263 Geosynthetic Design

263.1 General

This chapter provides design guidance 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.

Reinforced soil slopes should be utilized only when unreinforced slopes are not appropriate and retaining walls are not economical or are undesirable. ***FDM 215*** 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, and when excavation and replacement (or other ground modification methods) are not economical solutions.

Approved geosynthetic products are included in the ***Approved Products List (APL)***.

263.2 Contract Plans Content

Provide the geosynthetic application type and specific requirements to ensure the geosynthetic selected from the APL will be suitable. Refer to ***Standard Specification, Section 985*** to determine which test values will be available for selecting the products for each application from the APL.

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; the product brand names are not shown on the plans. Design reinforced slopes using the maximum reinforcement spacing allowed. For soft soils, design the reinforcement and provide the minimum total strength required.

Include the following information in the plans:

- Required reinforcement strength based on the maximum allowed vertical 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,
- Top and bottom elevations of the geosynthetic reinforcement layers,
- Surface treatments, and
- Any other required design parameters or limitations.

263.3 Shop Drawings and Redesigns

The contractor can choose to construct the reinforced soil structures either by: (1) using geosynthetic materials approved for the intended application in the APL meeting or exceeding the strength required in the plans and placed at or less than the spacing(s) shown in the plans, or (2) submitting an alternate design (redesign) which optimizes the use of a specific material and revises the material spacing within the limits contained in the design methodology in ***FDM 263.4***. Redesigns may be optimized for backfill specific material properties verified prior to the redesign or based on generic properties which must be verified prior to backfill placement. All designs must meet the design methodology requirements contained in ***FDM 263.4***.

Modification for Non-Conventional Projects:
Delete the first sentence of the above paragraph and replace with the following: Construct the reinforced soil structures using geosynthetic materials approved for the intended application in the APL, meeting or exceeding the strength required in the plans and placed at or less than the spacing(s) shown on the Plans.

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

(1) Verify horizontal and vertical geometry with the contract plans.

(2) The soil reinforcement must be approved for the intended application in the APL.

(3) The soil reinforcement design values do not exceed the values in the APL.

(4) Verify that the material strengths and number of layers of the product selected meet or exceed the design shown in the contract plans.

(5) Soil properties for the fill material chosen by the contractor must 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 FDM 263.4 and the contract plans, and the soil properties for the fill material chosen by the contractor meet or exceed those used in the redesign.

See ***Standard Specifications, Section 145*** for requirements associated with contractor-initiated redesigns.

263.4 Geosynthetic Reinforcement Design Considerations

Only those geosynthetic products approved for usage on reinforced soil slopes in the APL are eligible for use on FDOT projects. Design the geosynthetic reinforced systems using comprehensive stability analyses methods that address both internal and external stability considerations by a Florida licensed Professional Engineer who specializes in geotechnical engineering.

263.5 Geosynthetic Reinforcement Design Requirements

Use the following design guidelines and requirements for the analyses and design of geosynthetic reinforcement:

(1) **Performance:** The design resistance factors must cover all uncertainties in the assumptions for the design limit state. The resistance factors must not exceed the following:

- (a) 0.65 against pullout failure.
- (b) 0.65 against sliding of the reinforced mass.
- (c) 0.75 against external, deep-seated failure.
- (d) 0.65 against external, deep-seated failure when supporting a structure.
- (e) 0.75 against compound failure; i.e., failure through the reinforcement.
- (f) 0.75 against internal failure.
- (g) 0.75 against local bearing failure (lateral squeeze).

(2) **Nominal Tension Resistance of Reinforcement:** The maximum long-term reinforcement tensile resistance of the geosynthetic must be:

$$T_a = \frac{T_{ult}}{RF_c RF_d \, CRF}$$

Where:

T_a = The nominal long-term reinforcement tensile resistance.

T_{ult} = The ultimate strength of a geosynthetic in accordance with ***ASTM D 6637*** for the reinforcement oriented normal to the slope.

RF_c = Reduction factor for installation damage during construction for the appropriate fill material (sand or lime rock).

RF_d = Reduction factor for durability (due to chemical or biological degradation).

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

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

These reinforcement specific parameters can be found in the APL.

For applications involving reinforcing slopes with geosynthetic, the minimum design life is 75 years.

(3) **Soil Reinforcement Interaction:** Friction reduction factors are presented as Soil-Geosynthetic Friction values in the APL for each approved geosynthetic product.

263.6 Geosynthetic Reinforcement Design Guidelines

These 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 further details.

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

Step 1. Establish the geometry and loading - see ***Figure 263.6.1***.

Step 2. Determine the engineering properties of the in-situ 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: $\varphi = 30°$, $\gamma = 105$ pcf, $c = 0$;

For crushed lime rock fill: $\varphi = 34°$, $\gamma = 115$ 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 and service limit state deformations.

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 ***Figure 263.6.2***.

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

Step 3. Obtain the engineering properties of the embankment fill materials.

Step 4. Establish appropriate resistance factors and operational settlement criteria for the embankment.

The resistance factors must not exceed the following:

(a) 0.65 against bearing failure of subsoil.

(b) 0.65 against pullout failure in select soil.

(c) 0.50 against pullout failure in plastic soil.

(d) 0.65 against lateral spreading (sliding) of the embankment.

(e) 0.75 against external, deep-seated failure at the end of construction.

(f) 0.65 against external, deep-seated failure at the end of construction, when supporting a structure.

(g) 0.65 against tensile failure of the reinforcement.

Settlement criteria: depends upon project requirements.

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

Step 6. The geosynthetic reinforcement should be designed for strain compatibility with the weak in-situ soil.

Based on the type of weak in-situ soil, the maximum design strain in the geosynthetic ($\varepsilon_{geosynthetic}$) is as follows:

Cohesionless soil: $\varepsilon_{geosynthetic} = 5\%$*

Cohesive soils: $\varepsilon_{geosynthetic} = 5\%$*

Peat: $\varepsilon_{geosynthetic} = 10\%$*

* For all cases, limit $\varepsilon_{geosynthetic}$ to the strain at failure minus 2.5%.

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.

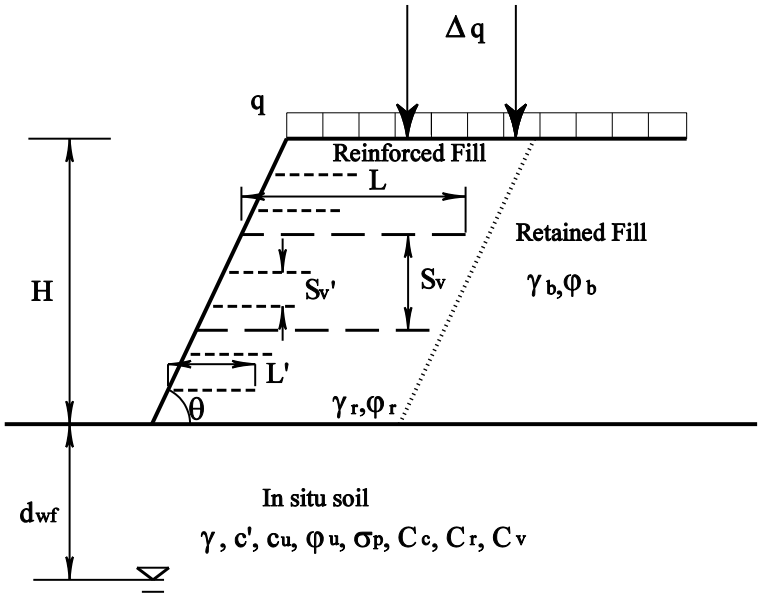
Step 10. Establish construction sequence and procedures.

Include all stages of construction. Base the analysis of each stage on the estimated strength of the subsoils at the end of the previous construction stage.

Step 11. Establish construction observation requirements.

Use instrumentation such as settlement plates, piezometers, and/or inclinometers to monitor the performance of the construction. Establish the monitoring criteria, such as the maximum rate of piezometric and/or settlement change that must occur before the next stage of construction can proceed.

Figure 263.6.1 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

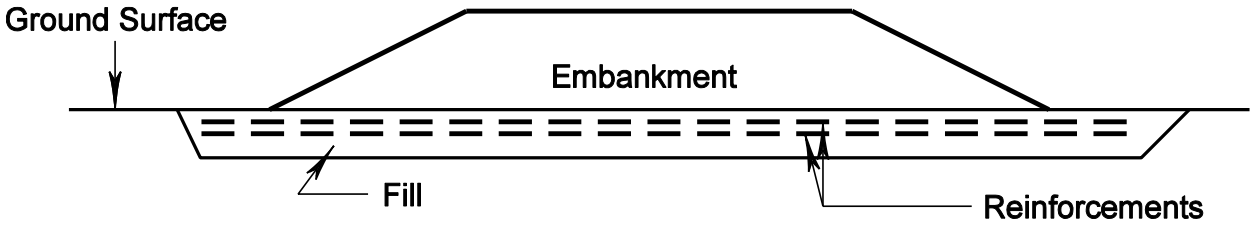
d_{wf} = depth to groundwater table in foundation

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

Figure 263.6.2 Geosynthetic Reinforced Foundations Over Soft Soils



(1) The spacing between any two reinforcements must be 6 to 12 inches.

(2) Extend the reinforcement layer(s) below the embankment to 3 feet beyond the toe of slope or the development length required to resist pullout, whichever is longer.

(3) Additional layers of reinforcement may be added below or within the embankment.