# Chapter 31

# Geosynthetic Design



Exhibits

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# Chapter 31

# 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.

Reinforced soil slopes should be utilized only when unreinforced slopes are not appropriate 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, 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 geosynthetic materials approved for the intended application on ***Design Standards Index 501*** meeting or exceeding the strength required in the plans and placed at or less than the spacing(s) shown on the Plans, 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***. Backfill specific soil properties are seldom available at the design phase of a project. Therefore, the contractor must identify and determine the properties of the fill material in accordance with FM 1 T-236 prior to submitting an alternate design. Using backfill specific material properties allows for optimization of the design resulting in a corresponding cost benefit to the

Department. All designs shall meet the design methodology requirements contained in ***Section 31.4***.

| Modification for Non-Conventional Projects: |
| --- |
| Delete the first sentence of the above paragraph and replace with the following:<br><br>Construct the reinforced soil structures using geosynthetic materials approved for the intended application on ***Design Standards Index 501*** 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 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. The soil reinforcement must be approved for the intended application in ***Design Standards Index 501***.
3. The soil reinforcement design values do not exceed the values in ***Design Standards Index 501***.
4. Verify that 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 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 ***Section 31.4*** and the Contract Plans, and the soil properties for the fill material chosen by the contractor meets or exceeds those used in the redesign.

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 approved for usage on reinforced soil slopes in ***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. The resistance factors shall 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 shall be:

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

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 limerock).

$RF_d$ = 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 ***Design Standards Index 501***.

For applications involving reinforcing slopes with geosynthetic, the design life is not less than 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

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 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 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 limerock 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 ***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 appropriate resistance factors and operational settlement criteria for the embankment.

The resistance factors shall 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.

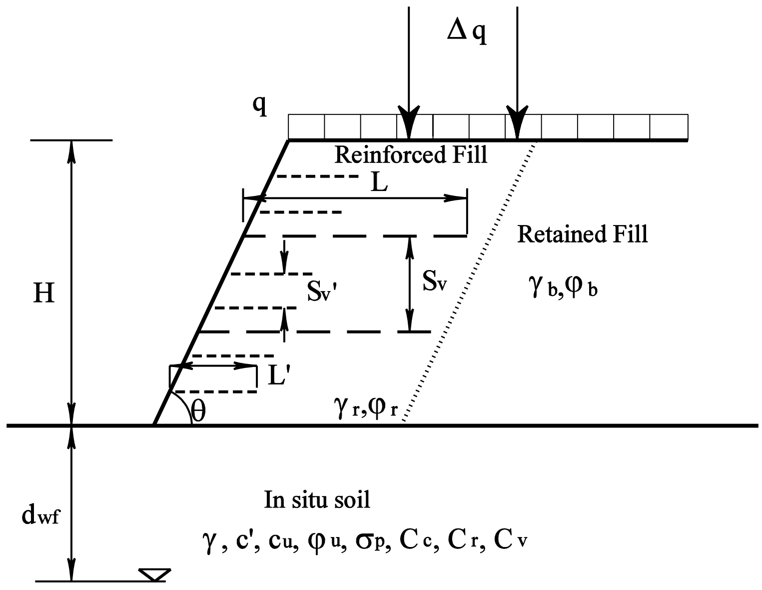
Step 10. Establish construction sequence and procedures.

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.

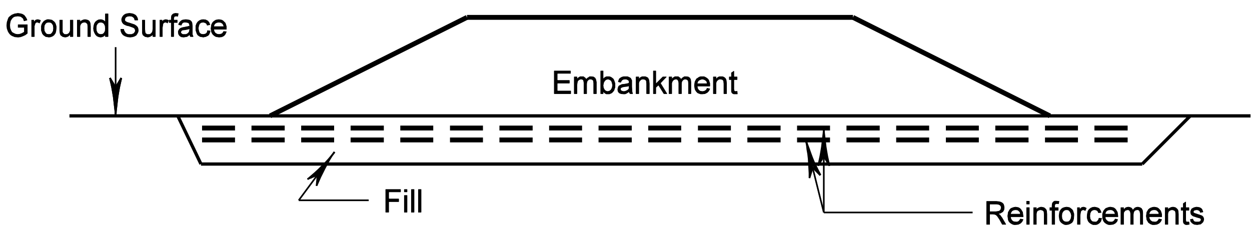
## Exhibit 31-A Geosynthetic Reinforced Soil Slopes




**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 |
| $\gamma_r$, $\gamma_b$, & $\gamma$ | = | unit weights of soils in reinforced, retained and foundation, respectively |
| $\varphi_r$, $\varphi_b$, & $\varphi$ | = | 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




1. The spacing between any two reinforcements shall 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.