Geosynthetics in Stabilization

By
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North American Geosynthetics Society
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Presentation Outline

• Introduction
• Definitions
• Materials
• Design
• Specifications
• Economics
• Installation
• Summary
Introduction

- L. David Suits
  - Retired – New York State DOT, Geotechnical Engineering Bureau. Soil Mechanics Laboratory Supervisor
    - Responsible for all soils foundation design testing
    - Responsible for all geosynthetic testing and approval for use on NYS DOT projects
  - Past chair – ASTM International Committee D35 on Geosynthetics
  - Current chair – ISO TC 221 on Geosynthetics
  - Past chair of various committees in TRB
  - Currently – Executive Director, North American Geosynthetics Society – Chapter of the International Geosynthetics Society
Soil Stabilization

Definition:

• when a geosynthetic is placed at the subgrade/fill interface to increase the support of construction equipment over a weak or soft subgrade
Base Reinforcement

Definition:

- When a geosynthetic is placed as a tensile element at the bottom or within a flexible pavement base (or sub-base) course to:
  (i) improve the service life;
  (ii) obtain equivalent performance with a reduced structural section; or
  (iii) combination of (i) and (ii)
Soil Stabilization

Applications:

- Temporary roadways
- Initial construction lift of permanent roads
- Area construction platforms
Stabilization
Geotextile Design Guidelines

• Information from National Highway Institute Course No. 132013 – “Geosynthetic Design & Construction Guidelines”
PROCEDURE

• Bender & Barenberg (1978)
• Kinney & Barenberg (1980)
• Stewart et al. (1977)
• Giroud & Noiray (1981)
• Haliburton & Baron (1983)
• Jewell, et al. (1989; 1990; 1996)
• Giroud & Hannn (2004)
Case History Design Procedure
USFS Quinault Test Section

- 1 to 1.6 m cohesive subgrade over glacial till
- Water table at or near surface
- Several low-strength nonwoven geotextiles tried
Quinault Test Section

- Design Procedures
- Geotextile Requirement
- Installation Cost
- Construction Procedure
- Aggregate Cover
USFS Conclusions

- Minimum lift thickness to protect geotextile
- Geotextile acted primarily in separation
- All geotextiles performed satisfactorily
- Geotextile use was cost-effective
USFS Method (Steward et al., 1977)

Considers:

• Vehicle passes
• Axle configurations
• Tire pressures
• Subgrade Strength
• Rut depth
USFS Method (Steward et al., 1977)

Limitations:
• Aggregate layer must be compacted to CBR = 80
• Aggregate layer must be cohesionless
• Vehicle passes < 10,000
• Geosynthetic survivability
• Subgrade undrained shear strength
  ▫ < 2000 psf (90 kPa) (CBR < 3)

➢ Extended to Geogrids (e.g., USFS 2003)
Geotextile Design Steps - Temporary Unpaved Roads

1. Determine subgrade strength
   1. Undrained shear strength determination
      a) From field CBR, \( c \) (psi) = 4.3 \times CBR;
         \[ c \text{ (kPa)} = 30 \times CBR \]
      b) WES cone penetrometer, \( c = CI/10 \) or 11
         depending on soil type
      c) Vane shear, \( c \) is direct measurement
   2. Determine maximum single wheel loading
Geotextile Design Steps

3. Estimate amount of traffic
4. Establish tolerable rutting
5. Obtain bearing capacity factors
   1. Tables available in NHI Course Manual
   2. See Bearing Capacity Factor slide (slide 26)
6. Determine required aggregate thickness
   1. USFS Chart
7. Select design aggregate thickness
   1. Should be given to next higher 25 mm (1 in) from previous step
Geotextile Design Steps

8. Check geotextile drainage and filtration requirements
   1. AOS $\leq D_{85}$ (Wovens)
   2. AOS $\leq 1.8D_{85}$ (Non-wovens)
   3. $k_{\text{geotextile}} \geq k_{\text{soil}}$
   4. Geotextile Permittivity $\leq 0.1$ sec$^{-1}$

9. Determine geotextile survivability requirements
10. Specify geotextile property requirements
11. Specify construction requirements
# Bearing Capacity Factors $N_c$

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ruts</th>
<th>Traffic (Passes of 18 kip [80 kN] axle load)</th>
<th>$N_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>without Geotextile</td>
<td>&lt; 50 mm</td>
<td>&gt; 1000</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>&gt; 100 mm</td>
<td>&lt; 100</td>
<td>3.3</td>
</tr>
<tr>
<td>with Geotextile</td>
<td>&lt; 50 mm</td>
<td>&gt; 1000</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>&gt; 100 mm</td>
<td>&lt; 100</td>
<td>6.0</td>
</tr>
</tbody>
</table>
CBR = 1  =>  $c_u = 30 \text{ kPa}$

Single Wheel Load = 45 kN

~ 5000 passes & 2 - 4 in. Ruts

Use  \( N_c = 3 \) w/o geotextile

\( N_c = 5.5 \) w/ geotextile

Unstabilized:  \( c_u N_c = 90 \) (kPa)

Depth = 475 mm (19 in.)

Stabilized:  \( c_u N_c = 165 \) (kPa)

Depth = 325 mm (13 in.)
Geotextile Requirements

- Soil retention
- Permeability
- Clogging potential
- Survivability
## AASHTO Specification M-288 - Stabilization

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength Class</td>
<td>Class 1</td>
</tr>
<tr>
<td>Geotextile Structure</td>
<td>Woven &amp; Non-Woven</td>
</tr>
<tr>
<td>Minimum Permittivity</td>
<td>0.05 sec⁻¹</td>
</tr>
<tr>
<td>Max Apparent Opening Size</td>
<td>0.43 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Elongation</th>
<th>Class 1</th>
<th>Elongation</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 50%</td>
<td>≥ 50%</td>
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<tr>
<td>Grab Str.</td>
<td>315 lbf³</td>
<td>200 lbf</td>
<td></td>
</tr>
<tr>
<td>Tear Str.</td>
<td>110 lbf</td>
<td>80 lbf</td>
<td></td>
</tr>
<tr>
<td>Puncture*</td>
<td>620 lbf</td>
<td>433 lbf</td>
<td></td>
</tr>
</tbody>
</table>

* ASTM D6241 – 50 mm (2 in) dia probe
AASHTO Specification M-288

• Conditions for specifying lesser strength geotextile
  ▫ Based on field experience a class 2 or 3 geotextile has been found to have sufficient survivability, and/or
  ▫ The engineer has found the class of geotextile to have sufficient survivability based on laboratory testing and visual inspection of a geotextile sample removed from a field test section constructed under anticipated field conditions.
**ODOT Stabilization Geotextile Spec**

- **Type D: Subgrade-Base Separation or Stabilization**
  - Minimum Tensile Strength[^ASTM D4632] = 180 lb (800 N)
  - Maximum Elongation[^ASTM D4632] = 50%
  - Minimum Puncture Strength[^ASTM D4833] = 70 lb (310 N), or
  - Minimum Puncture Strength[^ASTM D6241] = 385 lb (1715 N)
  - Minimum Tear Strength[^ASTM D4533] = 70 lb (310 N)
  - From strength point, basically an AASHTO Class 3 woven
  - Apparent Opening Size[^ASTM D4751] = Same as Type A
    - Soil Type-1: Soils with 50% or less passing No. 200 (75 μm) sieve
      - AOS ≤ 0.6 mm
    - Soil Type-2: Soils with 50 to 85% passing No. 200 (75 μm) sieve
      - AOS ≤ 0.3 mm
  - Permittivity[^ASTM D4491] = 0.05 sec⁻¹
GEOGRIDS IN TEMPORARY AND UNPAVED ROADS
Geogrids

- Stewart et al., with $N_c = 5.8$ (USFS, 2003)

- Giroud and Hann (2004)

\[
h = \frac{0.868 + (0.661 - 1.006 J^2) \left( \frac{r}{h} \right)^{1.5} \log N}{1 + 0.204 \left( \frac{3.48 CBR_{bc}}{CBR_{sg}} \right)^{0.3} - 1}
\]

\[
\left( \sqrt{\frac{P}{\pi r^2}} \right) \left( \frac{\frac{S}{f_s}}{1 - 0.9e^{\frac{-r^2}{h^2}}} \right) ^{N_c f_c CBR_{sg}} - 1
\]
Geogrids - Modified Stewart Method

- $N_c = 5.8$
- Use geotextile as a separator
  - Grid will not prevent fines from migrating into base course aggregate
- Follow previously described design method
Geogrids – Giroud & Hann Method

• Assumptions:
  ▫ Saturated subgrade soil
    • Exhibits undrained behavior under traffic loading
    • Subgrade soil modulus
      • Correlation between field CBR and field resilient modulus
    • Ratio of base course resilient modulus to subgrade soil limited to 5
Giroud and Hann Method Limitations

- Rut depth 50 – 100 mm (2 – 4 in)
- Field CBR < 5
- Base course modulus to subgrade soil modulus ratio = 5
- 10,000 ESALs trafficking for unpaved roads
- Tension membranes effect not accounted for
  - Negligible for rut depths < 100 mm (4 in)
Giroud and Hann Method

Limitations

- Geogrid reinforcement influence considered using $N_c = 5.71$ and aperture stability module ($J$) of grid
- Geotextile reinforcement influence considered using $N_c = 5.14$ and aperture stability module equal to 0
- Unreinforced unpaved roads, $N_c = 3.14$ and aperture stability module equal to 0
- Minimum base course aggregate thickness = 100 mm (4 in)
Geogrid Design Steps (Giroud & Hann)

• Use the previously described design steps with the following exceptions:
  ▫ Steps 4 – 6: Use Giroud & Hann equations
  ▫ Step 7 – Select base course thickness
  ▫ Step 8 – Check geotextile separation requirements
  ▫ Step 9 & 10 – Specify geogrid properties
  ▫ Step 11 – Specify construction requirements
Stabilization in Paved Roadways
Design Approach for Stabilization

- Standard methods (e.g., AASHTO) used to design pavement section.
- No structural support assumed for using geosynthetic.
- Aggregate savings is through reduction in stabilization aggregate (with no chemical stabilization required).
- Recommend temporary road method be used to design first construction lift (i.e., stabilizer lift).
- Place stabilization lift, then construct design pavement section (e.g., subbase, base, asphalt).
Geotextile Design Steps

- Assess the subgrade conditions.
- Estimate need for geosynthetic.
- Design pavement without geosynthetic.
- Determine need for additional aggregate.
- Determine thickness of stabilization aggregate requirements.
- Determine separation/filtration and survivability requirements.
- Specify geotextiles meeting or exceeding the survivability criteria.
- Specify construction protocols.
Design for Stabilization

- CBR < 3  \( S_u < 2000 \text{ psf} \)
- Fine grained wet, saturated soils
- AASHTO M-288 requirements
  - Survivability  Class 1 (AASHTO M288)
  - Minimum Permittivity  > 0.05 sec\(^{-1}\)
  - Maximum AOS  0.43 mm
- Drainage, Drainage, Drainage
AASHTO Specification M-288 - Stabilization

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<tr>
<td>Permittivity</td>
<td>0.05 - 0.5 sec⁻¹</td>
</tr>
<tr>
<td>Max Apparent Opening Size</td>
<td>0.43 mm (&lt; 50% fines)</td>
</tr>
<tr>
<td></td>
<td>0.3 mm (&gt; 50% fines)</td>
</tr>
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* ASTM D6241 – 50 mm (2 in) dia probe
Geogrids for Stabilization in Paved Roadways

• Design Methods
  ▫ Empirical Design Method
    • AASHTO Pp 46-01 (2001)
      • Recently became permanent spec
  ▫ Mechanistic-Empirical Design Approach (M-E)
Geogrids for Stabilization in Paved Roadways - Empirical Design Procedure

- Initial assessment of geosynthetic applicability
  - Subgrade strength
  - Aggregate thickness for unreinforced section
  - Base/subbase material characteristics
  - Seasonal variation of moisture levels
  - Reinforcing mechanisms
  - Value added by geosynthetics
    - Added pavement life
    - Reduced maintenance
Geogrids for Stabilization in Paved Roadways - Empirical Design Procedure

• Design of unreinforced pavement section
  ▫ Based on established method for design of unreinforced pavements
  ▫ The structural layers
  ▫ Type of material
  ▫ Determined thickness for pavement section without geosynthetic
Geogrids for Stabilization in Paved Roadways - Empirical Design Procedure

- Investigate the potential benefits of using geosynthetics reinforcement
- Define reinforcement benefits in terms of Traffic Benefit Ratio (TBR) or Base Course Reduction Factor (BCR)
- Design reinforced pavement section
Geogrids for Stabilization in Paved Roadways - Empirical Design Procedure

- Do a cost-benefit analysis
- Develop specifications, bid documents, and construction drawings
- Monitor construction and document performance
Geogrids for Stabilization in Paved Roadways: M-E Design Procedure

• Selection of pavement structure
  ▫ Layers
  ▫ Types of materials
  ▫ Thicknesses

• Characterization of:
  ▫ Climate
  ▫ Traffic
  ▫ Site specific materials
Geogrids for Stabilization in Paved Roadways: M-E Design Procedure

• Analysis of mechanistic model of the pavement structure
• Calculation of critical responses
  ▫ Stresses and strains
• Evaluation of accumulated damage and distress
  ▫ Uses preset criteria

• May take several iterations considering different pavement structures
Geogrids for Stabilization in Paved Roadways: M-E Design Procedure

- Important components of the M-E method
  - A mechanistic model to calculate the critical responses.
  - Empirical performance or damage models that relate to the critical responses to the accumulated damage and distress levels.
<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Units</th>
<th>Requirement</th>
<th>Geogrid Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SURVIVABILITY</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Ultimate Multi-Rib Tensile Strength</td>
<td>ASTM D 6637</td>
<td>lb/ft (kN/m)</td>
<td>1230 (18) 820 (12) 820 (12)</td>
<td>CLASS 1⁴</td>
</tr>
<tr>
<td>Junction Strength⁵</td>
<td>GSI GRI GG2</td>
<td>lb (N)</td>
<td>25⁵ (110⁵) 25 (110) 8 (35)</td>
<td>CLASS 2</td>
</tr>
<tr>
<td>Ultraviolet Stability (Retained</td>
<td>ASTM D 4355</td>
<td>%</td>
<td>50% after 500 hours of</td>
<td>CLASS 3</td>
</tr>
<tr>
<td>Strength)</td>
<td></td>
<td></td>
<td>exposure</td>
<td></td>
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<tr>
<td><strong>OPENING CHARACTERISTICS</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Aperture Size</td>
<td>Direct</td>
<td>in. (mm)</td>
<td>0.5 to 3 in. (12.5 to 75 mm)</td>
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</tr>
<tr>
<td></td>
<td>measure</td>
<td></td>
<td>and Aperture Size ≥ D50 of</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>aggregate above</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Aperture Size ≤ 2·D85 of</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>aggregate above</td>
<td></td>
</tr>
<tr>
<td>Separation</td>
<td>ASTM D 422</td>
<td>mm</td>
<td>D85 of agg. above &lt; 5·D85</td>
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<td></td>
<td></td>
<td></td>
<td>subgrade</td>
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<td></td>
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<td></td>
<td>Other wise use separation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>geotextile</td>
<td></td>
</tr>
</tbody>
</table>
Ohio DOT Specification

- **TABLE 861.02-1  REQUIRED GEOGRID PROPERTIES**
- **Property** | **Test Method** | **Required Value**
- **Reinforcement Properties**
- Strength at 2% Strain | ASTM D 6637 | 400 lb/ft 5.8 kN/m
- Minimum Opening Size | Direct Measure | 0.75 in 19 mm
- Maximum Opening Size | Direct Measure | 3.0 in 76 mm

- **Survivability Index Values**
- Ultimate Tensile Strength | ASTM D 6637 | 1230 lb/ft 18 kN/m
- Junction Strength | GRI GG2 | 25 lb 110 N
- Ultraviolet Stability | ASTM D 4355 | 70 % at 500 hrs
Construction sequence
See Table 5-11
THANK YOU