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 procedure to develop designs 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.

Reinforced foundations over soft soils should be utilized when the existing soils are too weak to support the anticipated loading without excessive settlement and excavation and backfilling is not an economical solution.

Approved products for these designs are included on ***Index No. 501*** of the ***Design Standards***.

31.2 Contract Plans Content

Control drawings are required which depict the geometrics (plan and elevation view) of the area being reinforced. These designs are generic and are not based upon any one specific product or supplier. For reinforced slopes the designer shall design the slopes using the maximum reinforcement spacings allowed. For soft soils the designer shall design the reinforcement and provide the minimum total strength required.

The plans shall depict the required reinforcement strength based on the maximum allowed spacing of these materials, the extent and the number of layers of geosynthetic reinforcement, vertical spacing of geosynthetic reinforcement, orientation of geosynthetic facing details, details at special structures or obstructions, typical construction sequence, and top and bottom elevations of the geosynthetic reinforcement. Product names are not to be shown in the plans. Surface treatments and any other required design parameters or limitations shall also be shown in the plans.

31.3 Bid Procedure

Geosynthetic Reinforced Soil Slopes shall be bid with Pay Item No.145-1.

Geosynthetic Reinforced Foundations Over Soft Soils shall be bid with Pay Item No. 145-2.

31.4 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 31.5****.* The properties of site specific backfill is seldom available at the design phase of a project. This being the case, subsequent alternate designs are encouraged after the backfill source is known. 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 31.5***.

The shop drawing reviewer shall be experienced in 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 material test results meet or exceed 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 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 31.5*** and the Contract Plans.

If a redesign is submitted, complete plans shall be provided which include: plan view, elevation view, and details in accordance with the Plans and Specifications. These shall show the extent, number of layers of geosynthetic reinforcement, minimum properties of each geosynthetic reinforcement layer, vertical spacing of geosynthetic reinforcement, orientation of geosynthetic facing details, details at special structures or obstructions, typical construction sequence, and top and bottom elevations of the geosynthetic reinforcement. Calculations shall be submitted to substantiate the design meets the requirements in this document and in accordance with the Contract Plans. As a minimum these shall clearly show the derivation of reinforcement requirements (i.e., type, spacing, length, etc.) and determination of all design parameters and factors. All plans and calculations are to be sealed by a Professional Engineer licensed in the State of Florida.

31.5 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.

31.5.1 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.

31.5.2 Requirements

1. **Performance:** The design factors of safety used shall be adequate to cover all uncertainties in the assumptions and design. Required minimum stability factors of safety are:

    a. 1.5 against pullout failure.

    b. 1.5 against sliding of the reinforced mass.

    c. 1.3 against external, deep-seated failure.

    d. 1.3 against compound failure, i.e., failure behind and through the reinforcement.

    e. 1.3 against internal failure.

    f. 1.3 against local bearing failure (lateral squeeze).

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

$$T_a = \frac{T_{ult}}{F_c \, F_d \, F_j \, CRF}$$

Where:

T_a = The allowable long term reinforcement tension. (T_a shall not exceed 19% T_{ult} for permanent applications or 29% T_{ult} for temporary applications).

T_{ult} = The ultimate strength of a geosynthetic.

F_c = Partial factor of safety for construction damage.

F_d = Partial factor of safety for durability.

F_j = Partial factor of safety 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 joined specimen strength. Use F_j = 1.0.

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:** Unless existing approved values are used, pullout resistance for design purposes shall be determined from pullout testing performed by an approved testing laboratory. The coefficient of interaction (C_i) shall be determined from controlled strain rate pullout testing done in accordance with GRI GG5. C_i is defined by the following relationship:

$$C_i = \frac{T_p}{2\,L\,\sigma_n\,\mathrm{TAN}\,\Phi}$$

Where:

T_p = Pullout capacity of reinforcement (lbs/foot of width).

L = Geosynthetic embedment length (ft.).

σ_n = Effective normal pressure (psf).

Φ = Effective friction angle of backfill.

The coefficient of interaction should be approximately constant for a given soil and geosynthetic material over a range of effective normal pressures. If a plot of C_i vs. σ_n indicates that C_i is approximately constant then that value shall be used for design. If the plot indicates a relatively wide variability of C_i over the anticipated range of normal stresses then either a single minimum value shall be used for C_i or a C_i corresponding to the effective stress at each expected grid elevation may be used.

The coefficient of interaction may be determined by any one of the following means:

a. Pullout testing may be performed on the proposed geosynthetics and actual soil backfill being proposed for the construction.

b. Pullout testing is required for geosynthetic products as part of the ***Design Standards, Index 501*** approval process. If, in the opinion of the Engineer, the existing approved pullout test data is representative of the proposed soil backfill and geosynthetic reinforcement, these corresponding C_i values may be used.

31.5.3 Design Guidelines

The design guidelines are excerpted from the FHWA Publications (a) ***No. FHWA-SA-96-071 "Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines"***, 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-AS-96-071***.

   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.

   The following values for the backfill soil within the reinforced volume shall be used:

   For sand backfill: φ= 30°, γ = 105 pcf, c = 0;
   For crushed limerock backfill: 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%

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.

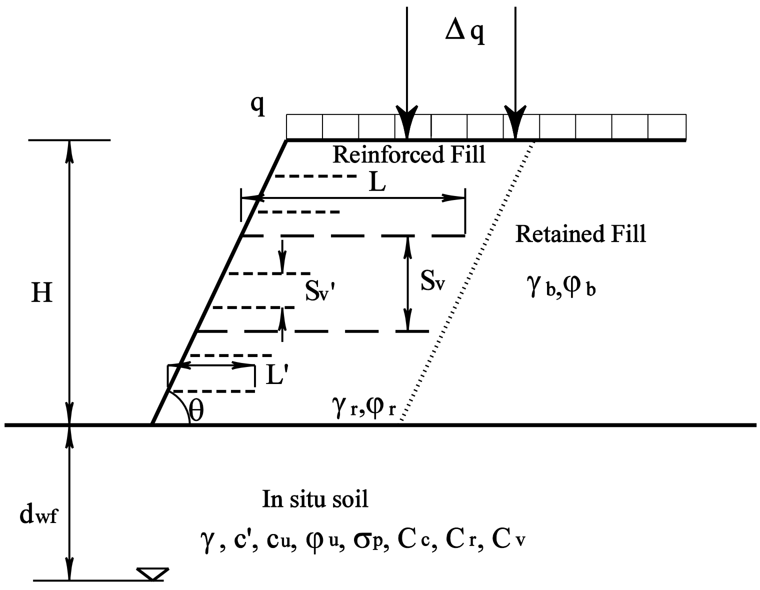
Step 10. Establish construction sequence and procedures.

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.

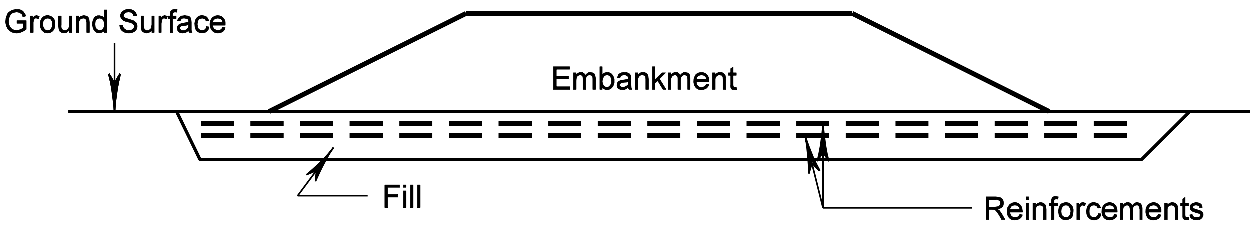
Exhibit 31-A Geosynthetic Reinforced Soil Slopes



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 minimum spacing between two reinforcements shall be 6 inches but not larger than 12 inches.