America's Infrastructure

2009 Grades

- Aviation: D
- Bridges: C
- Dams: D
- Drinking Water: D-
- Energy: D+
- Hazardous Waste: D
- Inland Waterways: D-
- Levees: D-
- Public Parks and Recreation: C-
- Rail: C-
- Roads: D-
- Schools: D
- Solid Waste: C+
- Transit: D
- Wastewater: D

America's Infrastructure GPA: D
Estimated 5 Year Investment
Need: $2.2 Trillion

Take Our Poll

Five categories received D-:
Which is the most urgent?
- Drinking Water: 54%
- Inland Waterways: 54%
- Levees: 10%

The Infrastructure Roundtables

Read the Civil Engineering report on these events about the 5 Key Solutions

It's Your State

What's the state of your State's infrastructure? Find out now

Infrastructure in the News

Join Our Facebook Group:
"Save America's Infrastructure"
ASCE Member? Be a Key Contact
Paying More for Gas is Good for Us
Meet the New Kid on the Blogroll
ASCE and Building America's Future Poll

Internet
“33% of America's major roads are in poor or mediocre condition…”

“The current spending level of $70.3 billion for highway capital improvements is well below the estimated $186 billion needed annually to substantially improve the nation's highways.”

Source: infrastructurereportcard.com
Some Causes of Premature Road Failure

1. Weak Subgrade
2. Poor Drainage
3. Excessive Loading
4. Construction Errors
5. Material Failure
6. Unintended Use
7. Construction Damage to Subgrade
8. Regional Issues
   • Heaving, Thermal Cracking
Geogrid Introduction
• Biaxial Geogrids
  – Extruded
  – Woven
  – Welded
  – Geogrid Composites

• Triaxial Geogrid
  – Extruded
• **Subgrade Improvement**
  – Undercut reduction in soft soils
  – Improved construction platform for road construction
  – Protection of sensitive subgrade soils

• **Pavement Base Reinforcement**
  – Stiffening of base aggregate layer
  – Reduction of pavement section
  – Extended life of pavement
SUBGRADE IMPROVEMENT

SOFT SUBGRADE

$M_r < 5,000 \text{ psi}$

HMA

AGGREGATE BASE

SUBGRADE

grid

8 in.

24 in.
PAVEMENT BASE REINFORCEMENT

↑ LIFE : ↓ COST

↑ STIFFNESS

↓ STRESS
Design Elements

- Geogrid
- Value Proposition
- Mechanically Stabilized Layer (MSL)
- Unbound Aggregate
- Research & Relevant Proof
- Design
Deformation in Wheel path

Control

Improved Performance

Geogrid BX

Geogrid TX

Trafficking tests at TRL comparing products of equivalent weight

Longer Design Life

Deformation (mm)

Number of passes (N)
Small-scale Trafficking
Aggregate Rutting Profiles

Unreinforced
3,000 axle passes

Geogrid BX
10,000 axle passes

Geogrid TX
10,000 axle passes
Subgrade Rutting Profiles - Unreinforced

Unreinforced
3,000 axle passes

Geogrid BX
10,000 axle passes

Geogrid TX
10,000 axle passes
Tri-Axial Cell Testing
Multistage Repeated Load Tri-Axial Cell Testing

PERCENT STRAIN VS. NUMBER OF CYCLES

[Graph showing percent strain vs. number of cycles for different materials]
\[ E = \frac{s}{v} \]

\[ E_c = \frac{s}{0.10} = 10\text{s} \]

\[ E_{TX5} = \frac{s}{0.0775} = 13\text{s} \]

\[ E_{TX160} = \frac{s}{0.066} = 15\text{s} \]

Geogrid 1 = 30\% modulus increase
Geogrid 2 = 50\% modulus increase
U.S. Army Corps of Engineers Full Scale APT
U.S. Army Corps of Engineers Full Scale APT

Geogrid
where applicable

Geogrid Strain Gauge (where applicable)

Earth Pressure Cell

Asphalt Strain Gauge

Single Depth Deflectometer

3 CBR
CH Subgrade

2 in.
4 in.
4 in.
28 in.

12.5 ft
4.5 ft
4 ft
4 ft
4 ft
4 ft
4.5 ft
12.5 ft

NOT TO SCALE
Figure 23. Accumulation of rutting at selected locations
Subgrade Stabilization
Design
Circa 1910
Geosynthetic Design Methods for Subgrade Stabilization

FHWA Geosynthetic Design and Construction Guidelines – 2008 Sections 5.4 and 5.5
Section 5.4 – Design Guidelines for the use of Geotextiles in Temporary and Unpaved Roads
  • 1977 Steward, et. al. (US Forestry Service)

Section 5.5 – Design Guidelines for the use of Geogrids in Temporary and Unpaved Roads
  • 2003 Tingle and Webster (U.S.A.C.O.E.)
  • 2004 Giroud and Han

A temporary or unpaved road may constitute improved subgrade or a construction platform for a permanent road.
Geotextile Only

Utilizes Bearing Capacity Factor - $N_C$

Developed prior to the existence of biaxial geogrid
“the following limitations apply:

- the aggregate layer must be
  a) compacted to CBR 80,
  b) cohesionless (nonplastic);
- vehicle passes less than 10,000;
- geotextile survivability criteria must be considered; and
- subgrade undrained shear strength less than about 90 kPa (CBR <3)”

Source: U.S.F.S. Steward, et. al. 1977
Modified Steward, et. al. for geogrids and geotextiles

Utilizes Bearing Capacity Factor - $N_C$

Identifies 3 performance mechanisms of geogrid
Geogrid Mechanisms

1. Lateral Restraint
   “Confinement”
   (true stability)

2. Improved Bearing Capacity
   “Snowshoe Effect”
   (load distribution)

3. Tensioned Membrane
   “Hammock Effect”
   (initial tension)

Source: U.S. Army Corps of Engineers ETL 1110-1-189
“In the early stages of research regarding geogrid reinforcement of pavement systems, the tensioned membrane effect was thought to be the primary reinforcement mechanism. However, subsequent investigations have shown that reinforcement benefits are obtained without significant deformation of the pavement section. Thus, lateral restraint has been identified as the primary reinforcement mechanism, followed by the improved bearing capacity concept and the tensioned membrane effect.

Source: U.S. Army Corps of Engineers ETL 1110-1-189
Geogrid and geotextile
Built on principles of Giroud and Noiray (1981) design method for geotextiles
Individual geogrids must be empirically calibrated to formula
Utilizes Bearing Capacity Factor \( N_C \)
Utilizes Bearing Capacity Mobilization Coefficient \( m \)
Utilizes Stress Distribution Angle \( \alpha \)
“Due to their large apertures, geogrids may interlock with base course aggregate if there is an appropriate relationship between geogrid aperture size and aggregate particle size. While the degree of interlocking depends on the relationship between geogrid aperture size and aggregate particle size, the effectiveness of interlocking depends on the in-plane stiffness of the geogrid and the stability of the geogrid ribs and junctions. As a result of interlocking, the mechanisms of unpaved structure reinforcement are different for geotextiles and geogrids.”
Only three (3) design methods detailed for soft subgrades

Steward, et. al. only pertains to geotextiles

Tingle and Webster built on Steward’s study and developed geogrid performance mechanisms

Giroud and Han introduce bearing capacity mobilization and stress distribution factors for geogrid
SpectraPave4 Pro™ Software for Unpaved and Paved Applications using Tensar Geogrid. Place cursor on icons for descriptions.
Traffic Conditions
- Axle load (kips): 20
- Tire pressure (psi): 100
- Axle passes (each): 2500
- Maximum rut depth (in): 1.5

Soil Conditions
- Aggregate Fill CBR (%): 20
- Design Subgrade CBR (%): 1.6

Geogrid Reinforcement
- Unreinforced
- TX140
- TX160
### Unpaved Application - Data Input

<table>
<thead>
<tr>
<th>Geosynthetic</th>
<th>Aggregate Fill Thickness (in)</th>
<th>Aggregate Fill Thickness Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calculated</td>
<td>Required</td>
</tr>
<tr>
<td>Unreinforced</td>
<td>24.05</td>
<td>25</td>
</tr>
<tr>
<td>Tensar® TX140</td>
<td>12.9</td>
<td>13</td>
</tr>
<tr>
<td>Tensar® TX160</td>
<td>8.46</td>
<td>9</td>
</tr>
</tbody>
</table>

**Click Here to Conduct Unpaved Application Cost Analysis**

**Click Here to Check Subgrade Separation**

---

**Graph**

- **Unreinforced**
- **Tensar® TX140**
- **Tensar® TX160**

**Y-axis:** Aggregate Fill Thickness (in)

**X-axis:** Design Subgrade CBR (%)

---

**SpectraPave4 Pro™ Software for Unpaved and Paved Applications, Version 3.0, February, 2010**

**Unpaved Application Cost Analysis**

<table>
<thead>
<tr>
<th></th>
<th>Unreinforced</th>
<th>TX140</th>
<th>TX160</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate costs</strong></td>
<td>$129,871</td>
<td>$67,533</td>
<td>$46,753</td>
</tr>
<tr>
<td><strong>Geogrid costs</strong></td>
<td>$0</td>
<td>$24,014</td>
<td>$36,021</td>
</tr>
<tr>
<td><strong>Undercut costs</strong></td>
<td>$24,113</td>
<td>$12,539</td>
<td>$8,681</td>
</tr>
<tr>
<td><strong>Additional fill costs</strong></td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total project costs</strong></td>
<td>$153,983</td>
<td>$89,610</td>
<td>$105,619</td>
</tr>
<tr>
<td><strong>Overall project savings</strong></td>
<td>$0</td>
<td>$49,898</td>
<td>$62,528</td>
</tr>
<tr>
<td><strong>Percent savings</strong></td>
<td>0%</td>
<td>32%</td>
<td>41%</td>
</tr>
</tbody>
</table>

**Legend**
- Aggregate fill
- Existing subgrade
- Additional fill required
- Geogrid

**Proposed Grade**
- Unreinforced: 25 in
- TX140: 13 in
- TX160: 9 in
Pavement Design with Geogrid
Pavement Base Reinforcement

- Equal performance for considerably less cost
- Increased performance with lower life cycle costs
- Optimized – Increased performance for the same cost
Mechanisms – Tensile Membrane Effect

Source: USACOE ETL 1110-1-189
Mechanisms – Improved Bearing Capacity

\[
\text{stress} / \text{strain} = \text{M}
\]

Reinforced Shear Surface

Unreinforced Shear Surface

\[\downarrow \text{strain}\]
Mechanisms – Lateral Restraint

Lateral Restraint Due to Friction and Aggregate Interlock

\[ M_r = \frac{\text{stress}}{\text{strain}} \]

\[ \text{stress} = M_r \]

Lateral Shear Flow

Source: USACOE ETL 1110-1-189
AASHTO 1993 Pavement Design Formula

\[
\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{1094} + 2.32 \times \log_{10}(M_R) - 8.07
\]

\(W_{18}\) = predicted number of 80 kN (18,000 lb.) ESALs
\(Z_R\) = standard normal deviate
\(S_O\) = combined standard error of the traffic prediction and performance prediction
\(S_N\) = Structural Number (an index that is indicative of the total pavement thickness required

\(= a_1D_1 + a_2D_2m_2 + a_3D_3m_3 + \ldots\)

\(a_i = i^{th}\) layer coefficient

\(D_i = i^{th}\) layer thickness (inches)

\(m_i = i^{th}\) layer drainage coefficient

\(\Delta PSI\) = difference between the initial design serviceability index, \(p_o\), and the design terminal serviceability index, \(p_t\)

\(M_R\) = subgrade resilient modulus (in psi)
Standard Practice for

Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures

AASHTO Designation: R 50-09

1. SCOPE

1.1. This standard practice provides guidance to pavement designers interested in incorporating geosynthetics for the purpose of reinforcing the aggregate base course of flexible pavement structures. Geosynthetic reinforcement is intended to provide structural support of traffic loads over the life of the pavement.

1.1.1. For the purpose of this guide, base reinforcement is the use of a geosynthetic within, or directly beneath, the granular base course.

1.1.2. When referring to geosynthetics, the discussion is limited to geotextiles, geogrids, or geogrid/geotextile composites.

2. REFERENCED DOCUMENTS
6.1 Geosynthetics are used in the pavement structure for structural support of traffic loads over the design life of the pavement. The geosynthetic is expected to provide one or both of these benefits: 1) improved or extended service life of the pavement, or 2) a reduction in the thickness of the structural section.

AASHTO Designation: R 50-09

7.1.6.1 The traffic benefit ratio (TBR) is defined as the ratio of the number of load cycles of a reinforced pavement to reach a defined failure state, to the number of loads for the same unreinforced section to reach the same defined failure state.
Mechanically Stabilized Layer (MSL)

- Unconfined Zone
- Transition Zone (Partial confinement)
- Fully Confined Zone

Magnitude of confinement
Geogrid
<table>
<thead>
<tr>
<th>Layer</th>
<th>ACC: $a_i$ = 0.36 to 0.44</th>
<th>ABC: $a_i$ = 0.12 to 0.18</th>
<th>MSL: $a_i$ up to 0.28</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate</td>
<td></td>
<td>$\uparrow$ stress = $\uparrow$ $M_r$</td>
<td></td>
</tr>
<tr>
<td>Base</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
<td>$\downarrow$ stress = $\downarrow$ strain</td>
<td></td>
</tr>
</tbody>
</table>
SpectraPave4 Pro™ Software for Unpaved and Paved Applications using Tensar Geogrid. Place cursor on icons for descriptions.
**Design Traffic (ESALs) = 1,000,000**

### Unreinforced Section

<table>
<thead>
<tr>
<th>Layer</th>
<th>Di (in)</th>
<th>ai</th>
<th>mi</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC1</td>
<td>2.00</td>
<td>0.440</td>
<td>N/A</td>
<td>0.88</td>
</tr>
<tr>
<td>ACC2</td>
<td>4.00</td>
<td>0.360</td>
<td>N/A</td>
<td>1.44</td>
</tr>
<tr>
<td>ABC</td>
<td>12.00</td>
<td>0.140</td>
<td>1.0</td>
<td>1.68</td>
</tr>
</tbody>
</table>

**Overall Structural Number (SN): 4.00**

### Tensar TriAx Geogrid Reinforced Section

<table>
<thead>
<tr>
<th>Layer</th>
<th>Di (in)</th>
<th>ai</th>
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<td>0.440</td>
<td>N/A</td>
<td>0.88</td>
</tr>
<tr>
<td>ACC2</td>
<td>3.00</td>
<td>0.360</td>
<td>N/A</td>
<td>1.08</td>
</tr>
<tr>
<td>MSL</td>
<td>8.75</td>
<td>0.234</td>
<td>1.0</td>
<td>2.05</td>
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</tbody>
</table>

**Overall Structural Number (SN): 4.01**

**Calculated Traffic (ESAL's):**

- Unreinforced Section: 1,066,000
- Tensar TriAx Geogrid Reinforced Section: 1,084,000
Paved Application Cost Analysis - Data Input

LEGEND

- Existing Grade
- Finished Grade
- Tensar TriAx™ Geogrid
- Asphalt (ACC1+ACC2)
- Base (ABC+SBC)
- Base (MSL+SBC)
- Subgrade
- Additional Fill

Allowable Traffic (ESALs):
Section Unit Cost:
% Life Extension:
% Initial Cost Saving:

UNREINFORCED

TX5 REINFORCED

INITIAL CONSTRUCTION COSTS

<table>
<thead>
<tr>
<th>Material</th>
<th>UNREINFORCED</th>
<th>TX5 REINFORCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt (ACC1+ACC2)</td>
<td>$325,714</td>
<td>$272,804</td>
</tr>
<tr>
<td>Aggregate Base (ABC/MSL)</td>
<td>$175,560</td>
<td>$128,013</td>
</tr>
<tr>
<td>Subbase (SBC)</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Milling or Undercut</td>
<td>$36,667</td>
<td>$28,009</td>
</tr>
<tr>
<td>Additional Fill Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Geogrids</td>
<td>$0</td>
<td>$55,252</td>
</tr>
<tr>
<td><strong>Overall Project Cost</strong></td>
<td><strong>$537,941</strong></td>
<td><strong>$484,078</strong></td>
</tr>
</tbody>
</table>

Click Here to Perform a Life Cycle Cost Analysis
Click Here to Modify Pavement Structure
### Design Traffic (ESALs) = 1,000,000

#### Unreinforced Section

<table>
<thead>
<tr>
<th>Layer</th>
<th>Di</th>
<th>ai</th>
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<td>N/A</td>
<td>1.44</td>
</tr>
<tr>
<td>ABC</td>
<td>12.00</td>
<td>0.140</td>
<td>1.0</td>
<td>1.68</td>
</tr>
</tbody>
</table>

**Overall Structural Number (SN)** = 4.00

#### Tensar TriAx™ Geogrid Reinforced Section

<table>
<thead>
<tr>
<th>Layer</th>
<th>Di</th>
<th>ai</th>
<th>mi</th>
<th>SN</th>
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<td>ACC2</td>
<td>3.00</td>
<td>0.360</td>
<td>N/A</td>
<td>1.44</td>
</tr>
<tr>
<td>MSL</td>
<td>12.00</td>
<td>0.215</td>
<td>1.0</td>
<td>2.58</td>
</tr>
</tbody>
</table>

**Overall Structural Number (SN)** = 4.54

### Calculated Traffic (ESAL's)

- **1,066,000**
- **2,549,000**
Legends:
- Dotted line: Existing Grade
- Solid line: Finished Grade
- Dashed line: Tensar TriAx™ Geogrid
- Black: Asphalt (ACC1+ACC2)
- Yellow: Base (ABC+SBC)
- Orange: Base (MSL+SBC)
- Green: Subgrade
- Pink: Additional Fill

Allowable Traffic (ESALs):
- UNREINFORCED: 1,066,000
- TX5 REINFORCED: 2,549,000

Section Unit Cost:
- UNREINFORCED: $36.68/SY
- TX5 REINFORCED: $36.70/SY

% Life Extension:
- UNREINFORCED: 0%
- TX5 REINFORCED: 139%

% Initial Cost Saving:
- UNREINFORCED: 0%
- TX5 REINFORCED: 0%

Initial Construction Costs:

<table>
<thead>
<tr>
<th>Material</th>
<th>UNREINFORCED</th>
<th>REINFORCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt (ACC1+ACC2)</td>
<td>$325,714</td>
<td>$272,804</td>
</tr>
<tr>
<td>Aggregate Base (ABC+MSL)</td>
<td>$175,560</td>
<td>$175,560</td>
</tr>
<tr>
<td>Subbase (SBC)</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Milling or Undercut</td>
<td>$36,667</td>
<td>$34,630</td>
</tr>
<tr>
<td>Additional Fill Costs</td>
<td>$0</td>
<td>$55,252</td>
</tr>
<tr>
<td>Geogrids</td>
<td>$0</td>
<td></td>
</tr>
<tr>
<td>Overall Project Cost</td>
<td>$537,941</td>
<td>$538,246</td>
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</tbody>
</table>
### Material Properties

<table>
<thead>
<tr>
<th>Layer Name</th>
<th>Layer Coefficient</th>
<th>Drainage Factor</th>
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</thead>
<tbody>
<tr>
<td>ACC1  - Asphalt Wearing Course</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td>ACC2  - Dense-graded Asphalt Course</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>ABC   - Aggregate Base Course</td>
<td>0.14</td>
<td>1.0</td>
</tr>
<tr>
<td>SBC   - Subbase Course</td>
<td>0.08</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Design Traffic (ESALs)
- 100,000

### Unreinforced Section

<table>
<thead>
<tr>
<th>Layer Name</th>
<th>Thickness (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACC1</td>
<td>2.00</td>
</tr>
<tr>
<td>ACC2</td>
<td>4.00</td>
</tr>
<tr>
<td>ABC</td>
<td>12.00</td>
</tr>
<tr>
<td>SBC</td>
<td>6.00</td>
</tr>
</tbody>
</table>

### Tensar TriAx™ Geogrid Reinforced Section

- **Layer Name**
  - ACC1
  - ACC2
  - ABC
  - MSL
  - SBC
- **Thickness (in)**
  - 2.00
  - 3.00
  - 12.00
  - 6.00
- **Tensar Geogrid Reinforcement**
  - TX5

### Reliability (%)
- 90%

### Subgrade Resilient Modulus (psi)
- 5000

### Serviceability
- Initial
- Terminal
- 3.25
LEGEND

<table>
<thead>
<tr>
<th>Layer</th>
<th>UNREINFORCED</th>
<th>TX5 REINFORCED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finished Grade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensar TriAx™ Geogrid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt (ACC1+ACC2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base (ABC+SBC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base (MSL+SBC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional Fill</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Allowable Traffic (ESALs): 522,000
Section Unit Cost: $36.68/SY
% Life Extension: 0%
% Initial Cost Saving: 0%

INITIAL CONSTRUCTION COSTS

<table>
<thead>
<tr>
<th>Layer</th>
<th>UNREINFORCED</th>
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</tr>
<tr>
<td>Additional Fill Costs</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Geogrids</td>
<td>$0</td>
<td>$55,252</td>
</tr>
<tr>
<td>Overall Project Cost</td>
<td>$537,941</td>
<td>$538,246</td>
</tr>
</tbody>
</table>
## Pavement Design Summary

<table>
<thead>
<tr>
<th>Pavement</th>
<th>HMA Thickness</th>
<th>Agg Base Thickness</th>
<th>ESALs</th>
<th>+ / -</th>
<th>Svcblty Loss</th>
<th>Cost $/SY</th>
<th>+ / -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Design</td>
<td>6&quot;</td>
<td>12&quot;</td>
<td>1,066,000</td>
<td>N.A.</td>
<td>2</td>
<td>$36.68</td>
<td>N.A.</td>
</tr>
<tr>
<td>Reinforced for Maximum Cost Savings</td>
<td>5&quot;</td>
<td>8.75&quot;</td>
<td>1,084,000</td>
<td>2%</td>
<td>2</td>
<td>$33.01</td>
<td>-10%</td>
</tr>
<tr>
<td>Reinforced for Maximum Performance Cost Neutral</td>
<td>5&quot;</td>
<td>12&quot;</td>
<td>2,549,000</td>
<td>139%</td>
<td>2</td>
<td>$36.70</td>
<td>0%</td>
</tr>
<tr>
<td>Reinforced for Optimized Serviceability Cost Neutral</td>
<td>5&quot;</td>
<td>12&quot;</td>
<td>1,087,000</td>
<td>2%</td>
<td>1.25</td>
<td>$36.70</td>
<td>0%</td>
</tr>
</tbody>
</table>
Specifications
Design Elements

- Geogrid
- Value Proposition
- Research & Relevant Proof
- Unbound Aggregate
- Design
- Mechanically Stabilized Layer (MSL)
“Extruded geogrids are formed using a polymer sheet that is punched and drawn in either one or two directions for improvement of engineering properties. Extruded geogrids have shown good performance when compared to other types for pavement reinforcement applications.”

Source: U.S. Army Corps of Engineers ETL 1110-1-189 (Tingle and Webster)
“In addition to the aperture stability modulus, other properties of geogrids likely affect their ability to interlock with aggregate and efficiently reinforce the base course. Tensile modulus at small strains is one obvious property that is important. Webster (1992) listed rib thickness, rib cross-section shape, junction strength, and aperture size as properties, in addition to aperture stability, that affect performance of geogrid-reinforced bases.”

Source: ASCE August 2004 Journal of Geotechnical and Geoenvironmental Engineering
3.1. Because the benefits of geosynthetic reinforced pavement structures may not be derived theoretically, test sections are necessary to obtain benefit quantification. Studies have been done that demonstrate the value added by a geosynthetic in a pavement structure. These studies, necessarily limited in scope, remain the basis for design in the field.
5.2 Design procedures use experimentally derived input parameters that are often geosynthetic specific. Thus, computed engineering designs and economic benefits are not easily translated to other geosynthetics. Therefore, users of this document are encouraged to affirm their designs with field verification of the reinforced pavement performance, both in engineering design and economic benefits.
Geogrid Specifications

• Material Specification
  – Specify only geogrid properties
  – Difficult to assess performance based on geogrid index properties only
  – Basis of design can be compromised

• System Specification
  – Specify performance of composite geogrid / aggregate system
  – Ensures an acceptable performance level
  – Protects your design
  – Uses results from full-scale testing to predict performance
  – Design methodologies endorsed by FHWA and AASHTO already exist
<table>
<thead>
<tr>
<th>Properties</th>
<th>•MD Values¹</th>
<th>•CMD Values¹</th>
<th>•General³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture Dimensions², mm(in)</td>
<td>±25 (1.0)</td>
<td>±33 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Minimum Rib Thickness²</td>
<td>±1.27 (0.05)</td>
<td>±1.27 (0.05)</td>
<td></td>
</tr>
<tr>
<td>Rib shape</td>
<td></td>
<td></td>
<td>•rectangular</td>
</tr>
<tr>
<td>Aperture shape</td>
<td></td>
<td></td>
<td>•rectangular</td>
</tr>
<tr>
<td>Junction Efficiency², %</td>
<td></td>
<td></td>
<td>•93</td>
</tr>
<tr>
<td>Aperture stability⁴, m-N/deg</td>
<td></td>
<td></td>
<td>•0.65</td>
</tr>
<tr>
<td>Flexural Stiffness⁵, mg-cm</td>
<td></td>
<td></td>
<td>•750,000</td>
</tr>
<tr>
<td>Tensile Strength @ 2% Strain⁶, kN/m (lb/ft)</td>
<td>±6.0 (410)</td>
<td>±9.0 (620)</td>
<td></td>
</tr>
<tr>
<td>Ultimate Tensile Strength⁶, kN/m (lb/ft)</td>
<td>±19.2 (1,310)</td>
<td>±28.8 (1,970)</td>
<td></td>
</tr>
<tr>
<td>Resistance to chemical degradation⁷</td>
<td></td>
<td></td>
<td>•100%</td>
</tr>
<tr>
<td>Resistance to ultra-violet light and weathering⁸</td>
<td></td>
<td></td>
<td>•100%</td>
</tr>
</tbody>
</table>
1. PERFORMANCE CRITERIA

A. The design of the pavement shall be in accordance with the 1993 American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures.

B. The design of the pavement shall be based on the following parameters:

   (1) Subgrade Resilient Modulus XX psi
   
   (2) Serviceability Loss XX
   
   (3) Reliability XX %
   
   (4) Standard Deviation 0.49
   
   (5) Design traffic = XX Equivalent Single Axle Loads (ESALs)

C. The Mechanically Stabilized Layer (MSL) within the pavement structure shall have a thickness of XX inches or as shown on the contract plans.

D. The MSL shall be incorporated into the pavement design by using modified layer coefficients. Modified layer coefficients shall be calibrated and validated with the results of full scale laboratory, field and/or accelerated pavement testing where actual geogrids are tested in-soil and in representative conditions.
Mechanically Stabilized Layers consisting of engineered composite sections of geogrid and aggregate are a reliable, value added method to improve soil performance.

Geogrid reinforcement in flexible pavements can be used to design for maximum initial cost savings or optimized designs that produce increased performance at equal cost.

Proven design methods, endorsed by FHWA and AASHTO, can be employed for subgrade stabilization and pavement design.

In order to ensure a road performs as intended, a performance specification is recommended.
Thank You

See you in the Hallway!