GUIDELINES FOR DESIGN AND CONSTRUCTION OF GEOSYNTHETIC REINFORCED SOIL INTEGRATED BRIDGE SYSTEM

Beam Seat (supported directly on bearing bed)
Jointless (continuous pavement)
Integrated Approach (geotextile wrapped layers at beams to form smooth transition)

Facing Elements (frictionally connected - top three courses pinned and grouted)

Bearing Pad Reinforcement (load shedding layers - spaced at ≤ 6 in.)

GRS Abutment (reinforcement spacing ≤ 12 in.)

Reinforced Soil Foundation (encapsulated with geotextile)

GEOTECHNICAL ENGINEERING MANUAL
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1. INTRODUCTION

The intent of this manual is to provide personnel in design and construction general information on GRS-IBS and proper installation techniques. Detailed design guidance is contained in FHWA Publication No. FHWA-HRT-11-026, *Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide*, June, 2012 and this manual provides excerpts from the reference.

The Geotechnical Engineering Bureau (GEB) provides earthwork and foundation engineering services for the design and construction of Departmental projects statewide. To span a feature in conflict with the geometry of a proposed roadway, the Department typically analyzes and designs a linked system of the:

- **Structure** – an assemblage of material to form a system capable of supporting loads, used to span a feature for the purpose of providing safe passage.
- **Foundation** – the lowest and supporting layer of a structure. The foundation transfers the load from a structure to the soil. Foundations are generally divided into two categories:
  - shallow foundation
  - deep foundation
- **Soil** underlying and surrounding the foundation.

The Federal Highway Administration (FHWA) has developed a low-cost, fast-construction technique that blends a portion of the typical structure and foundation elements together by using a soil composite mass via a Geosynthetically Reinforced Soil System (GRSS).

According to NYSDOT Standard Specifications, an internally stabilized earth system is a series of tensile reinforcing elements which, when placed in multiple layers within the backfill volume, improves the strength such that the vertical face of the stabilized earth volume is essentially self supporting. Therefore, a Geosynthetically Reinforced Soil System (GRSS) is an internally stabilized fill structure faced with either welded wire forms (typically used for temporary walls); geocells; or timbers.

A GRSS is comprised of earth backfill, extensible (geosynthetic) reinforcing elements used for internal stabilization and surface protection to resist erosion. For wall applications, the surface protection is the permanent facing elements (excluding precast units) or a geotextile face wrap which typically includes welded wire forms remaining from the installation operation.

GRSS technology has evolved considerably and FHWA has developed this into the Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) that blends the roadway into the superstructure. GRS-IBS includes a:

- Reinforced soil foundation,
- GRS abutment, and
- GRS integrated approach.
2. DEFINITIONS

Modified from Adams, et al. (2012):

**Biaxial**: Reinforcement strength is approximately equal in both the machine and the cross machine directions.

**Clear space**: The vertical distance between the top of the wall face (block) and base of the superstructure. Typically, this distance is about 3 in. or at least 2 percent of the wall height. The clear space will be used to establish a drip edge under the superstructure.

**GRS**: Geosynthetic Reinforced Soil (GRS) is alternating layers of compacted granular fill reinforced with geosynthetic reinforcement (e.g., geotextiles, geogrids). The primary reinforcement spacing in GRS is equal to 8 in.

Facing elements can be frictionally connected to the reinforcement layers to form the outer wall. The facing elements do not need mechanical connections to each other or to the layers of reinforcement. The 8 in. height ensures compaction at every lift and is compatible with the frictional connection to the recommended reinforcement. Most importantly, the use of 8 in. high blocks is dictated by the design methodology. In the internal stability analysis, the ultimate vertical capacity of the GRS Abutment is found empirically. The FHWA *Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide* provides a load-settlement performance of a GRS structure with reinforcement spaced at 8 in. It continues to state that if materials used are outside the recommendations, then a performance test must be performed to obtain the applicable stress-strain curve. The facing element is not structural and the guide does state that any facing element can be used. The outer wall facing can be built with natural rock, concrete modular block, gabions, timber, or geosynthetic wrapped face. However, with other facing elements, special design considerations may apply, and it goes on to state that such considerations are beyond the scope of the guide.

GRS is generic and can be built with any combination of geosynthetic reinforcement, compacted granular fill, and facing system, although some combinations of the three components are more compatible than others.

**GRS abutment**: A GRS system designed and built to support a bridge. Usually, GRS abutments have three sides: the abutment face wall and two wing walls. All GRS abutments must have the abutment face wall. In some circumstances, depending on the layout, a GRS abutment can be built with one or none of the wing walls.

**GRS abutment face wall**: The vertical or near vertical wall parallel to the center of bearing and designed to support the bridge. The length of a GRS abutment face wall is typically the total width of the bridge structure plus any additional width necessary to accommodate the structure (e.g., guardrail deflection distance).
GRS-IBS: A unique application of GRS technology in the specific context of bridge abutments. GRS-IBS is different from other, more general GRS abutments that use many common elements associated with traditional bridge abutments. GRS-IBS bridge abutments are built to economically support a bridge on the granular fill directly behind the block face. GRS-IBS can be used to integrate the bridge structure with the bridge approach to create a jointless bridge system.

The GRS-IBS specification stipulates adjacent concrete box beams or void slabs supported directly on the GRS abutments without a concrete footing or elastomeric pads. The bridge has no CIP concrete or approach slab. A typical cross section of IBS shows a GRS mass compacted directly behind the bridge beams to form the approach way and to create a smooth transition from the roadway to the bridge.

GRS mass or GRS structure: A composite mass built with GRS that creates a freestanding, internally supported structure with reduced lateral earth pressures with considerable strength. This design permits the use of lightweight modular blocks and the elimination of mechanical connections between blocks and the reinforcement. A GRS mass is not supported externally and, therefore, the facing system is not considered a structural element in design. A GRS mass is not rigid and is therefore tolerant to differential foundation settlement.

GRS wall: Any wall built with GRS.

GRS wing wall: A wall attached and adjacent to the abutment face wall. The wing walls are built at the same time as the abutment face wall and at a right or other angle to the abutment face wall. The wing walls are built to support the roadway and the approach embankment. The wing walls must be designed to retain the soil fill in the core of the approach embankment and to protect the abutment from erosion.

Setback: The lateral distance from the back of the wall face to the front of the bearing area. This distance must be a minimum of 8 in.

Uniaxial: Reinforcement strength is larger is one direction than the other.
3. DESIGN

Upon request, the Geotechnical Engineering Bureau will provide project specific recommendations as a basis for the Designer to prepare contract ready drawings for a GRS-IBS. Detailed design guidance is contained in FHWA Publication No. FHWA-HRT-11-026, *Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide*, June, 2012.

Some important project selection and design considerations:

**General**

- The use of GRS-IBS construction will typically be restricted by the Office of Structures and Geotechnical Engineering Bureau and will not be approved for use on limited access facilities or roadways with ADT over 400 vpd.
  
  *Approval by the DCES is mandatory prior to the start of any bridge design utilizing GRS-IBS technology.*

- Refer to the Bridge Manual (Section 11.6.1.4 - *Mechanically Stabilized Earth System (M.S.E.S.) Abutments*) for “Guidance for Use”. The GRS Abutments must meet these requirements (note the criteria regarding any bridge over waterway areas, which is of critical importance in determining applicability).

- The work zone traffic control for GRS-IBS should utilize an off-site detour to achieve the full benefits of this construction technique. A GRS-IBS is an accelerated bridge construction technique that reduces construction time (GRS-IBS is built in days or weeks, not months as there is no need to wait for cast-in-place concrete to dry and the substructure is immediately ready for the bridge). However, there are prescriptive lift thicknesses, compaction effort is critical, and protecting completed lifts from damage is compulsory. Therefore, staging sequences would complicate matters.

- The design methods described in the reference are appropriate for GRS-IBS structures (an abutment and wing walls) with a vertical or near vertical face and at a height that does not exceed 30 ft.

- Although the majority of bridges built with GRS-IBS have spans of less than 100 ft., spans of up to 140 ft. have been constructed. While larger spans are possible, the bearing stress on the GRS abutment is limited to 4,000 lb/ft². The demands of longer spans on GRS-IBS are not fully understood at this time, and it is recommended that engineers limit bridge spans to approximately 140 ft. until further research has been completed.

- The use of GRS-IBS should not be used where existing or anticipated underground utilities are present within the abutment area.

- Avoid the use of GRS-IBS where a full 75 year service life (as required by the LRFD Bridge Design Specifications) is needed.
Hydraulics

- GRS bridges planned for waterway crossings must have foundations designed, detailed and constructed in compliance with FHWA publication HRT-11-026 *Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide*.
- If considering a site for a GRS-IBS waterway crossing, designers should begin with a field reconnaissance of the site, watershed, and upstream and downstream sections. A review of air photos can help in evaluating channel migration trends. Bridge inspection records should be checked for scour history, if any, at the existing structure. Site conditions where GRS-IBS bridges may be feasible include:
  - low velocity stream
  - flow equalization span
  - abutments set well back from stream banks
  - no calculated scour depth
  - no history of lateral channel migration
- Foundation design for waterway bridges shall include a hydraulic analysis with scour evaluation and assessment of channel stability. Elements of the hydraulic analysis include estimating design flow, development of water surface profile through the bridge opening, scour assessment (contraction, abutment and long-term degradation), and, if necessary, the design of scour countermeasures to protect the bridge or stabilize the channel.
- Scour evaluation methods shall be in accordance with FHWA HEC-18 *Evaluating Scour at Bridges*. Engineered countermeasures may be required to prevent the loss of soil from underneath the GRS abutment. Any scour countermeasure shall be designed and constructed in accordance with FHWA HEC-23 *Bridge Scour and Stream Instability Countermeasures*.

Design Assumptions

- The spacing of the reinforcement (12 in. or less) is a principal factor in the performance of GRS-IBS. In nearly all of the GRS masses built in the United States as full-scale experiments or as in-service structures, however, the design has been based on an 8 in. layered system.
- The FHWA Design Guide publishes test results from an 8 in. layered system, assuming the standard concrete facing block having nominal dimensions of 8 in. x 8 in. x 16 in. Although it is stated that the empirical method is recommended (i.e. testing will provide the most accurate results for the design), the Guide does provide an analytical design methodology. Therefore, if other block types and/or dimensions are anticipated (note most concrete block facing units on the Approved List do not meet these assumed dimensions), a project specific design is required.
- A GRS mass is a composite material that is stabilized internally.
- Both the compacted granular fill and the reinforcement layers strain laterally together in response to vertical stress until the system approaches a failure condition.
- A GRS mass is not supported externally, and therefore, the facing system is not considered a structural element in design.
• Lateral earth pressure at the face of a GRS mass (i.e., thrust) is not significant, eliminating connection failure as a possible limit state.
• The facing elements of a GRS mass are frictionally connected to the geosynthetic reinforcement.
• Under the prescribed granular fill and reinforcement conditions, reinforcement creep is not a concern for the sustained loads. Therefore, individual reduction factors for reinforcement creep are not necessary. Creep can be accommodated safely within the factor of safety used for design.

**Design Plan Requirements and Considerations**

• Complete all necessary data tables and notes and include them in the contract documents to supplement the GRS-IBS details.
• A full height block is typical in front of the bearing seat. However, a half-height block and/or special height polystyrene board may be required to accommodate elevations. If this is required, show project specific details in the contract documents.
• Where beam type superstructures are used, show project specific details in the contract documents for grade beam and backwall. In these cases, expansion joints will be required between the backwall and bridge deck.
• When a backwall is used, Begin/End Bridge Stations will be at front face of the backwall. Otherwise, Begin/End Bridge Stations will be located at ends of the superstructure.
• Show details for filling the concrete block facing units with concrete and rebar for special locations (e.g. corners of wingwall, face of abutment).
• Detail scour countermeasures. Indicate the countermeasure type and finish slope. Ensure the finish slope and elevation of stone fill provide for at least 2.5 ft. of cover over RSF.
• The Generic GRS-IBS Details (shown in Appendix A) needs to be modified and developed into the contract documents.
• The structural dimensions (Width & Toe of RSF, Length of Reinforcement, Bearing Bed Reinforcement Length, Bearing Width of Beam Seat, etc.) need to be determined and included in the contract documents.
• The spatial dimensions (Elevations, Centerline, Stationing, Wingwall Orientations, etc.) need to be included in the contract documents.
• The superstructure shall consist of adjacent prestressed box beam/slab units with a 6 in. composite cast-in-place concrete deck. Consult the Office of Structures for appropriate details.
4. CONSTRUCTION GUIDELINES

GRS-IBS technology uses alternating layers of compacted granular fill material and sheets of geosynthetic reinforcement to provide support for the bridge. The general construction process is to place a course of facing block, place and compact the select backfill, and place the sheet of geosynthetic reinforcement. The process is continually repeated until the GRS abutment is complete.

4.1 Reinforced Soil Foundation (RSF)

The base of the RSF should be cut smooth. It should be excavated to uniform depth, and all loose, unstable material should be removed from the site. The excavation should be backfilled as soon as possible to provide a suitable foundation and avoid adverse weather delays.

Depending on the conditions encountered, an undercut may be required. If the conditions are known in design, an undercut will be detailed and shown in the contract documents. If encountered in construction, the undercut recommendations will be determined by the Departmental Geotechnical Engineer.

The RSF should be encapsulated in geotextile reinforcement placed perpendicular to the abutment face to protect it from possible erosion. All overlapped sections of reinforcement in the area of the RSF should be oriented to prevent running water from penetrating the layers of reinforcement. The wrapped corners of the RSF need to be tight and without exposed soil within the RSF to complete the encapsulation.

The first course of wall block sits directly on the RSF so it is important that the fill material is graded and level before encapsulating the RSF.

4.2 Compaction

GRS-IBS are earthen structures that rely on the reinforced backfill behind the abutment facing for their structural stability. Proper compaction of the backfill and RSF area is of paramount importance in the construction of these systems.

Compaction directly behind the concrete block facing units should be performed in a manner that maintains wall alignment while improving the density of fill behind the block (Note that the facing elements are not rigidly connected to the reinforcement). Only hand operated equipment is allowed within 3 ft. of the face so as not to damage or dislocate the facing blocks. Lift thickness may have to be reduced to achieve required compaction.
4.3 Geosynthetics

After the geosynthetic is rolled out, it should be laid so that it is taut, free of wrinkles, and flat. The geosynthetic can be held in place with the fill. Placement of fill should be from the wall face backward to remove and prevent the formation of wrinkles in the geosynthetic.

Splices of reinforcement can occur without overlap. Splice seams should be staggered to avoid a continuous break in the reinforcement throughout the GRS structure. All splice seams should run perpendicular to the wall face.

Overlaps of adjacent geosynthetic should be trimmed where they are in contact with the surface of the concrete block facing unit to avoid varying geosynthetic thicknesses between the blocks. Any seams in the geosynthetic should be staggered with each successive layer of the GRS abutment.

All seams between adjacent sheets of geosynthetic located in the area beneath the footprint of the bridge seat should be perpendicular to the abutment wall face.

Driving should not be allowed directly on the geosynthetic reinforcement. Place a minimum 6 in. layer of granular fill prior to operating any vehicles or equipment over the geosynthetic reinforcement. In the bearing reinforcement zone, hand-operated compaction equipment should be used over the 4 in. lifts to prevent excessive installation damage of the reinforcement.

4.4 Concrete Block Facing Units

Careful attention should be paid to the placement of the first row of blocks. Since all other courses of block are built off the first row, it is essential to ensure that the bottom row is level and even for fast construction.

If a designed scour countermeasure such as a stone fill apron is used, place geotextile bedding under the apron and anchored between the first and second courses of concrete block facing units.

Since the concrete block facing units are dry stacked without mortar, it is important to avoid cracking the block and to maintain a horizontal uniform elevation by sweeping the top surface of the block clean of debris and fill material prior to the placement of the next layer of geosynthetic and block.

When setting a course of block, each block should be placed tightly against the adjoining block, preventing gaps from which fill material can escape. Before proceeding to the next layer, it is often useful to walk along the top of the blocks to easily identify a poorly seated block.
The vertical GRS wall should be checked for plumbness at least every other layer with a string line referenced off the back of the facing block from wall corner to corner.

### 4.5 Scour Countermeasures

Stone fill protection should be placed in a manner to prevent damaging the concrete block facing units. Damage can occur during the placement of the channel rock protection that extends above the solid concrete block zone.

### 4.6 Guide Rail

Universal structural steel S flange guide rail post and soil plate can be driven through the geosynthetic reinforcement.
REFERENCES


   http://www.dot.state.fl.us/rddesign/DS/Dev.shtm
APPENDIX
Appendix A – Generic GRS-IBS Details

Plan View: GRS-IBS Abutment
(modified Jones, 2012)
Appendix A – Generic GRS-IBS Details

Elevation View: GRS-IBS Abutment
(modified Jones, 2012)
Appendix A – Generic GRS-IBS Details

Isometric View: Beam Seat
(modified Jones, 2012)
Appendix A – Generic GRS-IBS Details

Section View
(modified Jones, 2012)
Appendix A – Generic GRS-IBS Details

Beam Seat and Integrated Approach Detail
(modified Jones, 2012)