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

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GRS-IBS

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

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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.

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FHWA's EDC Web Site

www.fhwa.dot.gov/everydaycounts

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

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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)

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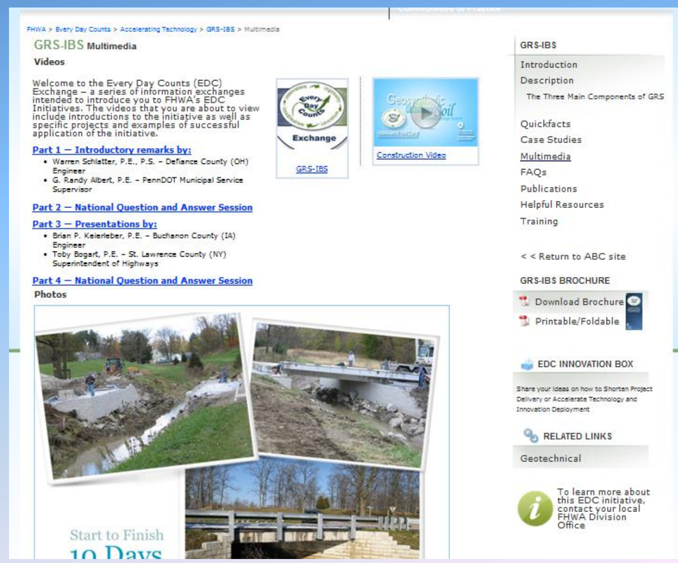
FHWA's EDC Web Site

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

Multimedia: Videos, Webinars & Pictures



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GRS – IBS

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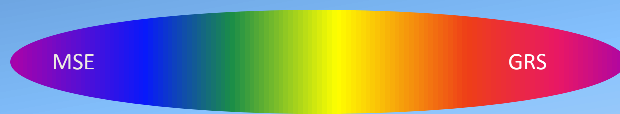
Degree of Composite Behavior



Reinforcement spacing

36” 30” 24” 18” 12” 6”

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

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

GRS Fundamentals

Cut-away of a GRS Mass

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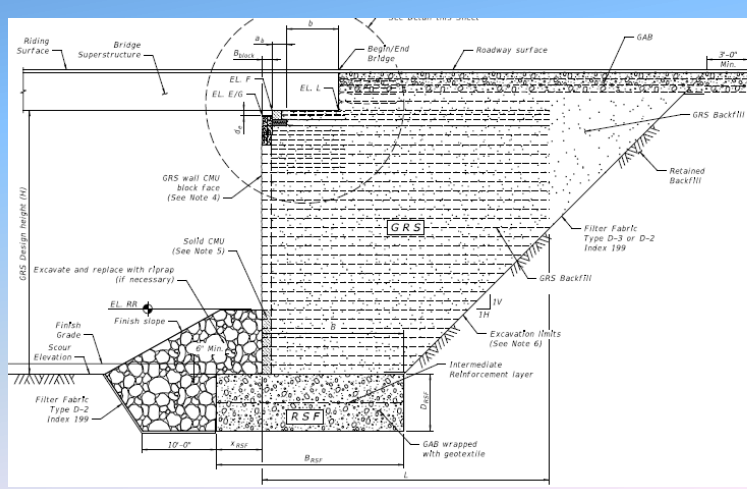
GRS Fundamentals

Cross-Section of GRS-IBS



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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?

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GRS Fundamentals

Site Selection

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

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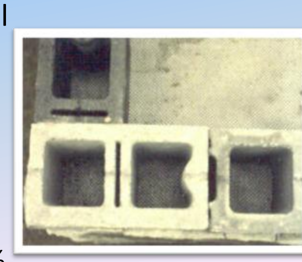
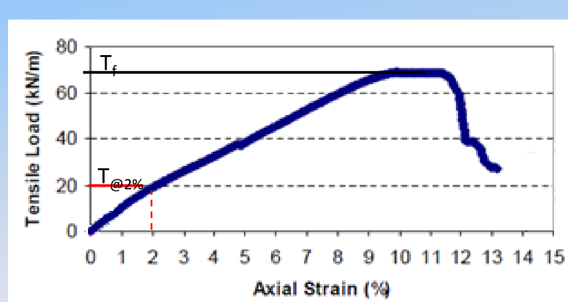
Facing Elements

- 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 ≥ 4,000 psi
    - Water absorption limit: 5%



Geosynthetic Reinforcement

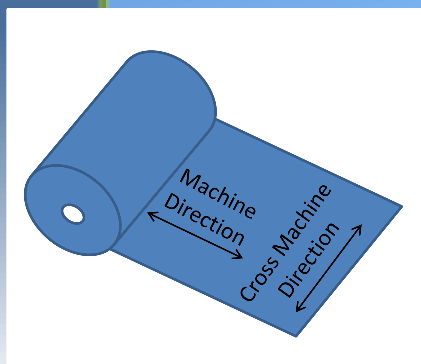
- Geosynthetic reinforcement material can include:
  - HDPE, PP, or PET Geogrids
  - PP or PET Woven geotextiles
- Ultimate Strength: T_{ult} = 4800 lb/ft (both directions)
- Strength at 2% Strain ($T_{2\%}$): Tensile Load @ 2% ε



Geosynthetic Reinforcement

Continued

- Cross Machine vs. Machine Direction



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

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Granular Backfill

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

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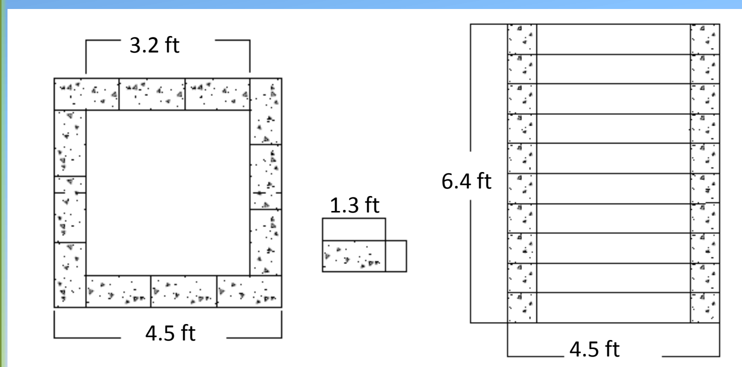
FHWA Research: Performance Testing and Monitoring

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

GRS Fundamentals

Performance Tests *Continued*

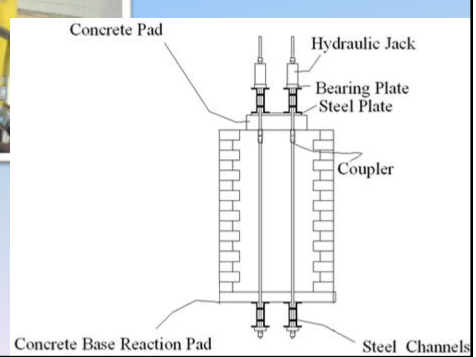


Top View

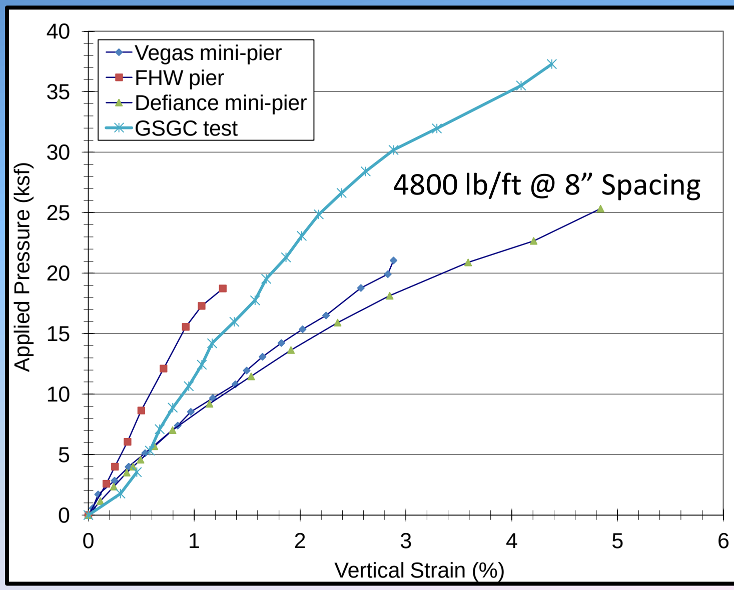
Side View

GRS Fundamentals

Performance Tests *Continued*



Performance Test Results



Performance Tests *Continued*

Before

After

Performance Test

2400 lb/ft @ 8” Spacing

Before

After

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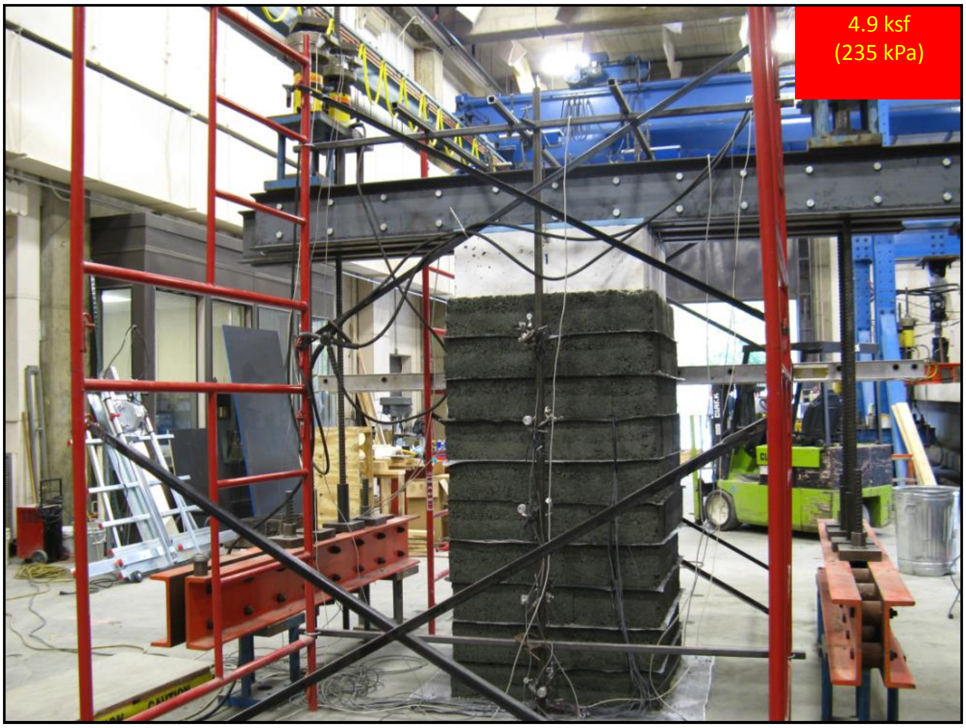
3.1 ksf
(148 kPa)


4.1 ksf
(196 kPa)


4.9 ksf
(235 kPa)


5.9 ksf
(282 kPa)


6.8 ksf
(326 kPa)


8.5 ksf
(407 kPa)


10.3 ksf
(493 kPa)

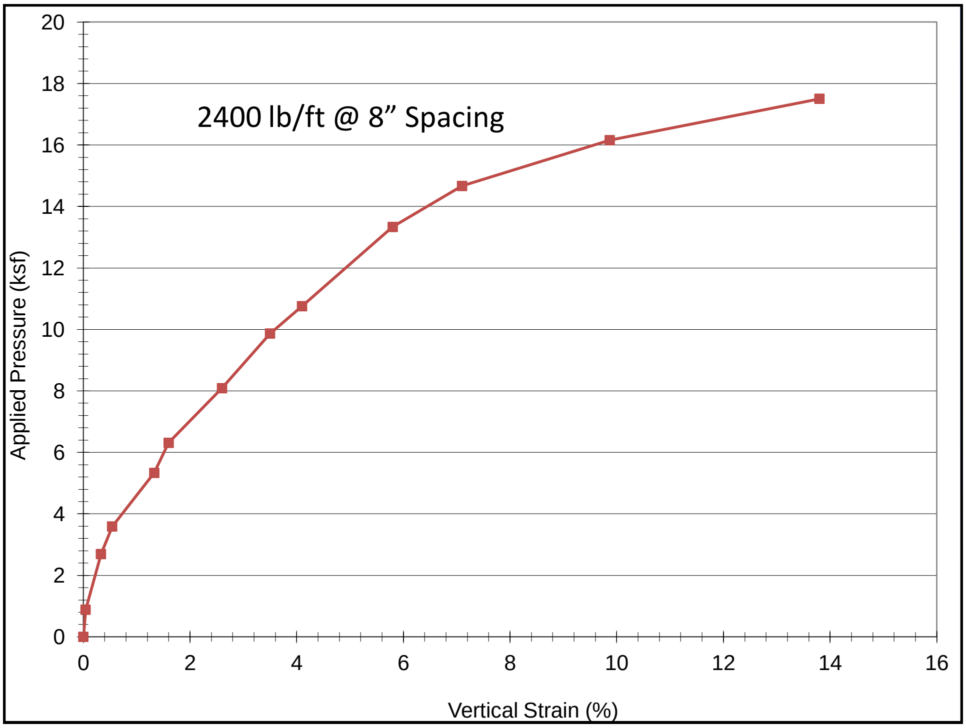

11.3 ksf
(541 kPa)


13.9 ksf
(666 kPa)


15.3 ksf
(733 kPa)

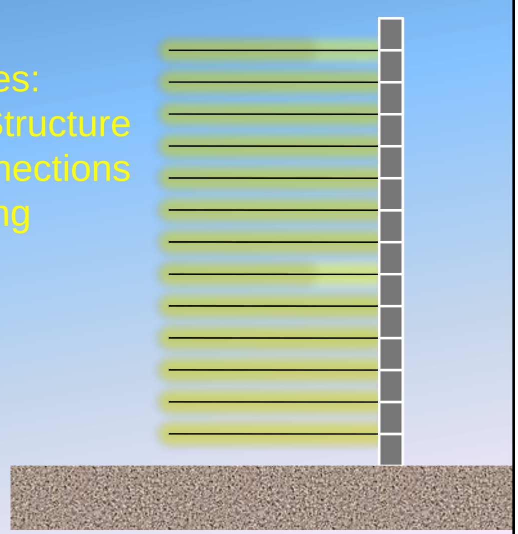

16.7 ksf
(800 kPa)


18.1 ksf
(867 kPa)



GRS Has Composite Behavior

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



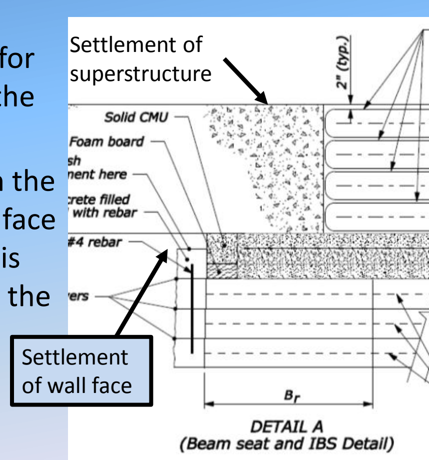
Performance Monitoring

Settlement Monitoring
Continued

Performance Monitoring

Settlement Monitoring
Continued

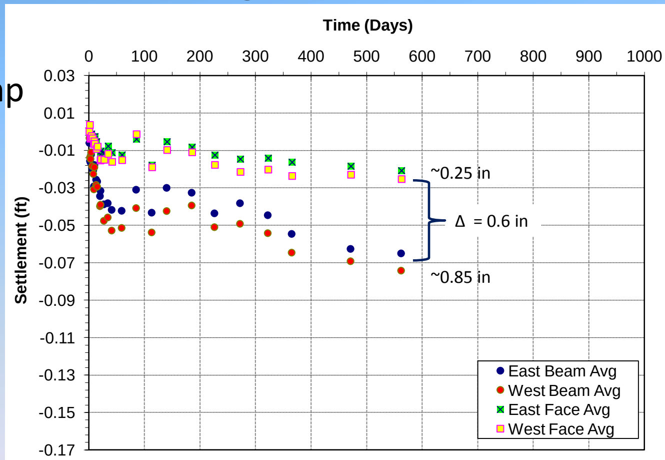
- Settlement is recorded for both the wall face and the superstructure
- The difference between the settlement on the wall face and the superstructure is the compression within the GRS mass



Performance Monitoring

Settlement Monitoring *Continued*

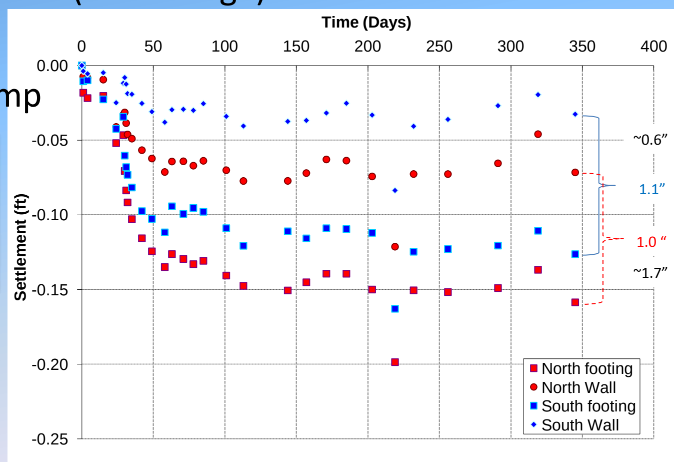
- EDM survey
  - Bowman Road (82' Bridge)
  - 7 y/o
  - No Bump



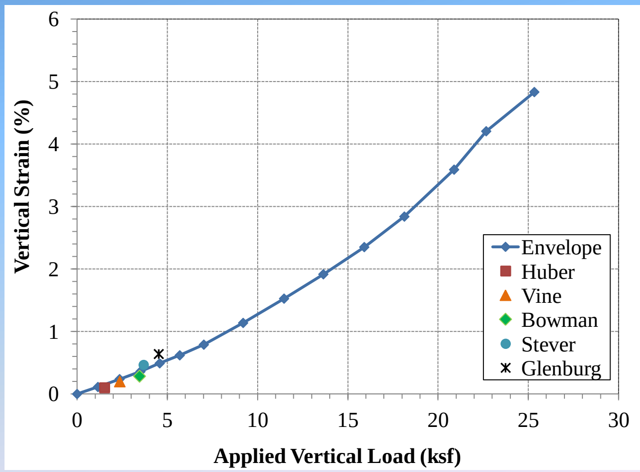
Performance Monitoring

Settlement Monitoring *Continued*

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

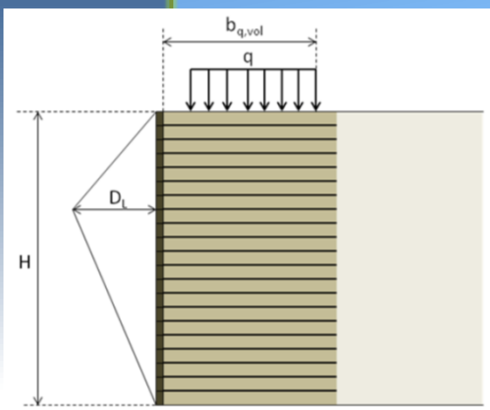


Vertical Deformation *Continued*



Lateral Deformation

Continued



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

$$\varepsilon_L = \frac{D_L}{b_{q,vol}} = \frac{2D_v}{H} = 2\varepsilon_v$$

Construction Video

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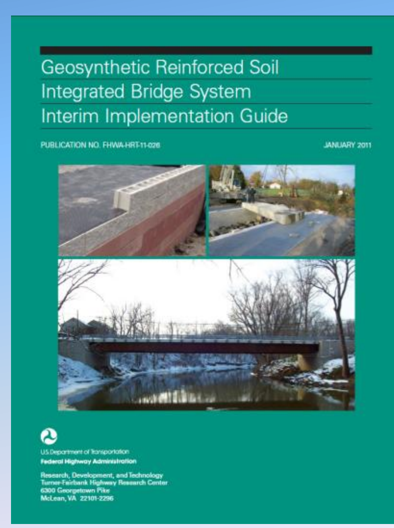
Design Method

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

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



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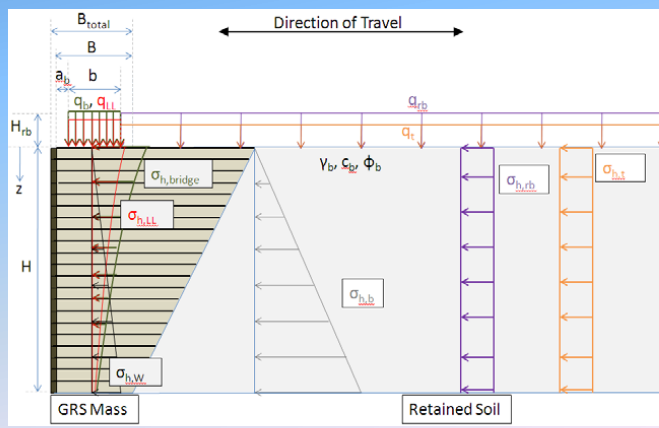
Design Method

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



LRFD Design

- LRFD External Stability
  - Sliding, ϕ=1.0
  - Bearing, ϕ=0.65
    - AASHTO also limits eccentricity
  - Global Stability, ϕ=0.65

LRFD Design

- Internal Stability
  - Factored Tensile Strength
    (strength limit state, ϕ=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 ?

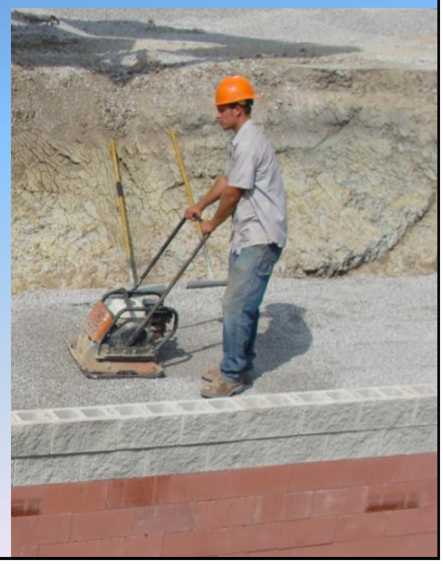
CONSTRUCTION OF GRS-IBS

QA/QC

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

Compaction

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



Construction of GRS-IBS

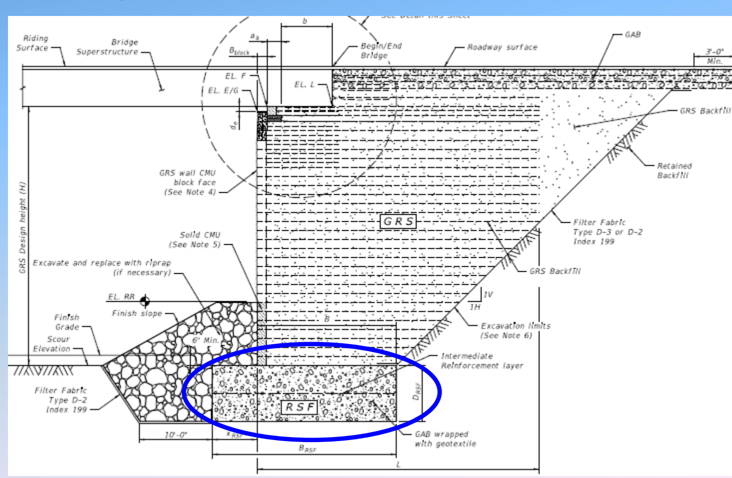
Labor and Equipment

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

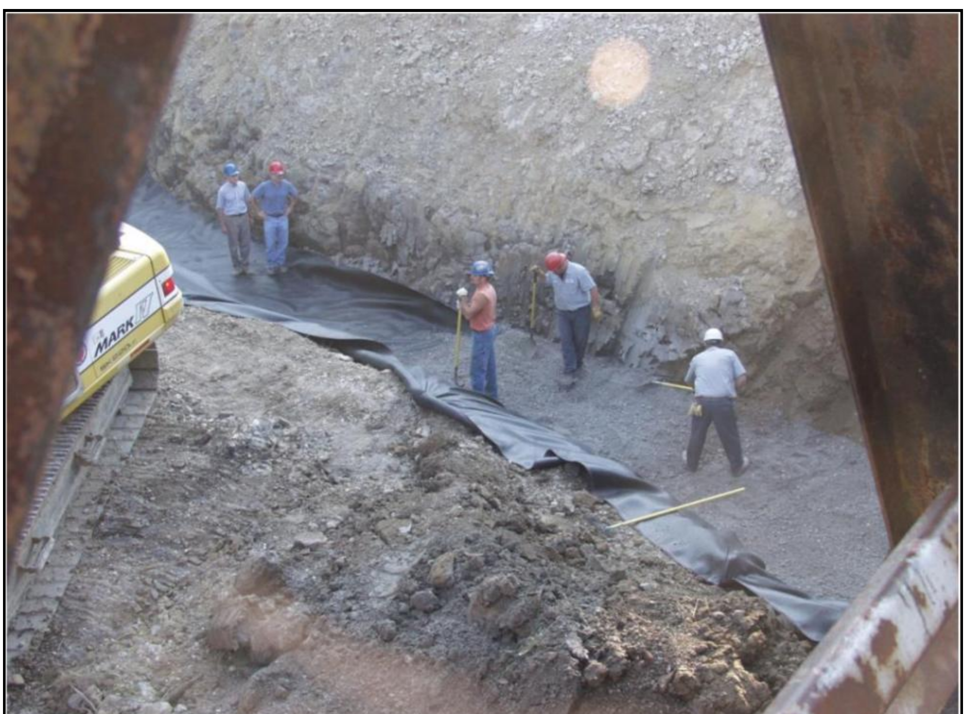
Excavation

Reinforced Soil Foundation (RSF)

- Provides embedment and increased bearing area

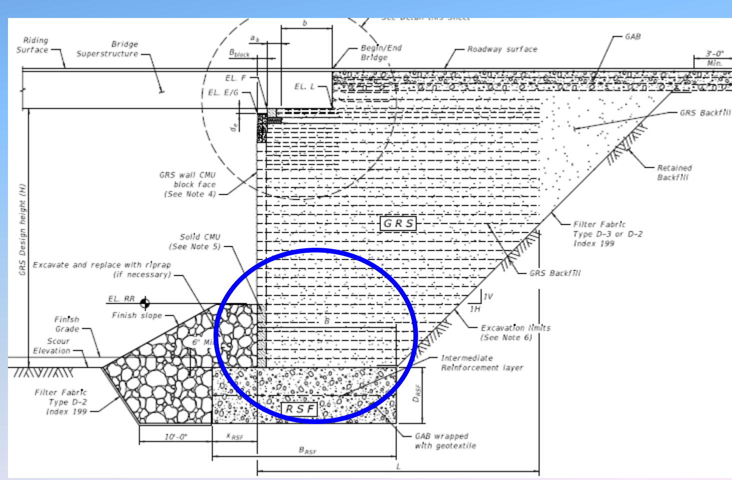


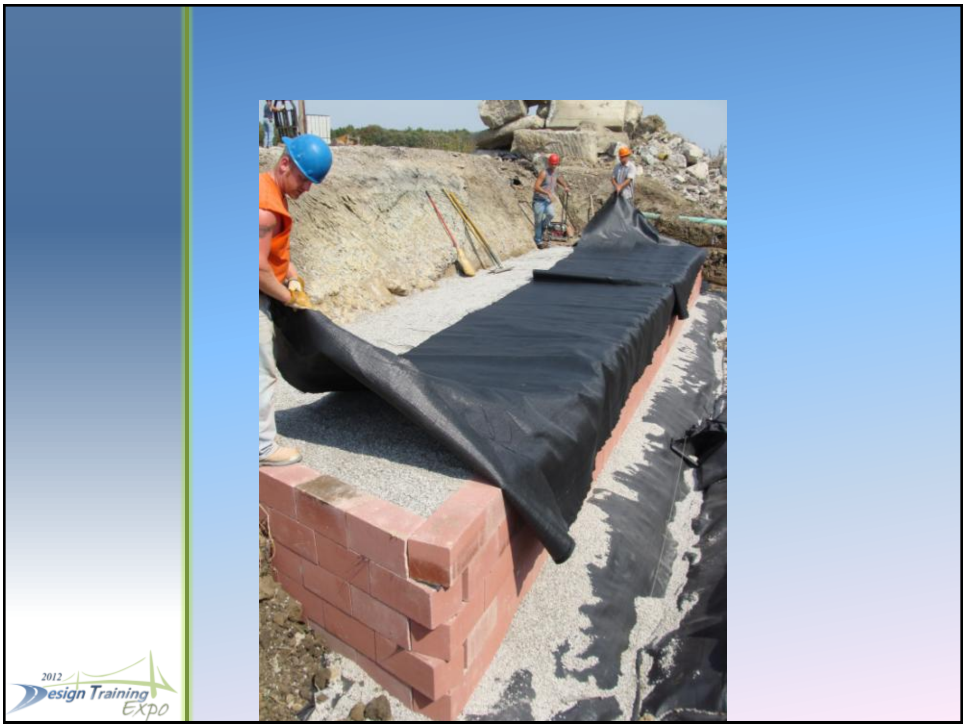

10/04/2005


MARK

GRS Abutment

- The first layers are important for leveling and alignment

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GRS Abutment *Continued*

- Wall Corners:
  - Right angle wall corners constructed with CMU corner blocks that have architectural detail on two sides
  - Walls with angles ≠ 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

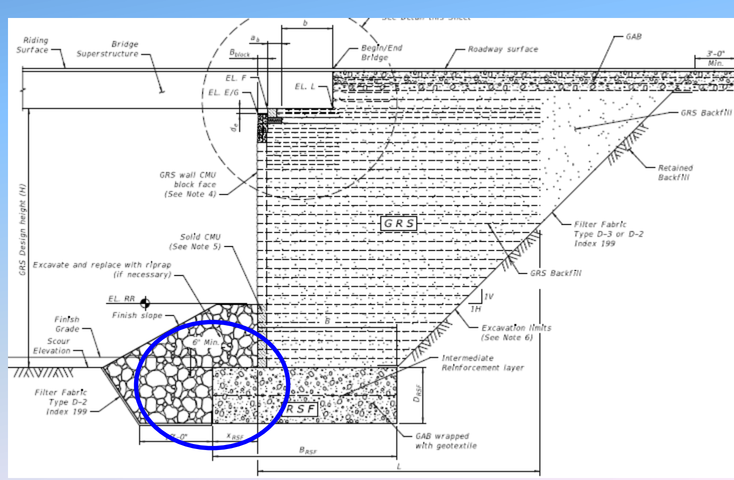
GRS Abutment *Continued*

- 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*

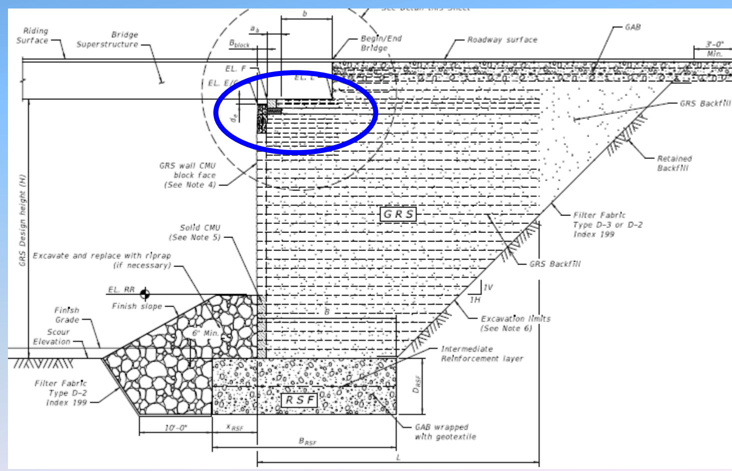
- Coping:
  - After filling the top three courses of block, a thin layer of the same concrete mix is placed on top of the block, to form the coping
  - Then hand trowel the coping either square or round and slope to drain

Scour Countermeasure




10/07/2005

Beam Seat



Construction of GRS-IBS

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.

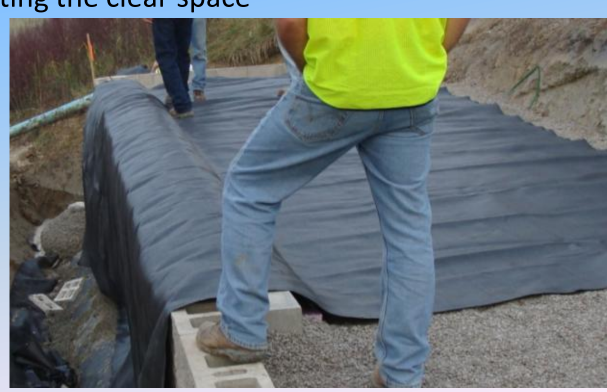
Beam Seat

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

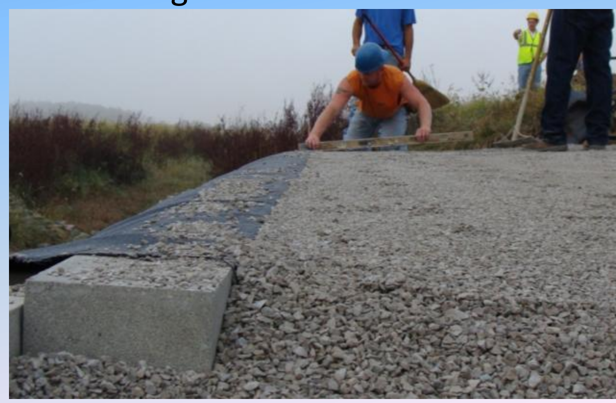
3) The first 4” wrapped layer of compacted fill is the thickness to the top of the foam board
4) The second 4” wrapped layer of compacted backfill is to the top of the 4” solid block creating the clear space



Construction of GRS-IBS

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



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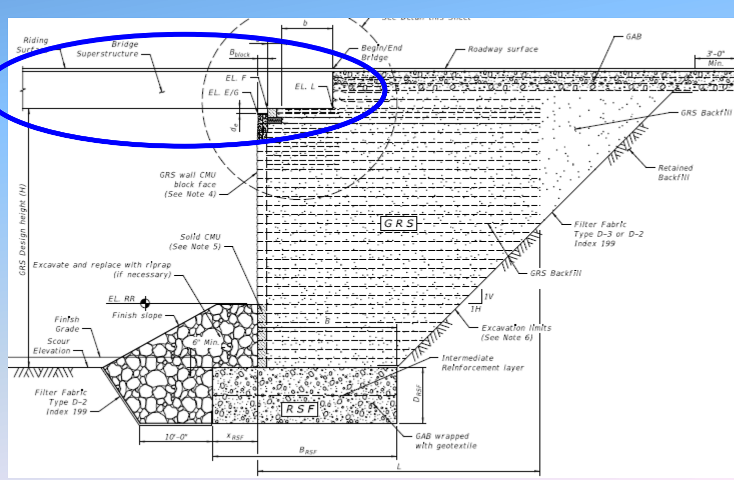
Construction of GRS-IBS

Superstructure



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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”)

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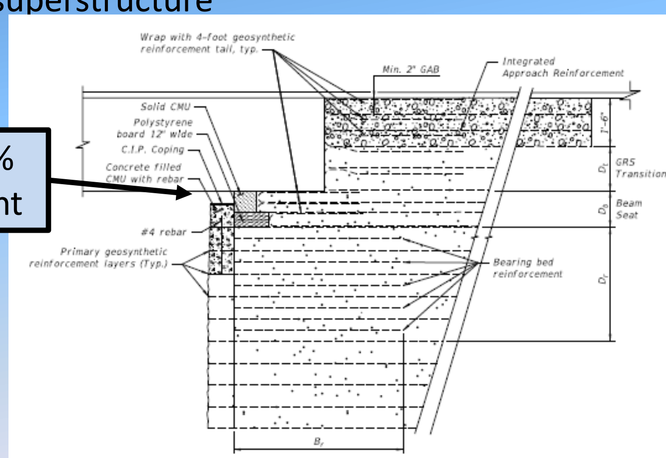
Construction of GRS-IBS

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



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

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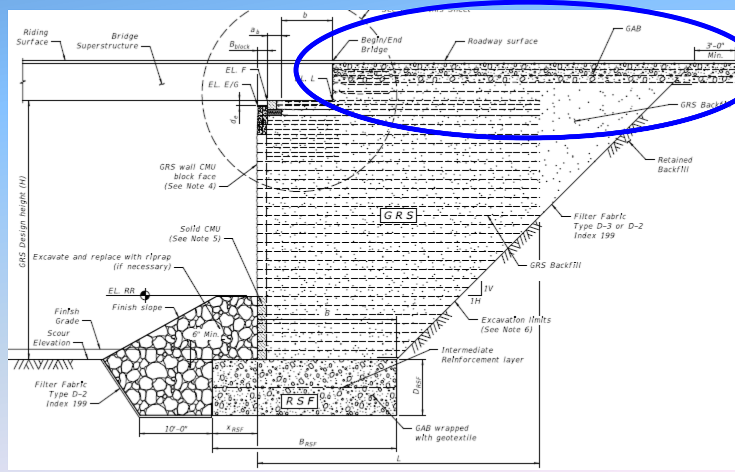
Construction of GRS-IBS

Approach Integration



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Construction of GRS-IBS

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.

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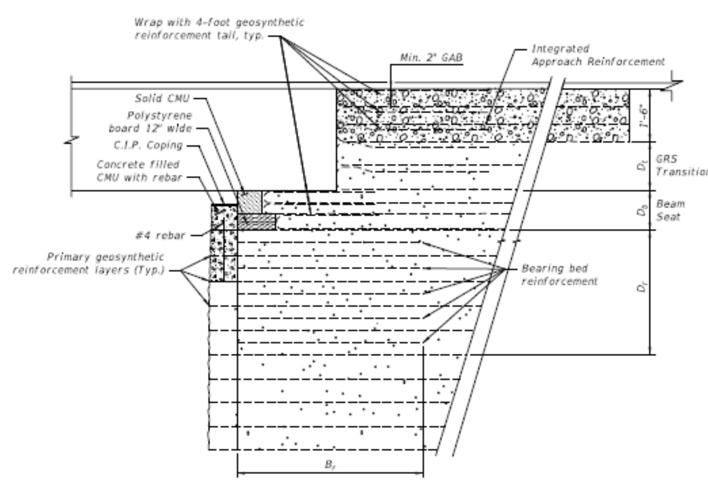
Approach Integration *Continued*

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.

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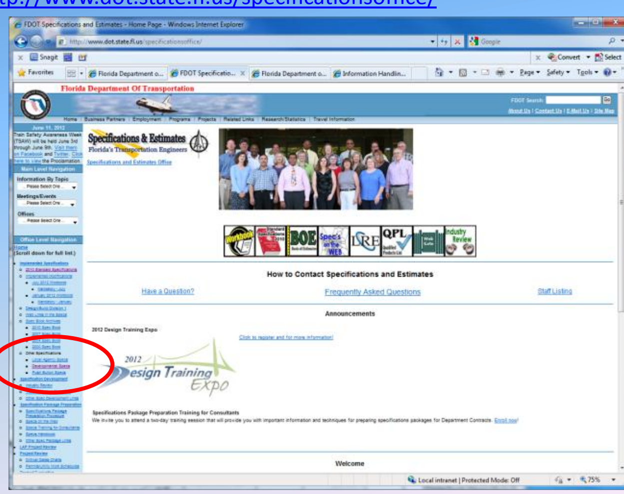
CONSTRUCTION OF GRS-IBS

Developmental Specification 549

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



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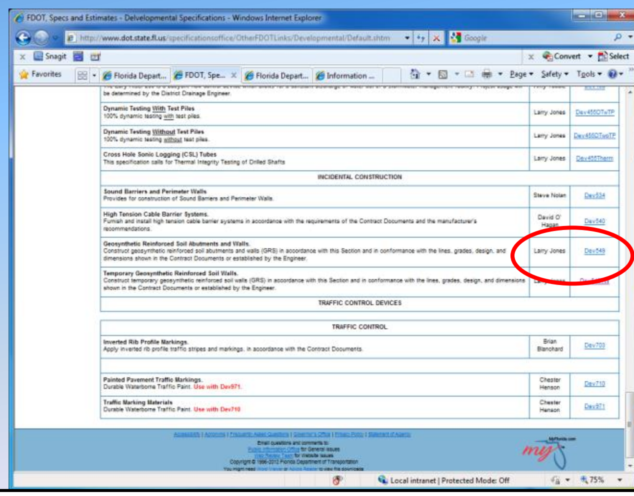
CONSTRUCTION OF GRS-IBS

Developmental Specification 549

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



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Developmental Design Standard 6025 (D6025 or D06025)

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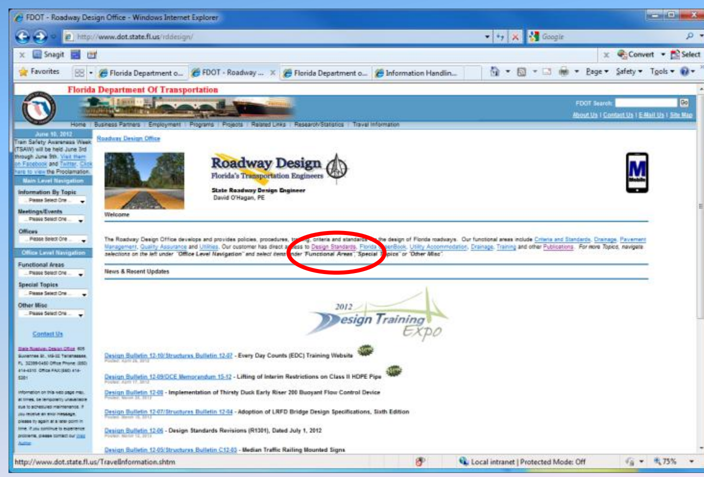
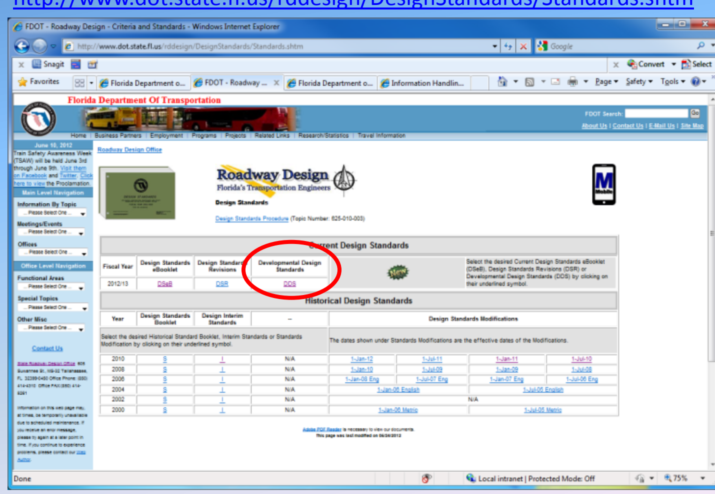
DDS D6025



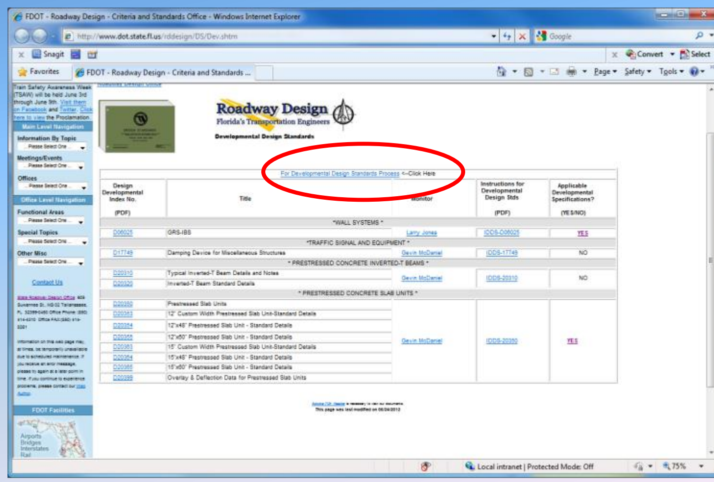
DDS D6025

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



DDS D6025

http://www.dot.state.fl.us/rddesign/DS/Dev.shtm



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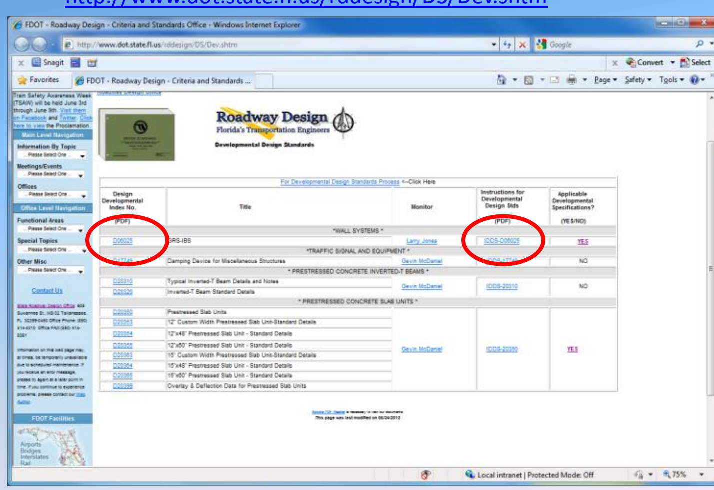

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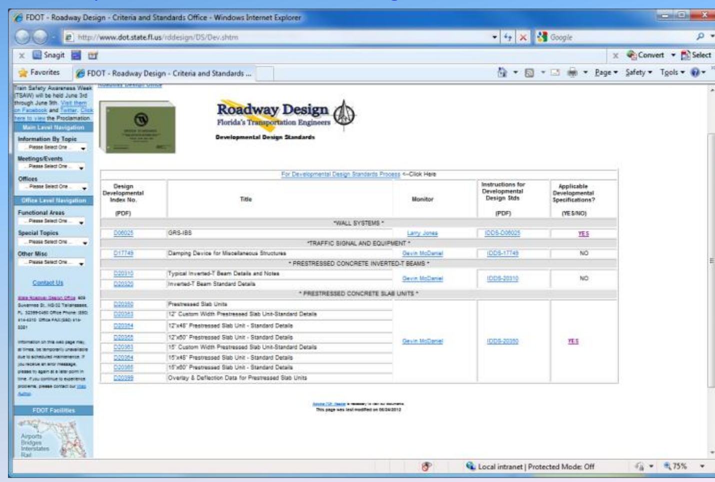
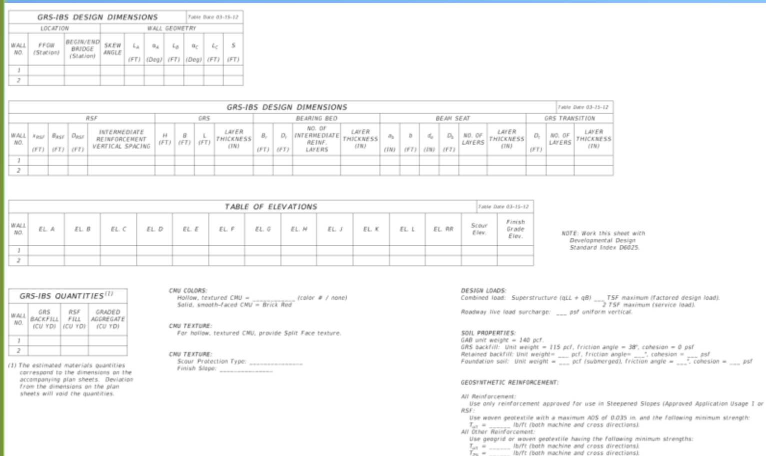


DDS D6025

http://www.dot.state.fl.us/rddesign/DS/Dev/D06025.pdf

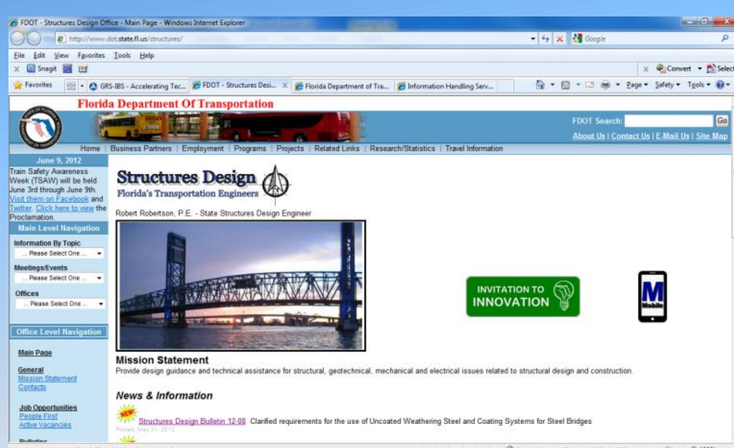
DDS D6025

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



FDOT Implementation

- Invitation to Innovation Website



FDOT Implementation

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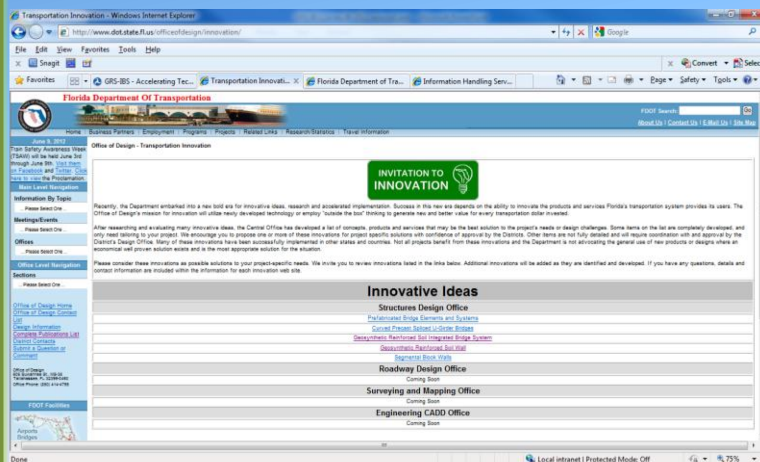

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FDOT Implementation

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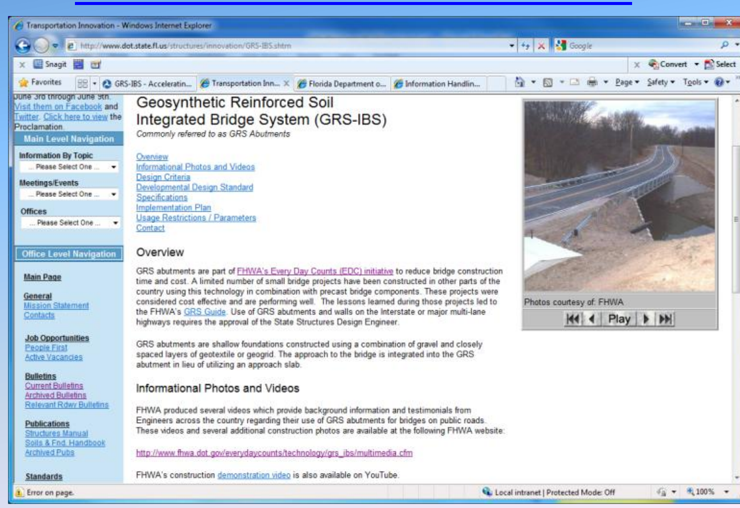

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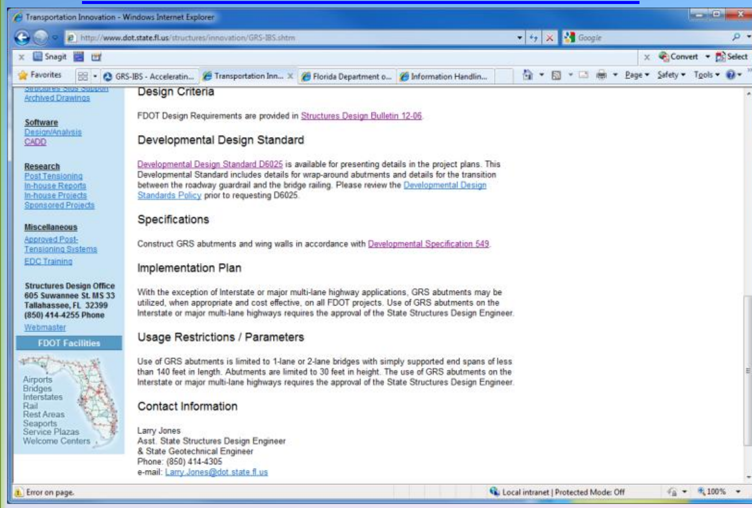
FDOT Implementation

- Invitation to Innovation Website



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Questions?

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