Chapter 31

Geosynthetic Design

Exhibits

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Geosynthetic Design

31.1 Purpose

The purpose of this chapter is to give the designer an understanding of the requirements for geosynthetic reinforced soil slopes and geosynthetic reinforced foundations over soft soils. A step-by-step method to develop and organize the plans is presented.

Reinforced soil slopes should be utilized when the right of way is insufficient to construct embankments with normal slopes and retaining walls are not economical or are undesirable. ***Section 2.4, Roadside Slopes*** of this volume contains design criteria for the use of roadside slopes.

Reinforced foundations over soft soils should be utilized when the existing soils are too weak to support the anticipated loading without soil failure or excessive differential settlement, and excavation and replacement or other ground modification method is not an economical solution.

Approved products for these designs are included in ***Design Standards Index 501***.

31.2 Contract Plans Content

See the instructions for ***Design Standards Index 501*** for plan content requirements.

31.3 Shop Drawings / Redesigns

The contractor can choose to construct the reinforced soil structures either by: (1) using materials which meet or exceed the strength required in the plans and be placed at or less than the plan spacing(s) or (2) submitting an alternate design which optimizes the use of a specific material and revises the material spacing within the limits contained in the design methodology in ***Section 31.4****.* The properties of site specific backfill are seldom available at the design phase of a project. Therefore, the contractor should indentify and determine the properties of the fill material prior to submitting an alternate design. Using soil properties of site specific material allows for optimization of the materials resulting in a corresponding cost benefit to the Department. All designs shall meet the design methodology contained in ***Section 31.4***.

The shop drawing reviewer shall be familiar with the requirements, design and detailing of these systems. The review shall consist of but not limited to the following items:

1. Verify horizontal and vertical geometry with the contract plans.
2. Soil reinforcement is listed in the ***Design Standards, Index 501***.
3. Soil reinforcement design values do not exceed the values in the ***Design Standards, Index 501***.
4. Verify the material strengths and number of layers of the product selected meets or exceeds the design shown in the contract plans.
5. Soil properties for the fill material chosen by the contractor meet or exceed those used in the design shown in the Contract Plans.
6. If a redesign is proposed, verify the design meets the requirements of ***Section 31.4*** and the Contract Plans.

See ***Specification Section 145*** for requirements associated with Contractor initiated redesigns.

31.4 Geosynthetic Reinforcement Design Methodology

This design methodology applies only for geosynthetic reinforced soil slopes and geosynthetic reinforced foundations over soft soils. Geosynthetic is a generic term for all synthetic materials used in Geotechnical engineering applications and includes geotextiles and geogrids.

31.4.1 Design Considerations

Only those geosynthetic products listed on the ***Design Standards***, ***Index 501*** are eligible for use on FDOT projects. The geosynthetic reinforced systems shall be designed using comprehensive stability analyses methods that address both internal and external stability considerations by a professional engineer licensed in Florida who specialized in Geotechnical engineering. The following design guidelines and requirements should be used for the analyses and design.

31.4.2 Requirements

1. **Performance:** The design resistance factors shall be adequate to cover all uncertainties in the assumptions for the design limit state. Required maximum resistance factors are:
    a. 0.65 against pullout failure.
    b. 0.65 against sliding of the reinforced mass.
    c. 0.75 against external, deep-seated failure.
    d. 0.75 against compound failure, i.e., failure behind and through the reinforcement.
    e. 0.75 against internal failure.
    f. 0.75 against local bearing failure (lateral squeeze).

2. **Allowable Tension:** The geosynthetic design shall be based on the following relationships:

$$T_a = \frac{T_{ult}}{RF_c RF_d RF_j RF_{LT} \text{ CRF}}$$

Where:

T_a = The allowable long term reinforcement tension.

T_{ult} = The ultimate strength of a geosynthetic in accordance with ***ASTM D 6637***.

RF_c = Partial reduction factor for construction damage.

RF_d = Partial reduction factor for durability (due to Chemical or Biological degradation).

RF_j = Partial reduction factor for joint strength where geosynthetics are connected together or overlapped in the direction of primary force development. The values of F_j should be taken as the ratio of the unjointed specimen strength to the jointed specimen strength. Use $F_J \geq 1.0$.

RF_{LT} = Partial reduction factor to limit the reinforcement tension to less than the Creep Reduced Strength as follows:

- 1.05 for temporary applications
- 1.25 for permanent applications

CRF = Creep reduction factor. CRF = T_{ult}/T_{creep}

T_{creep} = Serviceability state reinforcement tensile load based on minimum 10,000 hour creep tests.

These parameters can be found from the appropriate FDOT ***Design Standards, Index 501***.

For applications involving reinforcing slopes with geosynthetic, T_{creep} shall be projected for a design life of 75 years.

3. Soil Reinforcement Interaction: Friction reduction factors are presented as Soil-Geosynthetic Friction values in ***Design Standards Index 501*** for each approved geosynthetic product.

31.4.3 Design Guidelines

The design guidelines are excerpted from the FHWA Publications (a) **FHWA GEC 011** (***FHWA-NHI-10-024 & FHWA-NHI-10-025), "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes-Volumes 1 & 2"***, and (b) ***No. FHWA HI-95-038, "Geosynthetic Design and Construction Guidelines"***. Designers should refer to these publications for details.

1. **Reinforced Slope** - see reference (a) **FHWA GEC 011**.

Step 1. Establish the geometry and loading - see ***Exhibit 31-A***.

Step 2. Determine the engineering properties of the insitu soils.

Step 3. Determine the properties of the reinforced fill and the retained fill.

Use the following default values for fill soil within the reinforced volume when the fill material source is not known:

For sand fill: φ= 30°, γ = 105 pcf, c = 0;
For crushed limerock fill: φ= 34°, γ = 115 pcf, c = 0.

Step 4. Evaluate design parameters for the reinforcement.

Step 5. Check unreinforced slope stability.

Step 6. Design reinforcement to provide a stable slope.

Step 7. Check external stability.

Step 8. Evaluate requirements for subsurface and surface water runoff control.

2. **Reinforced Foundation over Soft Soils** - see reference (b) ***FHWA HI-95-038***.

Step 1. Define embankment dimensions and loading conditions- see ***Exhibit 31-B***.

Step 2. Establish the soil profile and determine the engineering properties of the foundation soil.

Step 3. Obtain engineering properties of embankment fill materials.

Step 4. Establish minimum appropriate factors of safety and operational settlement criteria for the embankment.

The factor of safety for:

Bearing capacity: 1.5
Global(rotational) shear stability at the end of construction: 1.3
Internal shear stability, long-term: 1.5
Lateral spreading (sliding): 1.5
Settlement criteria: depend upon project requirements

Step 5. Check bearing capacity, global stability (both short and long term), and lateral spreading stability.

Step 6. Establish tolerable geosynthetic deformation requirements and calculate the required reinforcement modulus, J, based on wide width tensile strength, T_{ls}, tested in according to (ASTM D 4595). The geosynthetic reinforcement should be designed for strain compatibility with the weak insitu soil, with creep being a non-design factor.

Based on type of filled materials, the strains are recommended as follows:

Cohesionless soils: $\varepsilon_{geosynthetic}$ = 5 to 10%*
Cohesive soils: $\varepsilon_{geosynthetic}$ = 2%*
Peat: $\varepsilon_{geosynthetic}$ = 2 to 10%*

* For all cases, limit $\varepsilon_{geosynthetic}$ to the strain at failure minus 2%

Reinforcement modulus is calculated as: $J = T_{ls} / \varepsilon_{geosynthetic}$

Step 7. Establish geosynthetic strength requirements in the geosynthetic's longitudinal direction.

Step 8. Establish geosynthetic properties.

Step 9. Estimate magnitude and rate of embankment settlement.

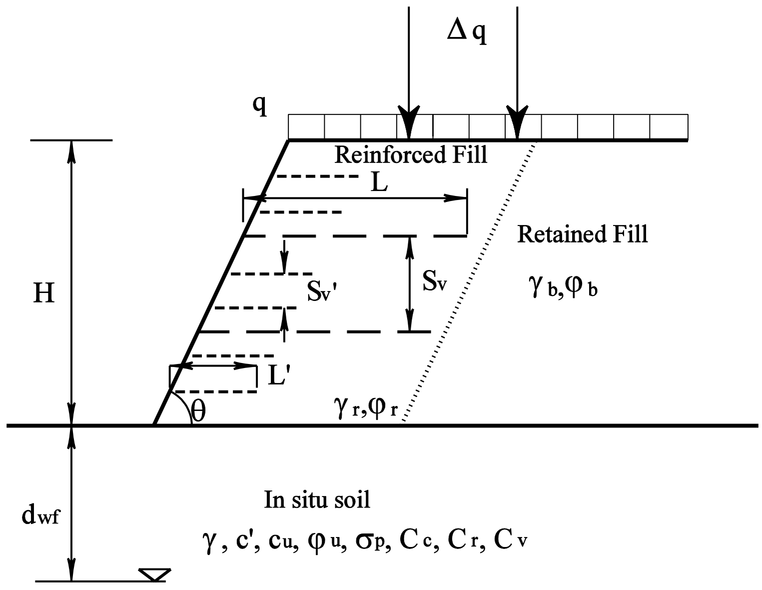
Step 10. Establish construction sequence and procedures.

This includes stage construction, if needed, and all the stability analyses for each stage of constructions. The analysis should be based on the estimated strength of the subsoils at the end of the previous construction stage.

Step 11. Establish construction observation requirements.

Instrumentations such as settlement plates, piezometers, and/or inclinometers should be designed to monitor the performance of the construction. The monitoring criteria, such as the maximum rate of piezometric and/or settlement change before the next stage of construction can proceed, etc., should also be established.

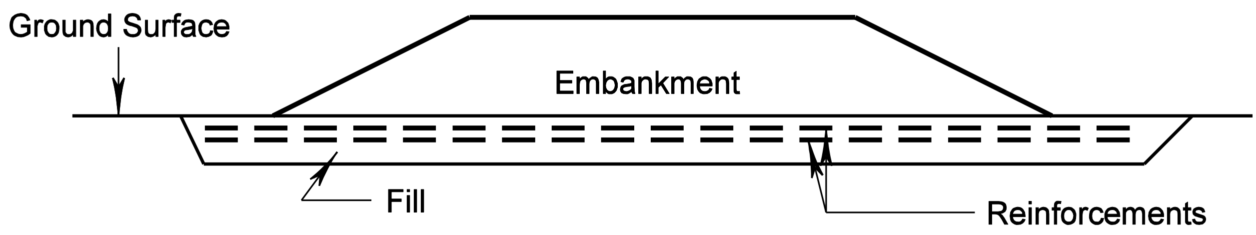
Exhibit 31-A Geosynthetic Reinforced Soil Slopes



Notations:

H	=	slope height
θ	=	slope angle
L	=	length of primary reinforcement
L'	=	length of secondary reinforcement, 4' minimum
S_v	=	vertical spacing between primary reinforcements, 4' maximum
S_v'	=	vertical spacing between secondary reinforcements, 1' maximum
q	=	surcharge load
Δq	=	temporary live load
d_{wf}	=	depth to groundwater table in foundation
γ_r, γ_b, & γ	=	unit weights of soils in reinforced, retained and foundation, respectively
φ_r, φ_b, & φ	=	friction angles of soils in reinforced, retained and foundation, respectively
c', c_u	=	cohesion strength parameters of foundation soil

Exhibit 31-B Geosynthetic Reinforced Foundations Over Soft Soils



The spacing between two reinforcements shall be 6 to 12 inches.