State-of-Practice on the Use of Geosynthetics in Roadway Applications

Mark H. Wayne, Ph.D., P.E.
Tensar International
mwayne@tensarcorp.com
30+ YEARS
Foundation & Pavement Optimization
FEDERAL HIGHWAY ADMINISTRATION
Why Geogrids?
Flexible Pavement Design

- Construction Platform
- Paved Road

(IDOT, 1982)

60% Thickness Requirements
32 K Tandem Axle – Dual Wheels
(12 K Equivalent Single Wheel Load)
500 Coverages
1 inch = 25 mm

Required Thickness Above Subgrade, Inches

Subgrade CBR

Remedial Procedures Required
Remedial Procedures Optional
Remedial Procedure Not Needed
Interface Immobilization

Particle Size Ratio
Fundamental to Piping Concept

Spherical particle “B” will just pass through pore space between three spheres “A” 6 1/2 times the diameter of “B”.

This size ratio is approximately that of a pea to billiard balls.

Preventing Piping with Graded (Natural) Filters

LEGEND
- in-place soil
- $D_{85}$ soil
- $D_{85}$ soil entrapped in filter
- soil migrated into filter, held by $D_{85}$ size soil particles
A Sieve Analysis of Tennis Balls…

Particle Size Distribution

% Finer by Weight

Γ 65 mm Uniform Diameter

Grain Size (mm)
... and also Marbles

Particle Size Distribution

% Finer by Weight

Grain Size (mm)

65 mm

13 mm Uniform Diameter

5x
Subgrade Particles Cannot Infiltrate Aggregate Fill Just as Marbles Cannot Infiltrate Tennis Balls, Provided They Don’t Move.
Filter Criteria

- For Clayey Subgrades:
  \[\text{Piping Ratio} = \frac{D_{15f}}{D_{85s}} < 5\]

- For Silty Subgrades:
  \[\text{Piping Ratio} = \frac{D_{15f}}{D_{85s}} < 5\]
  \[\text{Average Size Ratio} = \frac{D_{50f}}{D_{50s}} < 25\]
So if Water is Present and Filter Criteria are Not Satisfied...

• (1) Consider an Alternative (i.e. Sandier) Aggregate Fill, at Least for the First Lift.
• (2) Consider a Nonwoven Geotextile Beneath the Geogrid, but Only if the Subgrade is Not Silty.
AGGREGATE INTERACTION

FHWA Aperture Size Criteria

Aperture size $\geq D_{50}$ of Aggregate Fill and $\leq 2D_{85}$ of Aggregate Fill
PART 1 | Method development and calibration

The Giroud-Han design method for geosynthetic-reinforced unpaved roads

By J.P. Giroud and Jie Han
UNPAVED ROAD DESIGN

The following design equation for base course thickness was developed through calibration and verification with laboratory and field data (Giroud and Han, 2004b):

\[
h = \dfrac{0.868 + (0.661 - 1.006J^2)(\frac{r}{h})^{1.5}}{[1 + 0.204(R_E - 1)]} \log N \left( \dfrac{P}{\pi r^2} - 1 \right)^{-1} \left( \dfrac{s}{f_s} \left[ 1 - 0.9e^{-\left(\frac{r}{h}\right)^2} \right] N_c f_c CBR_{sg} \right)
\]  

Full Scale Testing Required to Calibrate and Validate
• FHWA Separation Criteria (Piping Ratio)
  ▫ D15 fill = 0.15mm
  ▫ D85 subgrade = 0.35mm
  ▫ D15/D85 = 0.43<5 OK

• Average Size Ratio
  ▫ D50fill = 3mm
  ▫ D50subgrade=0.1mm
  ▫ D50fill/D50subgrade=30 not < 25 but close and still worked fine for the SM used in this study.

• FHWA Aperture Size Criteria (Interaction)
  ▫ Aperture size ≥ D50 of GAB (3mm) and ≤ 2D85 of GAB
  ▫ TX130S – 22 mm ≥3 mm OK and ≤ 2*18 or 36mm OK
  ▫ BX1100 – 25mm/33mm > 3mm OK and ≤ 2*18 or 36mm OK
PAVED ROAD DESIGN

AASHTO ‘93
MEPDG
AASHTO STANDARD PRACTICE

Standard Practice for

Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures

AASHTO Designation: R 50-09
AASHTO 93

Figure 3.1. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input
PAVED ROAD DESIGN

Converted to a layer depth using coefficients.

\[ SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3 + \ldots \]
For the reinforced case, the TBR is applied to compute an adjusted, or equivalent reinforced, number of 18-kip equivalent single-axle load applications. The equivalent reinforced value is:

\[(W_{18})_R = W_{18} \times TBR\]

\[TBR = \frac{GEODGRID SECTION ESALs}{CONTROL SECTION ESALs}\]
MEPDG Output*

Service Life*

Pavement Distresses with Standard Asphalt Layer

Pavement Roughness
- No geogrid
- Design Limit
- Time
- with geogrid

Fatigue Cracking
- No geogrid
- Design Limit
- Time
- with geogrid

Rutting
- No geogrid
- Design Limit
- Time
- with geogrid

Pavement Distresses with Thick Asphalt Layer

Pavement Roughness
- No geogrid
- Design Limit
- Time
- with geogrid

Fatigue Cracking
- No geogrid
- Design Limit
- Time
- with geogrid

Rutting
- No geogrid
- Design Limit
- Time
- with geogrid

Performance vs. Index Property

![Graph showing Performance vs. Index Property](image)
Performance Evaluation

- Full-Scale Testing
Performance Evaluation

- Full-Scale Testing
Biaxial Geogrid Performance
Geogrid Performance

![Graph showing TIF vs Base Course Thickness for 4-in. AC, 6-in. AC, and 8-in. AC.]
Flexible Pavement Design

- Use of Performance Based Testing

\[ SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3 + ... \]
# Flexible Pavement Design

<table>
<thead>
<tr>
<th>MSL Aggregate thickness (in.)</th>
<th>Subgrade Resilient Modulus, Mr (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td>6</td>
<td>0.273</td>
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<tr>
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<td>18</td>
<td>0.191</td>
</tr>
</tbody>
</table>
Summary

- Optimize Pavement Foundation
  - Design Stabilization Platform
  - This is a Stabilization Layer
- Optimize Pavement
  - Design Base Course Stabilization Layer
  - Full Scale Testing for Support
Future Practice

- Laboratory Performance Testing
  - T307 Resilient Modulus
- Construction QC/QA
  - Intelligent Compaction
  - Dynamic/Static Plate Load Testing
T307 Triaxial Cell
T307 Resilient Modulus

The graph illustrates the relationship between bulk stress (psi) and resilient modulus, Mr (psi). Two sets of data points are represented: CONTROL (orange triangles) and TX5 (green squares). The lines indicate a linear increase in resilient modulus as the bulk stress increases.
T307 Quick Shear

![Graph showing Axial Stress vs Axial Strain for Control and TX5 samples.](image-url)
$k_s$ indicates changes in support conditions due to changes in pavement foundation materials.
$k_s$ shows compaction progress and soft area.
Automated in situ measurement technologies are setting new standards for quality assessment.

Automated testing to assess:
- Modulus of subgrade reaction
- In situ resilient modulus
- Confining stress dependent cyclic modulus

This equipment is US Patent Pending disclosed in U.S. Provisional Patent Application No. 61/621,059, filed April 11, 2012. A South American application will claim priority back to the pending U.S. provisional patent application.
Questions?