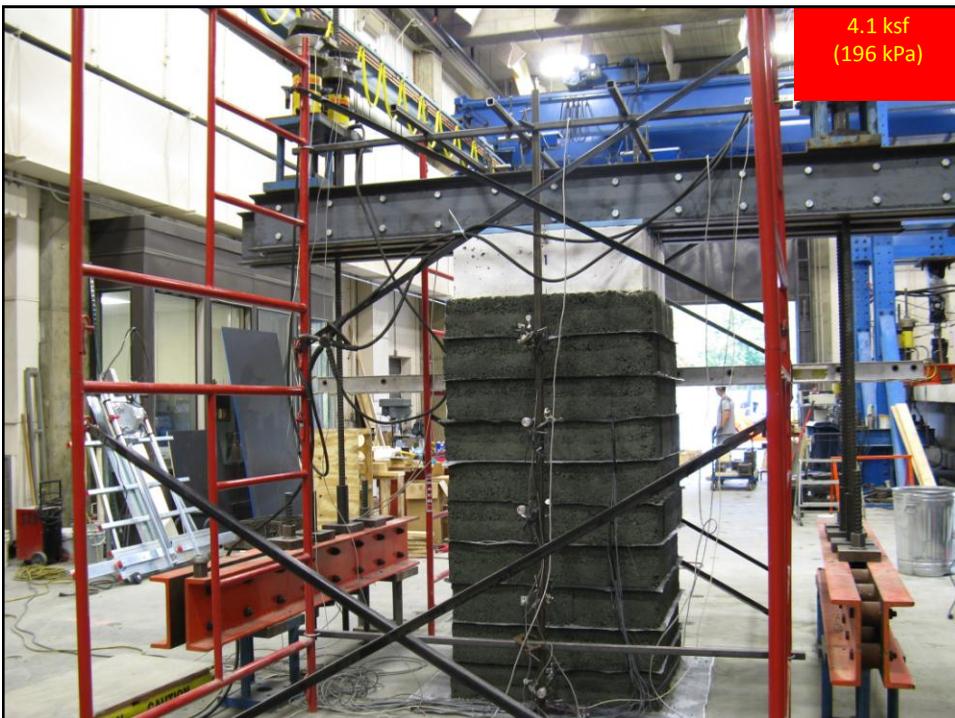
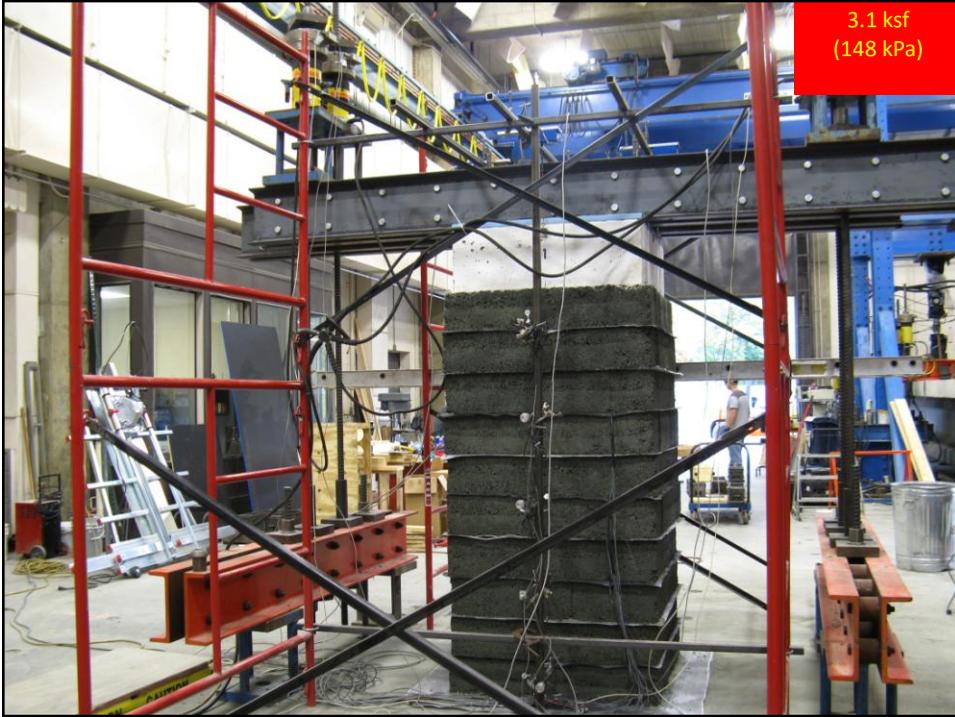
Performance Test 2400 lb/ft @ 8" Spacing

Before



After



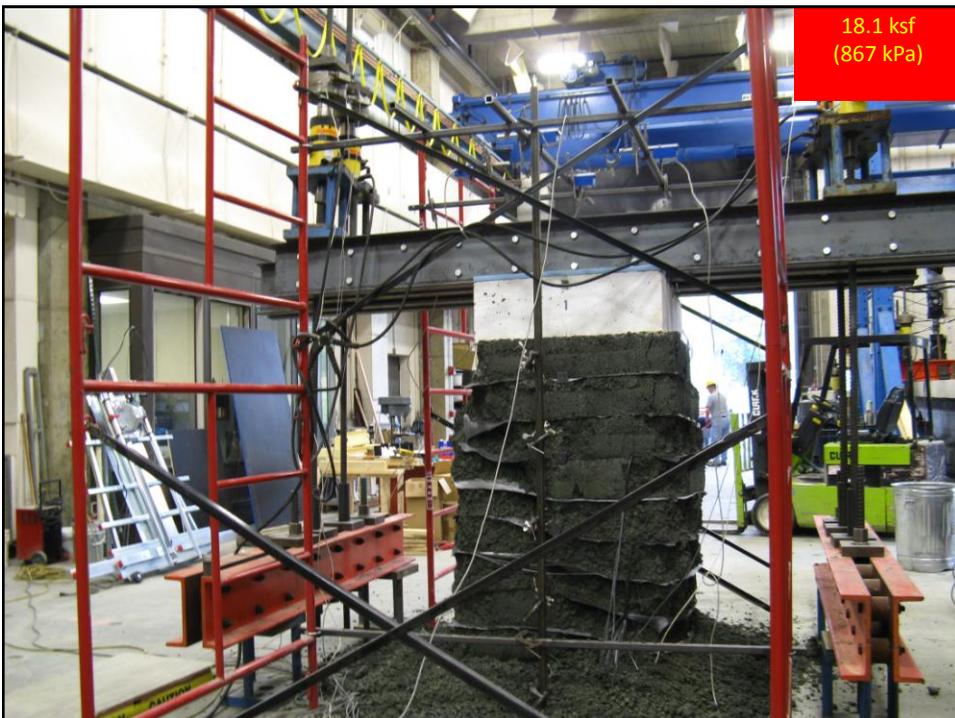


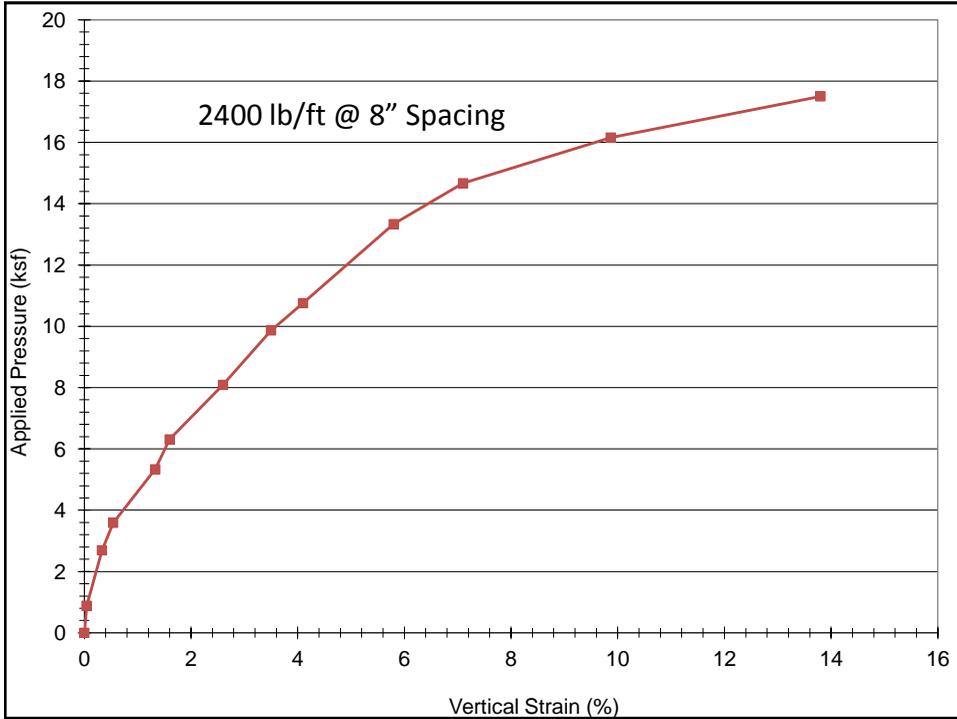












GRS Has Composite Behavior

- GRS differences:
 - Composite Structure
 - Friction Connections
 - Close Spacing

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Settlement Monitoring

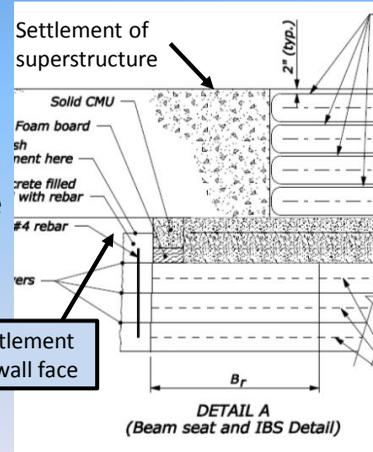
Continued



Settlement Monitoring

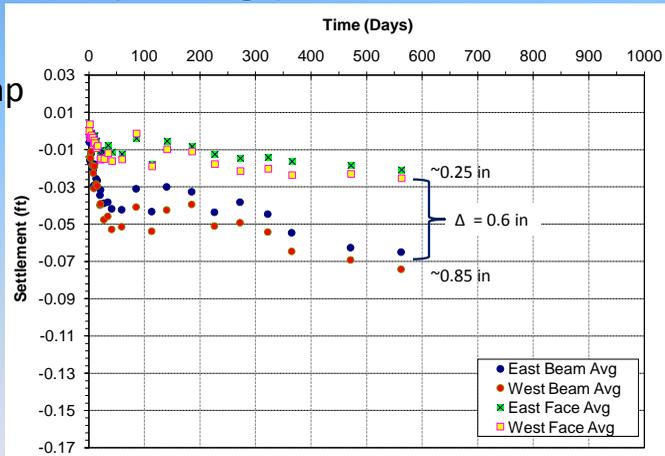
Continued

- Settlement is recorded for both the wall face and the superstructure
- The difference between the settlement on the wall face and the superstructure is the compression within the GRS mass



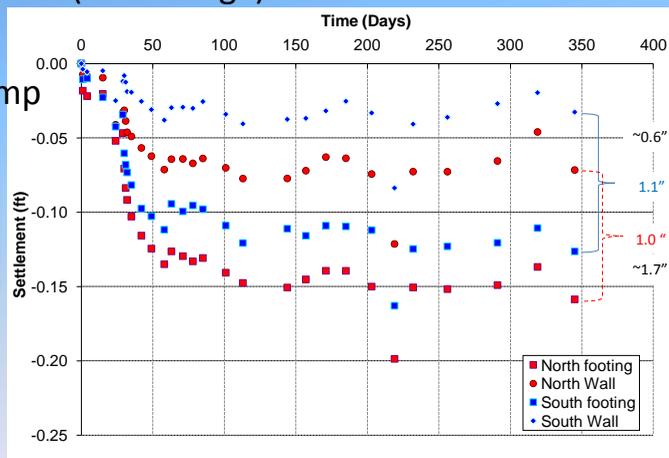
Settlement Monitoring *Continued*

- EDM survey
 - Bowman Road (82' Bridge)
 - 7 y/o
 - No Bump

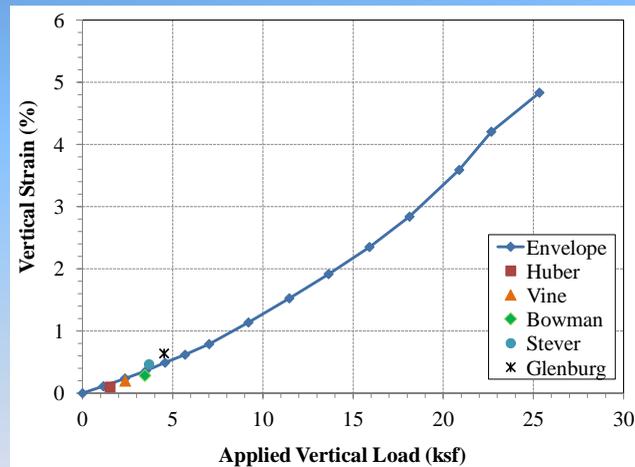


Settlement Monitoring *Continued*

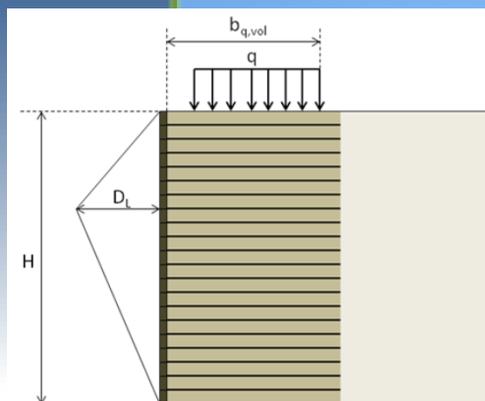
- EDM survey
 - Tiffin River (140' Bridge)
 - 3 y/o
 - No bump



Vertical Deformation *Continued*



Lateral Deformation *Continued*



$$\Delta V_{top} = b_{q,vol} L D_v = \Delta V_{face} = \frac{1}{2} H L D_L$$

$$\epsilon_L = \frac{D_L}{b_{q,vol}} = \frac{2D_v}{H} = 2\epsilon_v$$

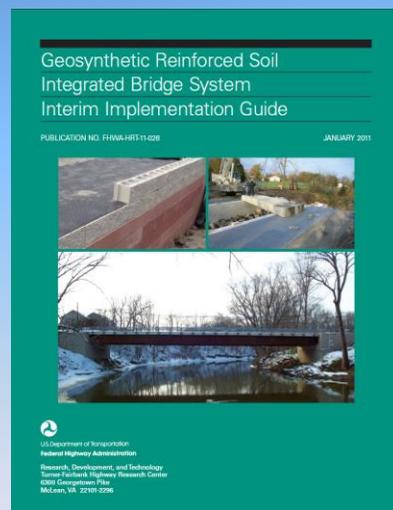
Construction Video



Design Method

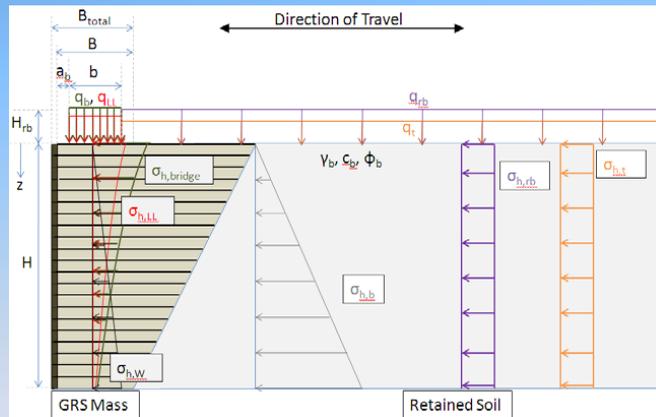
- FHWA GRS-IBS Design Guide
- Appendix C – LRFD Design

• <http://www.fhwa.dot.gov/publications/research/infrastructure/structures/11026/>



Design Method

- Generic Service Loading
 - $q_b + q_{LL} \leq 4000$ psf



LRFD Design

- LRFD External Stability
 - Sliding, $\phi=1.0$
 - Bearing, $\phi=0.65$
 - AASHTO also limits eccentricity
 - Global Stability, $\phi=0.65$

LRFD Design

• Internal Stability

- Factored Tensile Strength
(strength limit state, $\phi=0.45$)
- Strength at 2% strain
(service limit state, controls deformation)
- Uses Boussinesq theory for lateral stress in reinforcements



Is a 35' single span flat slab
feasible here?

What is the tolerable settlement ?



CONSTRUCTION OF GRS-IBS



Construction of GRS-IBS

QA/QC

- Block alignment
- Compaction
- Reinforcement placement
- Quality of construction materials
- Scour protection
- Drainage details



Construction of GRS-IBS

Compaction

- Compaction of the fill is extremely important
- Compact GAB to 95% of modified proctor, or Gravel to no movement



Construction of GRS-IBS

Labor and Equipment

- Common labor
- Equipment: Non-specialized
 - Hand tools
 - Measuring devices
 - Heavy equipment







Construction of GRS-IBS

GRS Abutment

- The first layers are important for leveling and alignment

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Construction of GRS-IBS

GRS Abutment *Continued*

- Wall Corners:
 - Right angle wall corners constructed with CMU corner blocks that have architectural detail on two sides
 - Walls with angles $\neq 90$ degrees require cutting of the corner blocks resulting in a vertical seam or joint. Fill with a dry concrete mix and install bent rebar



Construction of GRS-IBS

GRS Abutment *Continued*

- Top of Facing Wall:
 - The top three courses of CMU block are filled with concrete wall mix and pinned together with No. 4 rebar
 - The reinforcement in these cells needs to be cleared with a razor knife or burning to open the core for placement of concrete wall fill

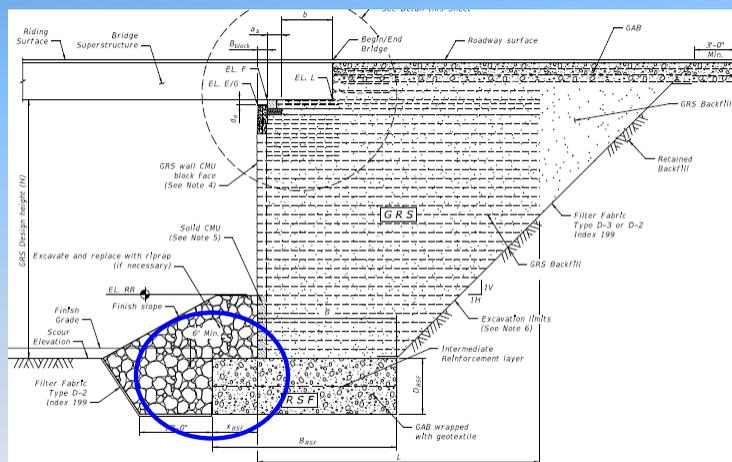


GRS Abutment *Continued*

- Coping:
 - After filling the top three courses of block, a thin layer of the same concrete mix is placed on top of the block, to form the coping
 - Then hand trowel the coping either square or round and slope to drain

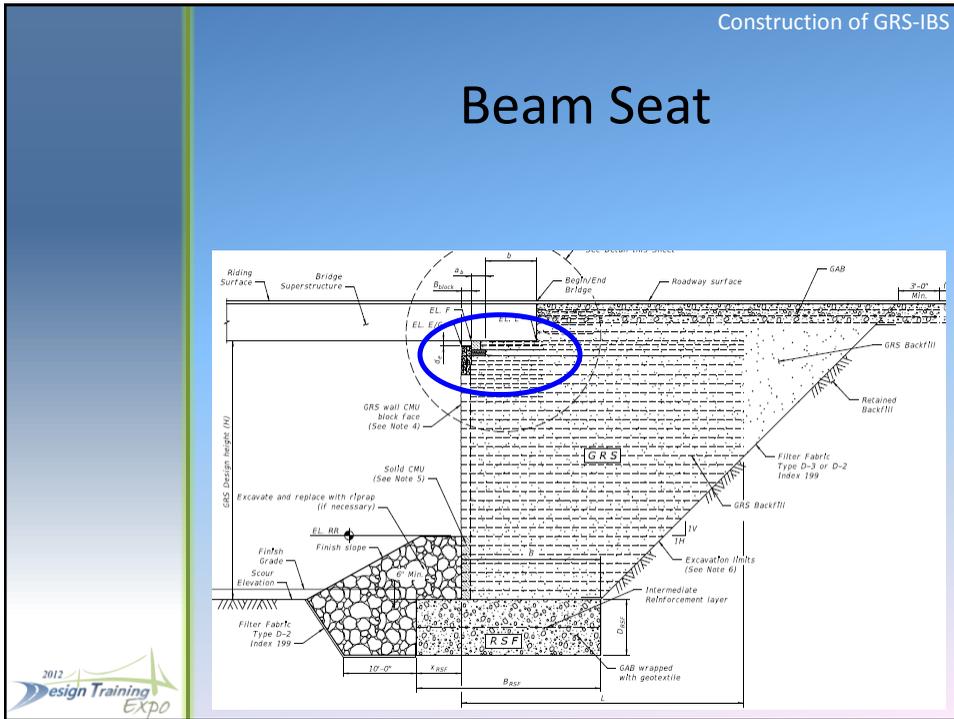


Scour Countermeasure





Beam Seat



Beam Seat

- 1) Place pre-cut foam board of 4 in" thickness on the top of the bearing bed reinforcement. The foam board should be butted against the back face of the CMU block.



Construction of GRS-IBS

Beam Seat

- 2) Set a 4" solid concrete block on top of the foam board, across the entire length of the bearing area.



Construction of GRS-IBS

Beam Seat

- 3) The first 4" wrapped layer of compacted fill is the thickness to the top of the foam board
- 4) The second 4" wrapped layer of compacted backfill is to the top of the 4" solid block creating the clear space

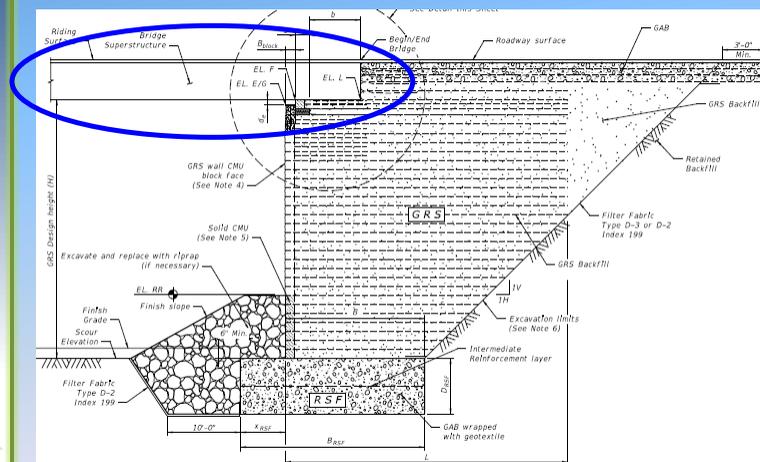


Beam Seat

- 5) Grade the surface aggregate of the beam seat slightly high (to about 0.5") to seat the superstructure level and maximize contact with the bearing area

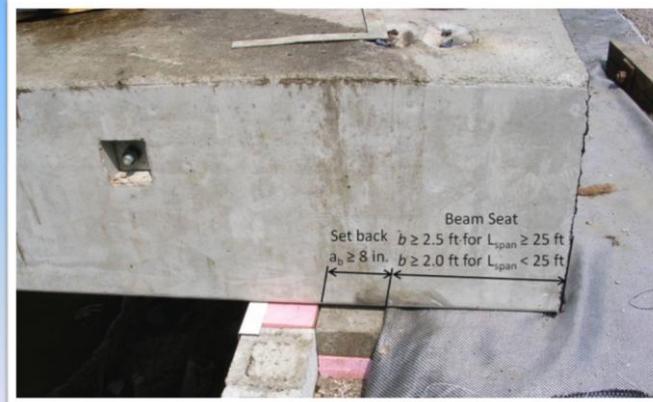


Superstructure



Superstructure

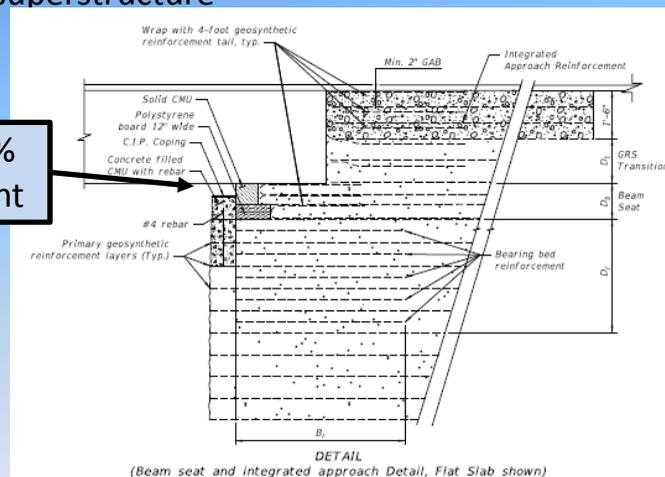
- Set Back: The distance between the back of the facing block and the front of the beam seat (use width of foam, currently 12")



Superstructure

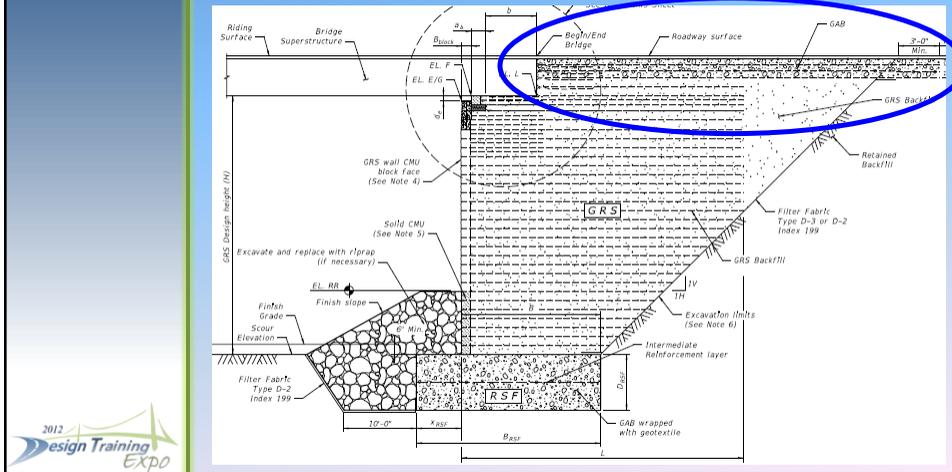
- Clear Space: The distance between the top of the wall face and the bottom of the superstructure

3" min or 2%
 of wall height





Approach Integration



Approach Integration *Continued*

- 1) Trim reinforcement sheet to provide planned length after it is wrapped and place behind the beam end. The width of the sheet should allow for wrapping of the sides after the fill layer is placed and compacted. Wrapping of the sides prevents migration of the fill laterally.

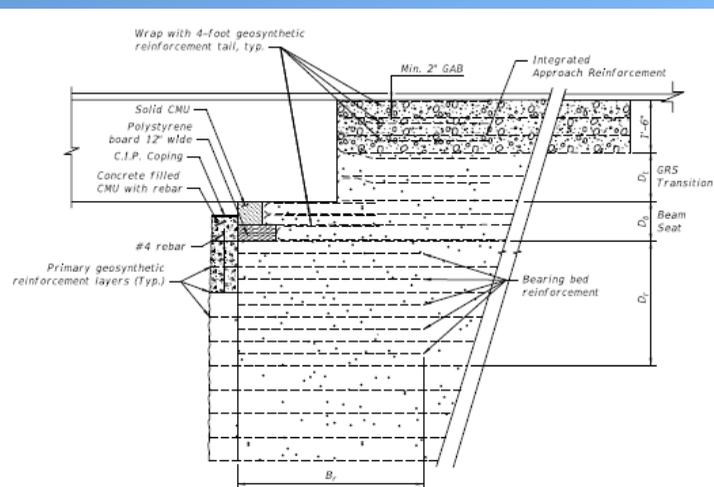


Approach Integration *Continued*

- 2) Place a 6" lift of GAB and compact per Specification 204
- 3) Cover with reinforcement and wrap sides. Wrapping of the sides prevents migration of the fill laterally.



Approach Integration *Continued*



DETAIL
(Beam seat and integrated approach Detail, Flat Slab shown)

FDOT Implementation

- Structures Design Bulletin 12-06:
Evaluation of GRS Abutments for Single Span Bridges, Bridges with Simply Supported End Spans and GRS Walls

<http://www.dot.state.fl.us/structures/Memos/StructuresDesignBulletin12-06.pdf>



FDOT Implementation

- Structures Design Bulletin 12-06
 - Revises Sections 3.12.12 & 3.13.4 of the January 2012 Structures Design Guidelines regarding (GRS) Walls and Abutments
 - Contains Links to:
 - FHWA Implementation Guide
 - Developmental Specification 549
 - Developmental Standard 6025



CONSTRUCTION OF GRS-IBS

- Developmental Specification 549
 - Request use of Developmental Spec for your project through the District Specifications Office.
 - DSO sends request to SSO, who then forwards the DS for the project specific Specs Package.



CONSTRUCTION OF GRS-IBS

Developmental Specification 549

<http://www.dot.state.fl.us/specificationsoffice/>

The screenshot shows the Florida Department of Transportation (FDOT) Specifications & Estimates website. The page is titled "Specifications & Estimates" and includes a navigation menu with links such as "Home", "Services", "About Us", "Contact Us", "Public Information", "Research Services", and "Special Information". The main content area features a "How to Contact Specifications and Estimates" section with links for "Have a Question?", "Frequently Asked Questions", and "Staff Lists". Below this is the "2012 Design Training Expo" section, which includes a logo and a list of links. A red circle highlights the "Developmental Spec" link in this list. The page also features a "Specifications Package Preparation Training for Contractors" section and a "Welcome" message at the bottom.



CONSTRUCTION OF GRS-IBS

Developmental Specification 549

<http://www.dot.state.fl.us/specificationsoffice/OtherFDOTLinks/Developmental/Default.shtm>

Specification Description	Author	Document Number
Dynamic Testing (DB) Test Piles 100% dynamic testing (DB) test piles	Larry Jones	Dev45501a10
Dynamic Testing (WB) Test Piles 100% dynamic testing (WB) test piles	Larry Jones	Dev45501a10
Cross Hole Sonic Logging (CHSL) Tubes This specification sets the format, integrity, testing of drilled shafts	Larry Jones	Dev45518am
INCIDENTAL CONSTRUCTION		
Sound Barriers and Perimeter Walls Provide for construction of Sound Barriers and Perimeter Walls	Steve Nolan	Dev334
High Tension Cable Barrier Systems Furnish and install high tension cable barrier systems in accordance with the requirements of the Contract Documents and the manufacturer's recommendations.	David O'Neil	Dev546
Geosynthetic Reinforced Soil Abutments and Walls Construct geosynthetic reinforced soil abutments and walls (GRS) in accordance with this Section and in conformance with the lines, grades, design, and dimensions shown in the Contract Documents or established by the Engineer.	Larry Jones	Dev549
Temporary Geosynthetic Reinforced Soil Walls Construct temporary geosynthetic reinforced soil walls (GRS) in accordance with this Section and in conformance with the lines, grades, design, and dimensions shown in the Contract Documents or established by the Engineer.	Larry Jones	Dev549
TRAFFIC CONTROL DEVICES		
TRAFFIC CONTROL		
Inverted RIB Profile Markings Apply inverted RIB profile traffic stripes and markings, in accordance with the Contract Documents.	Brian Blanchard	Dev420
Painted Pavement Traffic Markings Cure-in-place Traffic Paint. Use with Dev571.	Chester Johnson	Dev210
Traffic Marking Materials Cure-in-place Traffic Paint. Use with Dev571.	Chester Johnson	Dev210



Developmental Design

Standard 6025

(D6025 or D06025)



DDS D6025

2012 Design Training Expo

DDS D6025

<http://www.dot.state.fl.us/rddesign/DesignStandards/Standards.shtm>

2012 Design Training Expo

Year	Design Standards Standard	Design Standards Revisions	Design Standards Modifications
2010	S	J	N/A
2009	S	J	N/A
2008	S	J	N/A
2004	S	J	N/A
2002	S	J	N/A
2000	S	J	N/A

DDS D6025

<http://www.dot.state.fl.us/rddesign/DS/Dev/IDDS-D06025.pdf>

GRS-IBS DESIGN DIMENSIONS										
LOCATION					WALL GEOMETRY					
WALL NO.	FROM (Station)	TO (Station)	BEARING ANGLE (Deg)	SKIN ANGLE (Deg)	L ₁ (FT)	N ₁ (Deg)	L ₂ (FT)	N ₂ (Deg)	L ₃ (FT)	S (FT)
1										
2										

GRS-IBS DESIGN DIMENSIONS																					
RIP			GRS			REINFORCING BED			BEAM SLAB		GRS FINISH/TOP										
WALL NO.	Year (FT)	Hour (FT)	Hour (FT)	INTERMEDIATE REINFORCEMENT VERTICAL SPACING (FT)	H (FT)	B (FT)	LAYER THICKNESS (IN)	R (FT)	D (FT)	NO. OF INTERMEDIATE REINFORCING LAYERS	LAYER THICKNESS (IN)	A (IN)	P (IN)	N (IN)	D ₁ (IN)	D ₂ (IN)	NO. OF LAYERS	LAYER THICKNESS (IN)	D ₃ (IN)	LAYER THICKNESS (IN)	
1																					
2																					

TABLE OF ELEVATIONS														
WALL NO.	EL. A	EL. B	EL. C	EL. D	EL. E	EL. F	EL. G	EL. H	EL. I	EL. K	EL. L	EL. RR	Scour Elev.	Finish Elev.
1														
2														

GRS-IBS QUANTITIES ⁽¹⁾			
WALL NO.	GRS BACKFILL (CU YD)	RIP FILL (CU YD)	GRADED AUGER/LATE (CU YD)
1			
2			

(1) The estimator materials quantities are based on the dimensions on the accompanying plan sheets. Deviation from the dimensions on the plan sheets will affect the quantities.

CRU COLORS:
 Hollow, textured CRU = _____ (color # / name)
 Solid, smooth-faced CRU = "Brick Rip"

CRU TEXTURE:
 For hollow, textured CRU, provide Split Face texture.

CRU TEXTURE:
 Scour Protection Type: _____
 Finish Slope: _____

DESIGN LOADS:
 Combined load: Superstructure (SLL + SLL) → T₁ maximum factored design load.
 Roadway live load surcharge: _____ psf uniform vertical.

SOIL PROPERTIES:
 S&B unit weight = 140 pcf.
 GRS backfill: Unit weight = 115 pcf, Friction angle = 30°, cohesion = 0 psf.
 Riprock backfill: Unit weight = _____ pcf, Friction angle = _____, cohesion = _____ psf.
 Foundation soil: Unit weight = _____ pcf, Friction angle = _____, cohesion = _____ psf.

GEOSYNTHETIC REINFORCEMENT:
 All Reinforcement: Use only reinforcement approved for use in Steepest Slopes (Approved Application Usage 1 or 3).
 Use seven geotextile with a maximum OCS of 0.035 in, and the following minimum strength:
 T₁₀ = _____ (both machine and cross directions).
 All Other Reinforcement: Use geotextile or geogrid geotextile having the following minimum strengths:
 T₁₀ = _____ (both machine and cross directions).
 T₅₀ = _____ (both machine and cross directions).



FDOT Implementation

• Invitation to Innovation Website

The screenshot shows a web browser window displaying the Florida Department of Transportation (FDOT) Structures Design Office website. The page is titled "Invitation to Innovation" and features a large image of a bridge. The navigation menu includes "Home", "Business Partners", "Employment", "Programs", "Projects", "Related Links", "Research/Statistics", and "Travel Information". The main content area includes a "Mission Statement" section and a "News & Information" section with a link to "Structures Design Bulletin 12-03". The page also includes a search bar and a "Local Intranet | Protected Mode Off" indicator at the bottom.



FDOT Implementation

• [Invitation to Innovation Website](#)

Transportation Innovation - Windows Internet Explorer
<http://www.dot.state.fl.us/officeofdesign/innovation/>

Florida Department Of Transportation

Office of Design - Transportation Innovation

INVITATION TO INNOVATION

Previously, the Department embarked into a new ball as for innovative ideas, research and accelerated implementation. Success in this has not depended on the ability to innovate the products and services Florida's transportation system provides to users. The Office of Design's mission for innovation of state roads, advanced technology or anything, include the best thinking to generate new and better ideas to any transportation design process.

After reviewing and evaluating many innovative ideas, the Central Office has developed a number of concepts, products and services that may be the best solution to the project's needs or design challenges. Some items on the list are completely developed, and only need drawing to your project. We encourage you to propose one or more of these innovations for project specific solutions with confidence of approval by the District. Other items are not fully detailed and will require coordination with and approval by the District's Design Office. Many of these innovations have been successfully implemented in other states and countries. List of projects benefit from these innovations and the Department is not endorsing the general use of new products or designs where an economical and proven solution exists and is the most appropriate solution for the situation.

Please consider these innovations as possible solutions to your project-specific needs. We invite you to review innovations listed in the table below. Additional innovations will be added as they are identified and developed. If you have any questions, details and contact information are included with the information for each innovation web site.

Innovative Ideas

- Structures Design Office
 - Precast Segmental Box Girders and Systems
 - Cast-in-Place Segmental Concrete Bridges
 - Concrete Reinforced Soil Integrated Bridge System
 - Segmental Box Girdes
 - Segmental Box Girdes
- Roadway Design Office
 - Coming Soon
- Surveying and Mapping Office
 - Coming Soon
- Engineering CADD Office
 - Coming Soon

2012 Design Training Expo

FDOT Implementation

• [Invitation to Innovation Website](#)

Transportation Innovation - Windows Internet Explorer
<http://www.dot.state.fl.us/structures/innovation/GRS-IBS.htm>

Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS)
 Commonly referred to as GRS Abutments

Information By Topic
 Please Select One

Meetings/Events
 Please Select One

Offices
 Please Select One

Office Level Navigation

Main Page

General
 Mission Statement
 Contacts

Job Opportunities
 Please Find
 Active Vacancies

Bulletins
 Current Bulletins
 Archived Bulletins
 Relevant River Bulletins

Publications
 Structures Manual
 GRS & End Handbook
 Archived Pubs

Standards

Error on page.

GRS abutments are part of FHWA's Every Day Counts (EDC) initiative to reduce bridge construction time and cost. A limited number of small bridge projects have been constructed in other parts of the country using this technology in combination with precast bridge components. These projects were considered cost effective and are performing well. The lessons learned during those projects led to the FHWA's GRS Guide. Use of GRS abutments and walls on the interstate or major multi-lane highways requires the approval of the State Structures Design Engineer.

GRS abutments are shallow foundations constructed using a combination of gravel and closely spaced layers of geotextile or geogrid. The approach to the bridge is integrated into the GRS abutment in lieu of utilizing an approach slab.

Informational Photos and Videos

FHWA produced several videos which provide background information and testimonials from Engineers across the country regarding their use of GRS abutments for bridges on public roads. These videos and several additional construction photos are available at the following FHWA website:
http://www.fhwa.dot.gov/everydaycounts/technology/grs_ibs/multimedia.cfm

FHWA's construction demonstration video is also available on YouTube.

Photos courtesy of FHWA

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FDOT Implementation

- [Invitation to Innovation Website](#)

Transportation Innovation - Windows Internet Explorer

http://www.dot.state.fl.us/structures/innovation/GRS-IBS.htm

Design Criteria

FDOT Design Requirements are provided in [Structures Design Bulletin 12-05](#).

Developmental Design Standard

[Developmental Design Standard D6025](#) is available for presenting details in the project plans. This Developmental Standard includes details for wrap-around abutments and details for the transition between the roadway guardrail and the bridge railing. Please review the [Developmental Design Standards Policy](#) prior to requesting D6025.

Specifications

Construct GRS abutments and wing walls in accordance with [Developmental Specification 549](#).

Implementation Plan

With the exception of Interstate or major multi-lane highway applications, GRS abutments may be utilized, when appropriate and cost effective, on all FDOT projects. Use of GRS abutments on the Interstate or major multi-lane highways requires the approval of the State Structures Design Engineer.

Usage Restrictions / Parameters

Use of GRS abutments is limited to 1-lane or 2-lane bridges with simply supported end spans of less than 140 feet in length. Abutments are limited to 30 feet in height. The use of GRS abutments on the Interstate or major multi-lane highways requires the approval of the State Structures Design Engineer.

Contact Information

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Questions?

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