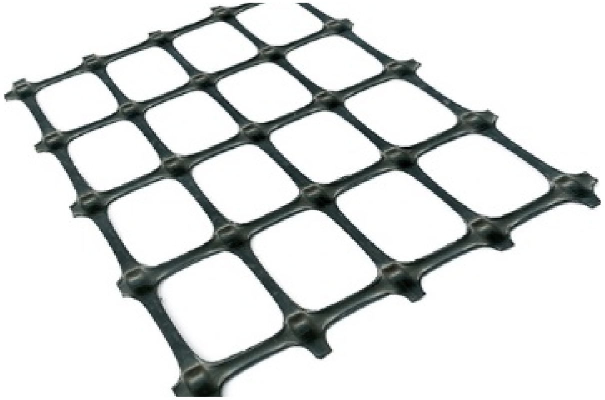
# Geosynthetics



National Concrete Pavement Technology Center
Iowa's Lunch–Hour Workshop
In cooperation with the Iowa DOT
and the Iowa Concrete Paving Association

# Presentation Items

1. What are Geosynthetics?
2. Soils and Support
3. Geogrids
4. Woven geotextiles

   Subbase/subgrade separation
5. Nonwoven geotextiles

   Separation Layer for Unbonded Concrete Overlays

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# What are Geosynthetics?

Geosynthetics are a class of **geomaterials** that are used to **improve soil conditions** for a number of applications. They consist of manufactured polymeric materials used in contact with soil materials or pavements as an integral part of a **man-made** system (ASTM D 4439).

Most common applications:

- Paved and unpaved roadways
- Reinforcing embankments & foundation soils
- Improving drainage

# What are Geosynthetics used for?

Geosynthetics have been used in pavement foundation layers for:

- Separation
- Filtration
- Drainage
- Reinforcement

The mechanisms by which geosynthetics provide reinforcement when placed at the subgrade interface include **lateral restraint** or **confinement** of subbase material and increase of bearing capacity.

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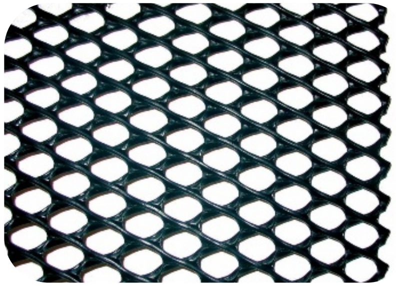
# Geosynthetics

Geotextile

Geogrid



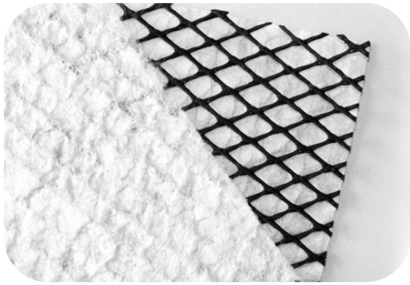
Geonet

Geomembrane

Geocell

Geosynthetic
clay liner

Geofoam



Geocomposite

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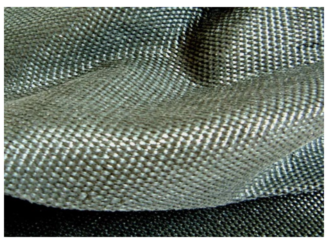
# Geosynthetic - Primary Uses

Polymer **Geogrids** act primarily as reinforcement by providing lateral restraint or confinement of aggregate layers above subgrade.



**Woven & Nonwoven Geotextiles** act primarily as separation layers between strata to prevent the upward migration of fine-grained particles from the subgrade into subbase layers.  The nonwoven can also provide lateral drainage.

# When to Use Geosynthetics

**Table 6H-1.04:** Appropriate Conditions for Geosynthetic Use

| Condition | Related Measures |
|---|---|
| Poor soils | USCS: SC, CL, CH, ML, MH, OH, or PT soils; or AASHTO: A-5, A-6, A-7, or A7-6 soils |
| Low strength | $S_u$ <13 kPa, CBR <3, or MR <4500 psi |
| High water table | Within zone of influence of surface soils |

When you have these soil conditions, consider improvements using geosynthetics

# When to Use Geosynthetics

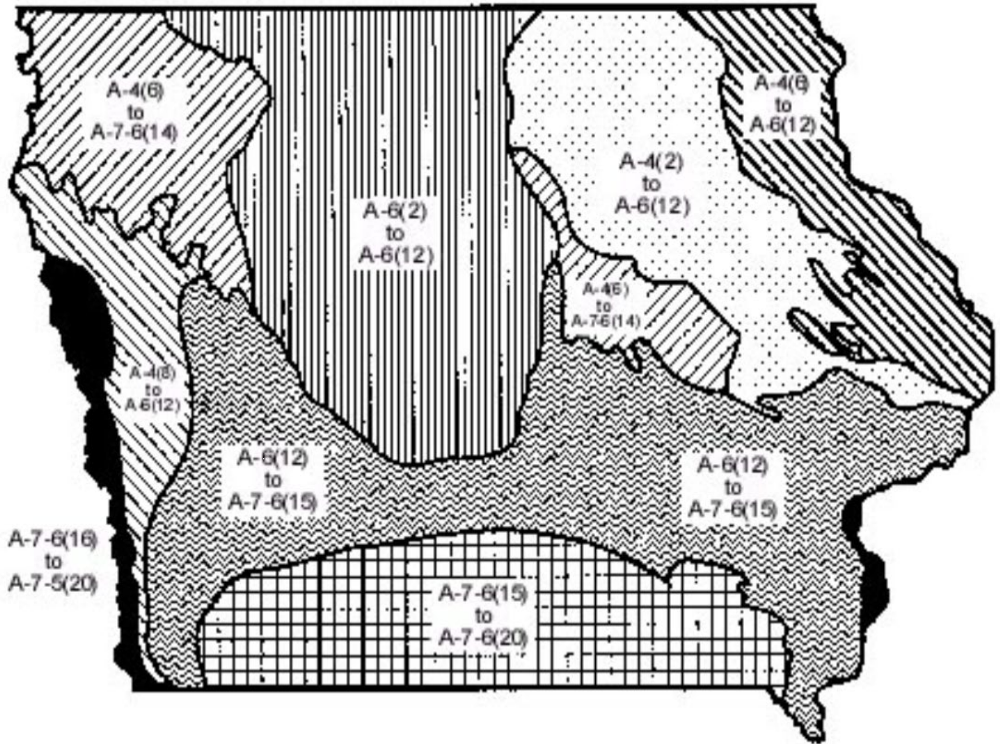
| CBR | Function | Geosynthetic Guidance |
|---|---|---|
| 2 – 3 | Filtration, some separation | Nonwoven |
| 1 – 2 | Filtration, separation, some reinforcement | Woven |
| < 1 | Filtration, separation, reinforcement | Geogrids, Woven & Nonwoven |

[1] $S_u$ (kPa) = undrained shear strength (1 kPa = 20.89 psf)

Source: Holtz et al. 1998

The Geosynthetic function to be provided is dependent on soil conditions

# AASHTO Distribution of Iowa Soil




A-4 through A-7 = Subgrade rating of Fair to Poor

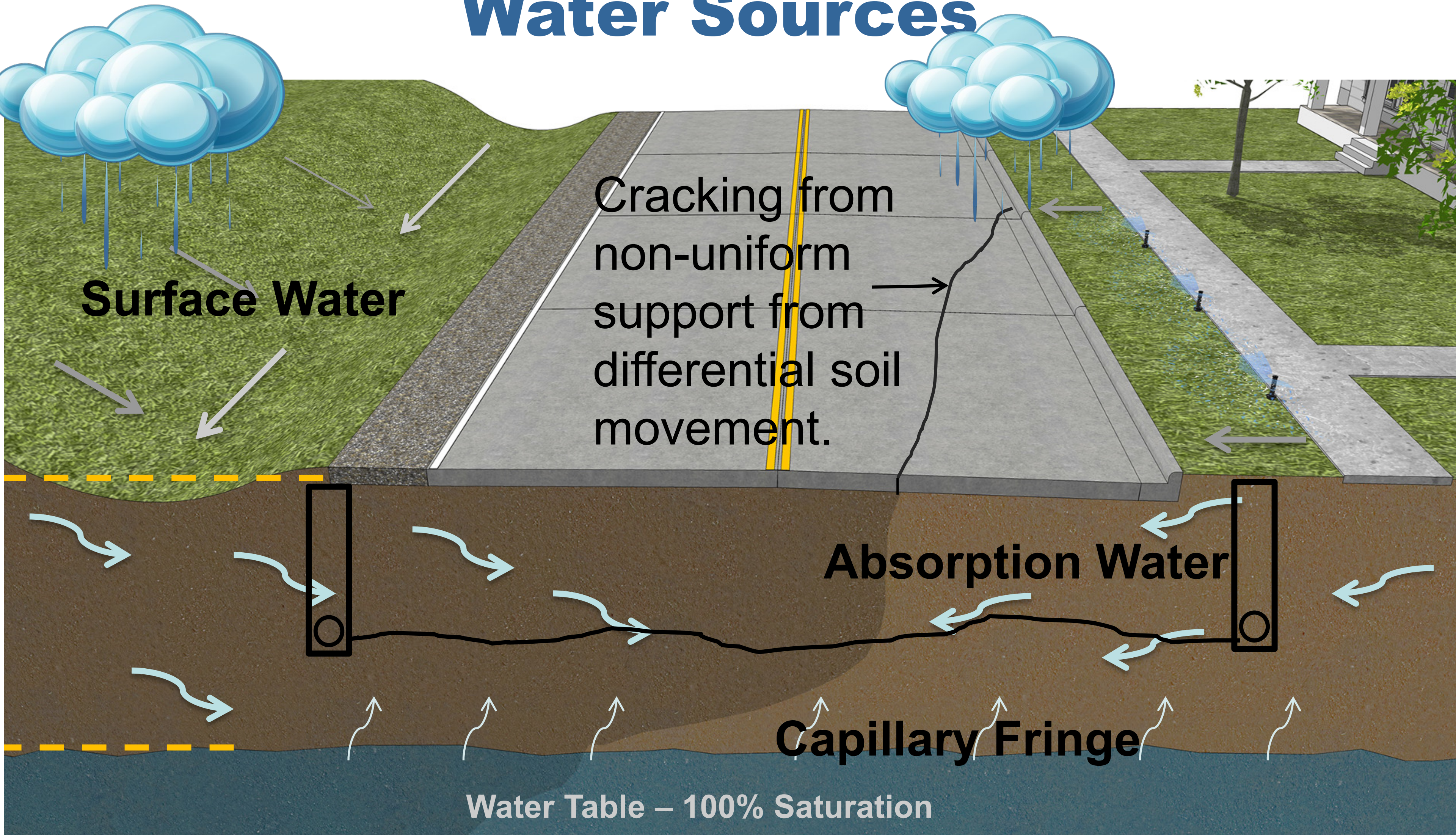
**A-4 soils** are predominantly silts with variable amounts of granular material or clay and some plasticity. Their strength varies with moisture content. These soils are very susceptible to frost heaving when located over sand pockets holding water in glacial till. They are very susceptible to erosion.

A-5 soils are silty soils with moderate liquid limit (40 max)

A-6 soils are clay soils with higher liquid limit (41 min)

A-7 soils are predominantly clay with variable amounts of granular material or silt. They are highly plastic and their strength varies appreciably with moisture content. They are also expansive.

# Water Sources




Capillary Action; Movement of water in narrow soil pores through intermolecular attractive forces between the soil and water.

# Iowa Soil Challenges

- High Plasticity = High Plasticity Index = Instability
- Expansive clays = Volume change
- Weak soils = Poor bearing capacity
- Wet/soft subgrade = Poor support

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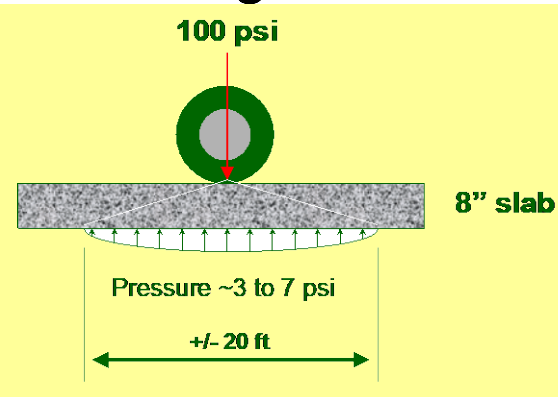
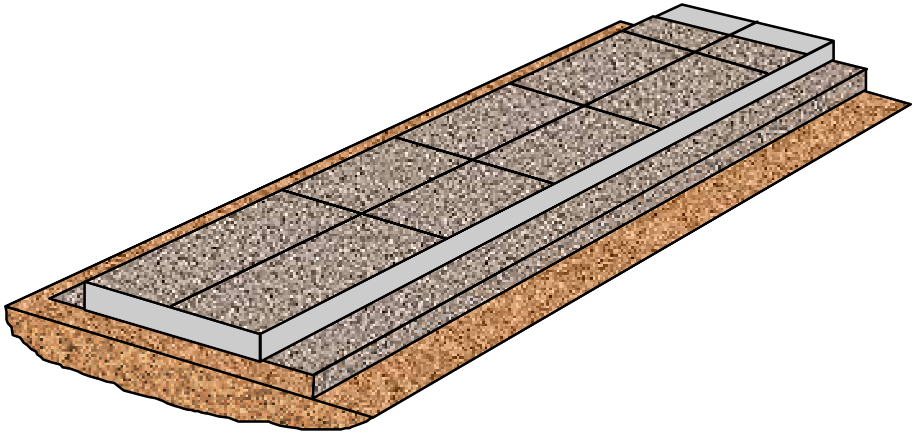
# Pavement Support Basics

- Firm, uniform, and non-erodible support is essential for concrete pavements
  - Reduces pavement defections from vehicle loadings
  - Avoids stress concentrations
- Must provide a stable working platform to expedite all construction operations
- Subgrade uniformity is more important than strength



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# Common Soil Improvement Options

<u>Soil Conditions</u>

Good

Bad

1. Scarify and drying
2. Blending soil
3. **Add geosynthetics for support**
4. Add chemical stabilization
5. Remove unsuitable and replace with select material in at least upper 2’

When evaluating soil conditions, a very poor soil may require chemical stabilization. (4”-6” ruts)

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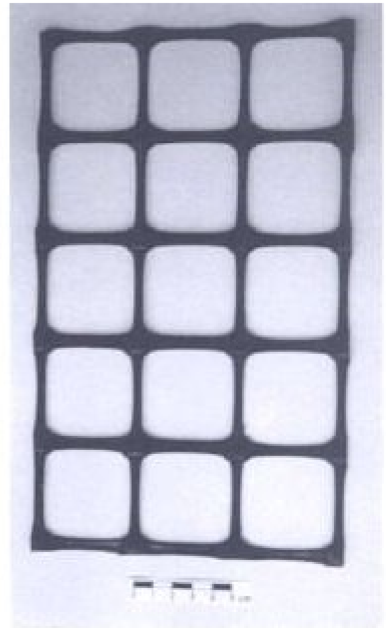
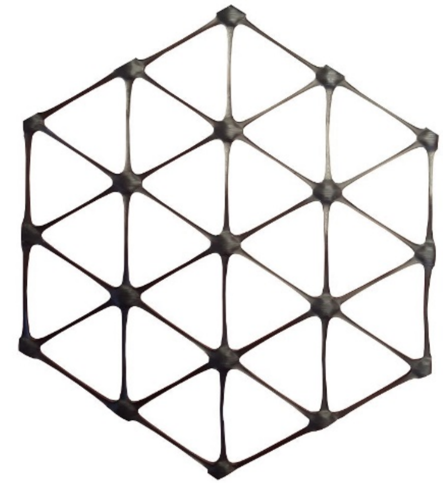
# Geogrids

Uniaxial



Biaxial



Triaxial

- Uniaxial – commonly used in retaining walls (one-directional strength)
- Manufactured with high-density polymers (higher stiffness than geotextiles)
- Size of aperture is partially dependent on the selection of aggregate

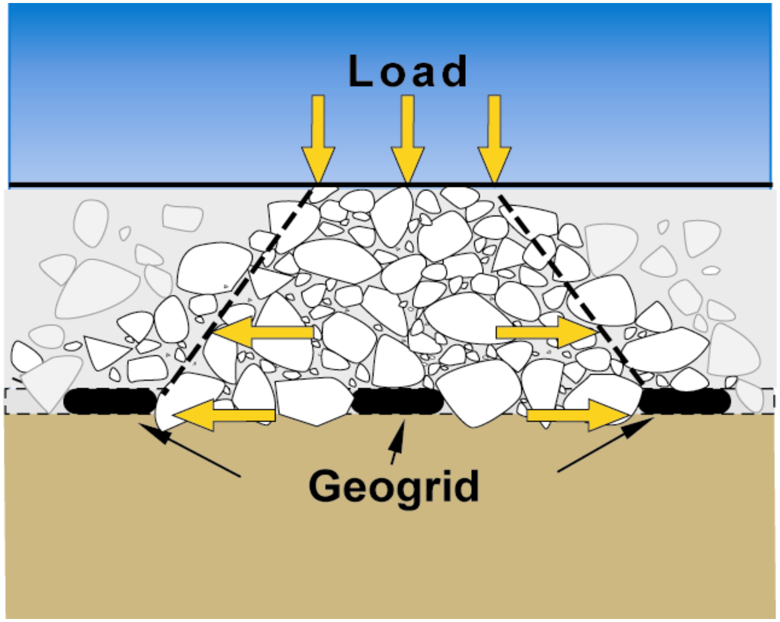
# Geogrids
# Application & Benefits

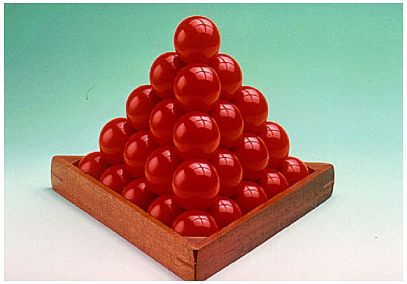
Geogrid + aggregate subbase:

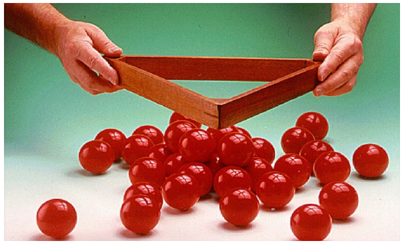
- Creates stronger composite structure
- Minimizes subbase fill
- Reduce undercut
- Serves as construction platform
- Extends service life

# Geogrid – Mechanical Interlock

Allows surrounding soil materials to interlock across the plane of the geogrid





# Geogrids & Geotextiles

Figure 4. Biaxial geogrid placed at the interface of subgrade and limestone base layers

Figure 3. Triaxial geogrid placed at the interface of subgrade and limestone base layers

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# Iowa DOT Geogrids Specs

Iowa DOT 4196.01.B.5

**Table 4196.01-5: Fabric for use as Subgrade Stabilization (Polymer Grid)**

| Property | Value | Test Method |
|---|---|---|
| Minimum tensile strength at 2% strain. Both directions. | 250 lbs./ft. | GRI Test Method GG1-87 |
| Maximum aperture. Both directions. | 2 in. | Internal Dimension Measuring Calipers |
| Minimum aperture. Both directions. | 0.5 in. | Internal Dimension Measuring Calipers |
| Minimum Ultimate junction strength. Both directions. | 800 lbs./ft. | GRI Test Method GG2-87 |

Image: Geofabrics

# Rectangular Geogrids Specs

SUDAS Specification
2010.2.04.C.5

**Table 2010.02: Geogrid (Rectangular or Square)**

| Property | Test Method | Units | Type 1[1] | Type 2 |
|---|---|---|---|---|
| Aperture stability modulus at 20 kg-cm | Kinney[2] - 01 | kg-cm/deg | 3.2 | 6.5 |
| Minimum true initial modulus in use | | | | |
| Machine direction (MD) | ASTM D 6637 | lb/ft | 15,080 | 32,890 |
| Cross Machine direction (CMD) | | | 20,560 | 44,725 |
| Tensile strength, 2% strain | | | | |
| MD Machine Direction | ASTM D 6637 | lb/ft | 270 | 410 |
| CMD Cross Machine Direction | | | 380 | 590 |
| Junction efficiency | GRI-GG2-87 | % | 93 | 93 |
| Flexural rigidity | ASTM D 1388 | mg-cm | 250,000 | 750,000 |
| Aperture size | | | | |
| Minimum | N/A | in. | 0.5 | 0.5 |
| Maximum | | | 2.0 | 2.0 |

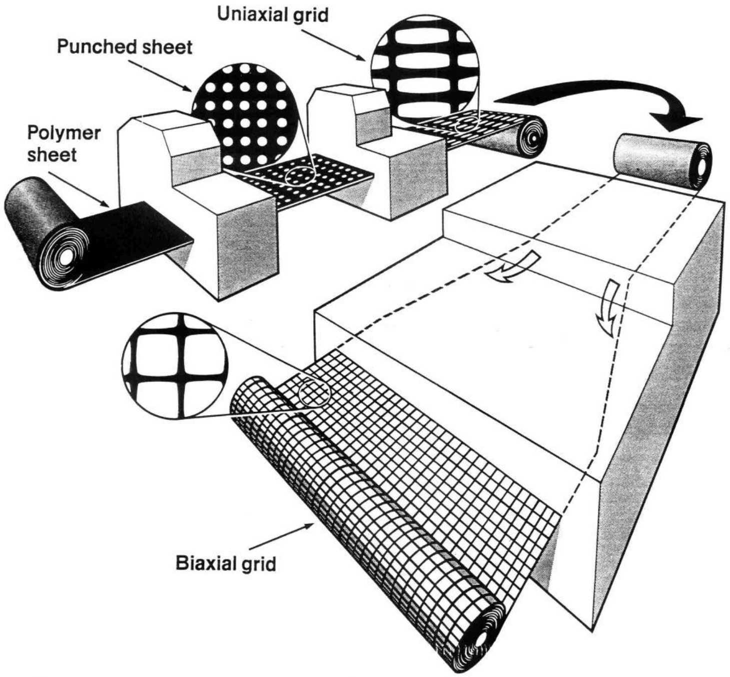
[1] Geogrids meeting the requirements of Iowa DOT Article 4196.01, B and Materials I.M. 496.01 will be acceptable

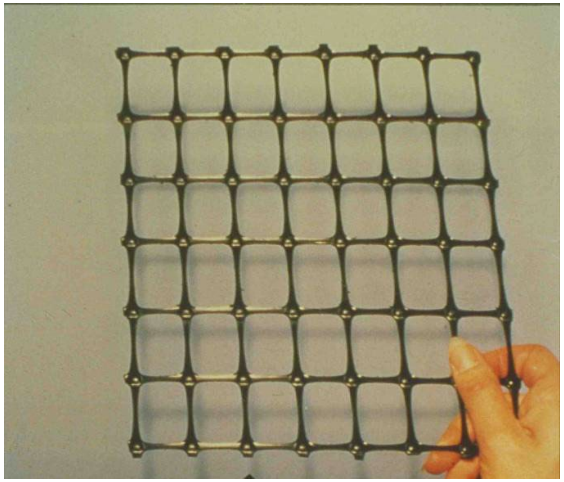
[2] Dr. Thomas C. Kinney, P.E. and US Army Corps of Engineers.

Image: Geofabrics

# Geogrid Manufacturing Process

- "Punched & Drawn" manufacturing process



- Polymers are drawn in one or two directions
- Square edges and stiff apertures promote mechanical interlock with aggregate

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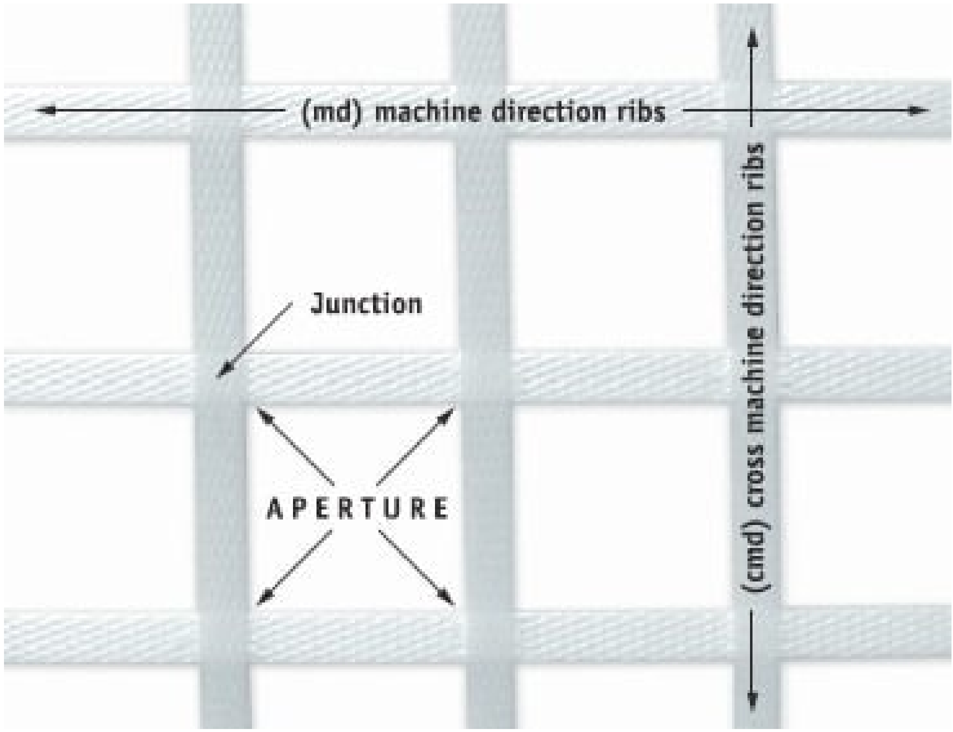
# Rectangular Geogrids Specs

CMD CMD CMD

MD

MD

MD




Roll of fabric

Direction of Machine Process

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# Triangular Geogrids Specs

SUDAS Specification
2010.2.04.C.5

**Table 2010.03: Geogrid (Triangular)**

| Property | Test Method | Units | Type 3 | Type 4 |
|---|---|---|---|---|
| Aperture stability modulus at 5 kg-cm | Kinney[1] - 01 | kg-cm/deg | 3.0 | 3.6 |
| Resistance to loss of load capacity | | | | |
| Chemical resistance | EPA 9090 Immersion | % | 90-100 | 90-100 |
| Ultra-violet light and weathering (500 hrs) | ASTM D 4355 | | | |
| Junction efficiency **Load Transfer Capability** | GRI-GG2-87 GRI-GG1-87 | % of ultimate tensile strength | 93 | 93 |
| Radial stiffness | ASTM D 6637 | lb/ft @ 0.5% strain | 15,000 | 20,000 |
| Rib Patch | | | | |
| Longitudinal | N/A | in. | 1.5-1.75 | 1.5-1.75 |
| Diagonal | | | | |
| Mid-rib depth | N/A | in. | 0.04-0.06 | 0.05-0.08 |
| Mid-rib width | N/A | in. | 0.035-0.05 | 0.035-0.055 |

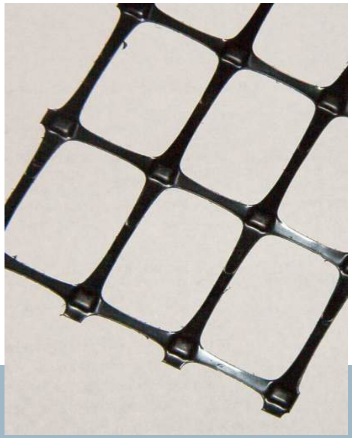
[1] Dr. Thomas C. Kinney, P.E. and US Army Corps of Engineers.

Image: Geofabrics

# Rectangular vs. Triangular

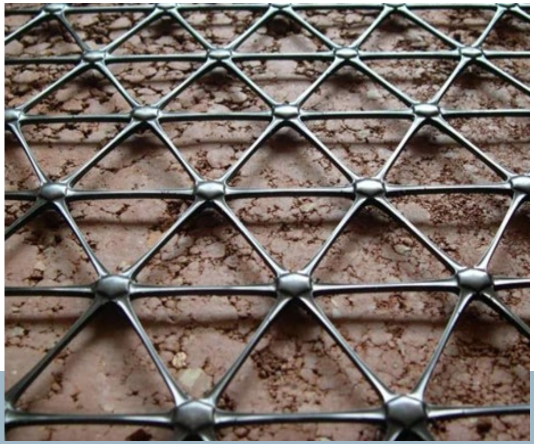
**<u>Biaxial Geogrids</u>**

- Lower Cost ($2-$3/SY)
- US Manufactured
- Lower Cost for equal Performance
- Positive 35 year track record



**<u>Triaxial Geogrids</u>**

- Higher Cost ($3-$5/SY)
- US Manufactured
- Proprietary
- 8 year track record
- Limited testing compared to BX



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# What About Migration of Soils?

Improper selection of materials may lead to decreased performance

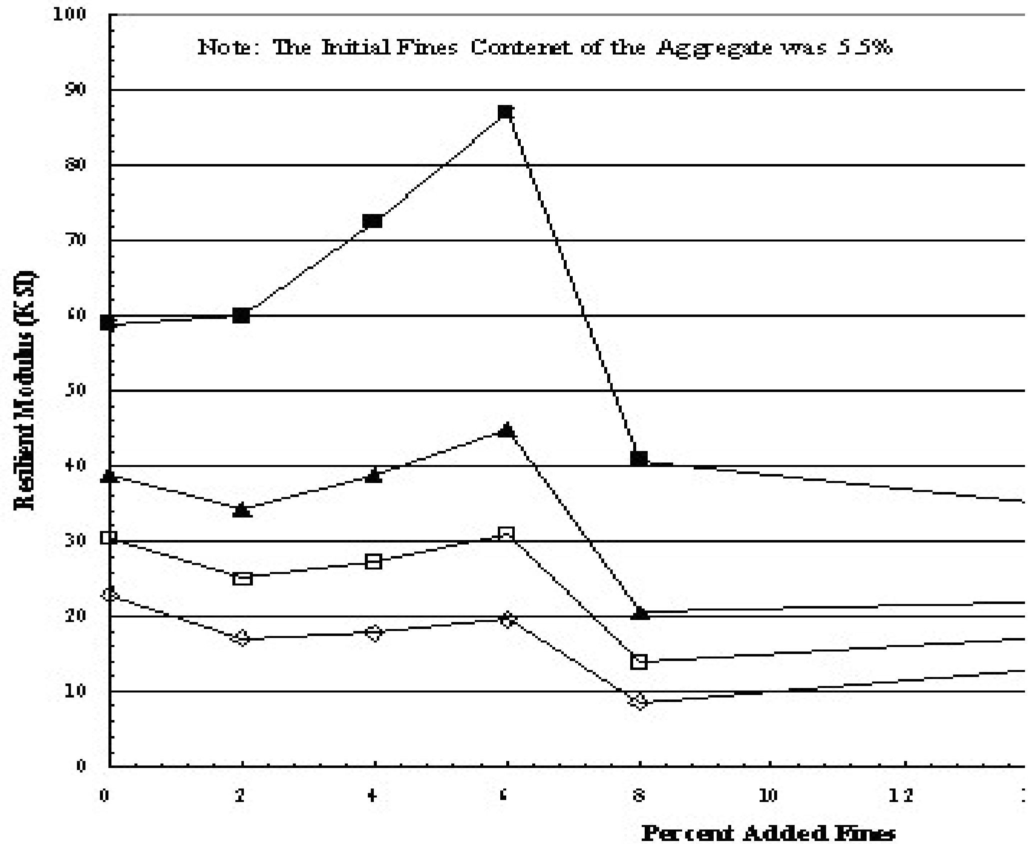
Rock too small or grid too large

Rock too large or grid too small

Images: Geofabrics

# Jorenby & Hicks Research Findings

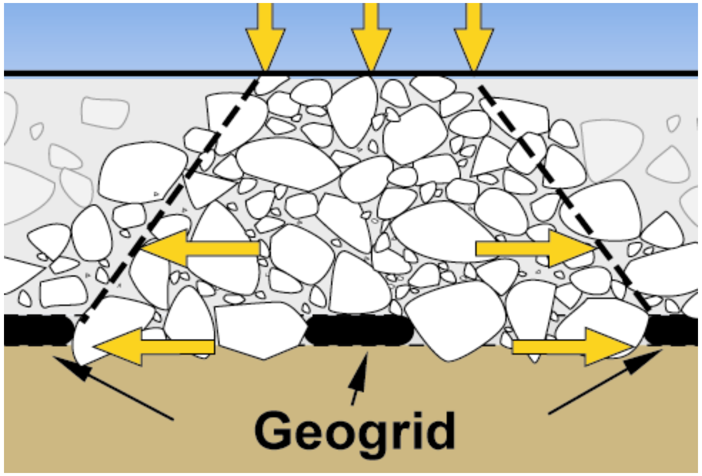
- Used a 1" minus crushed aggregate with 5.5% initial fines
- Introduced 8% soil contamination, in steps
- Aggregate structural strength dropped 50% with only 13% total fines
- Loss of drainage capability occurs with only 8% total fines content




**Excessive fines lead to decrease in Resilient Modulus (k value)**

# Proper Selection of Materials

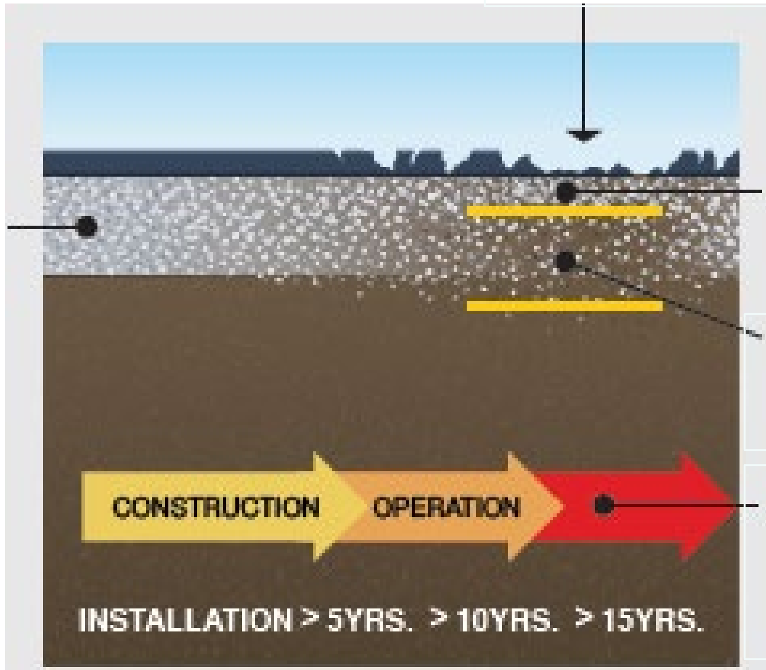
Properly selected geogrid and aggregate subbase provide separation through lateral restraint.




# Progressive Loss of Pavement Foundation

Distressed Pavement

Design Base Aggregate Thickness




Thin Base Effective Thickness

Weakened Contaminated Layer

Failure, Rehabilitation Required

**Premise for localized or total road reconstruction is the loss of foundation support.**

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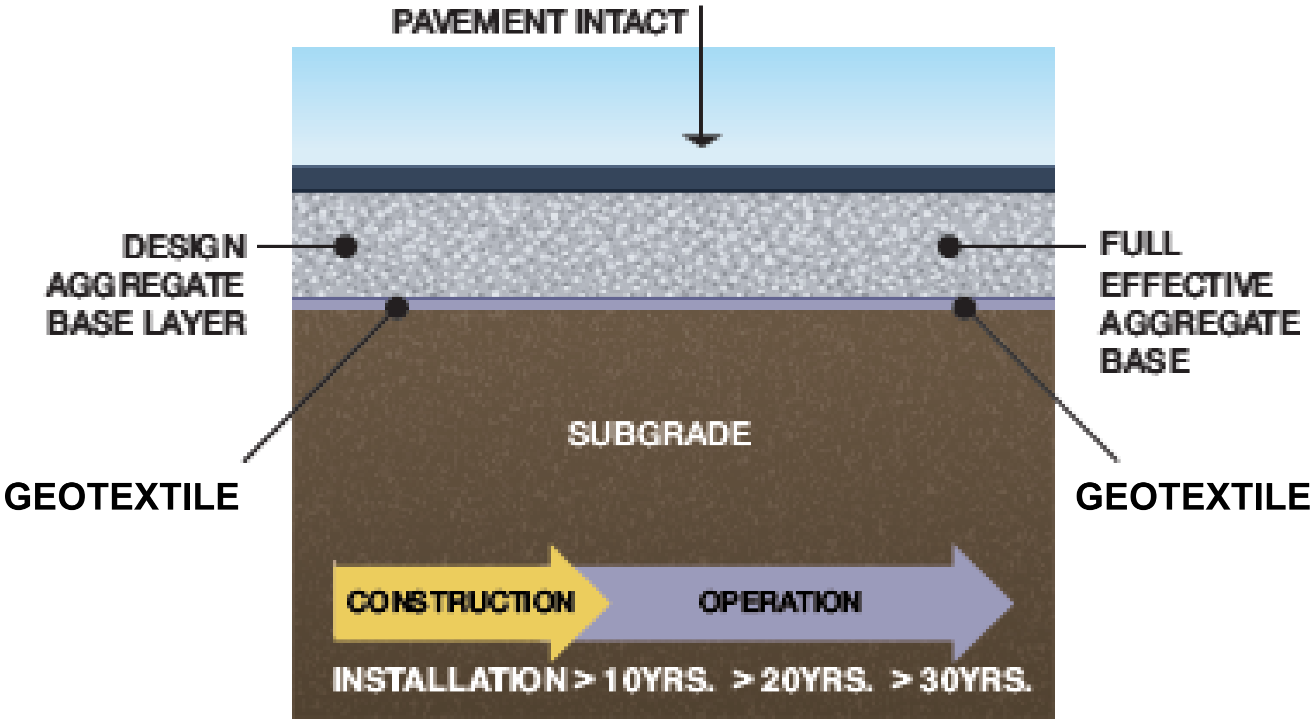
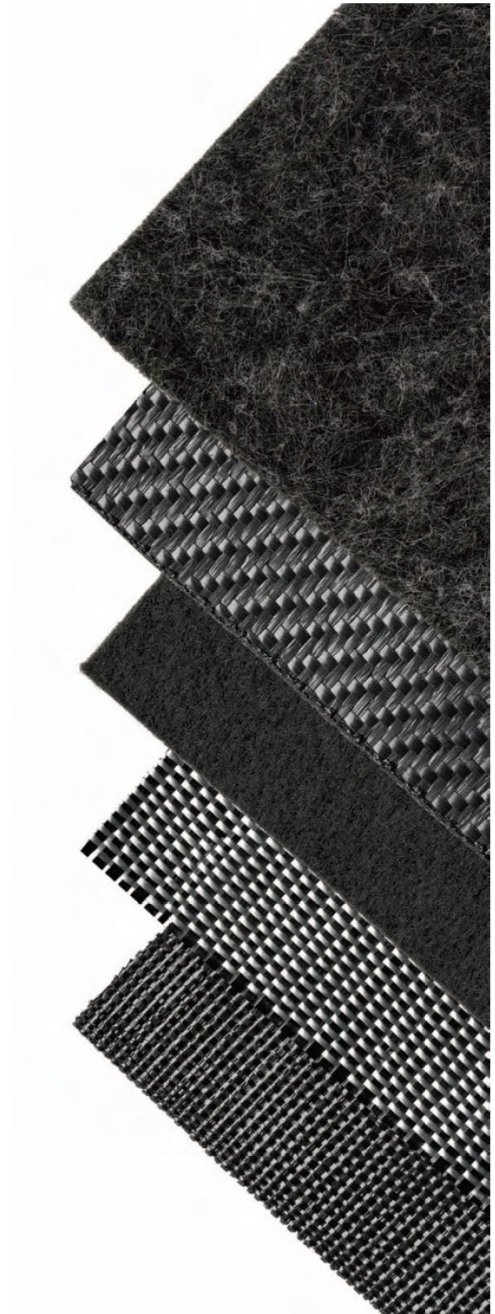
# Solution – Provide Separation with Geotextile



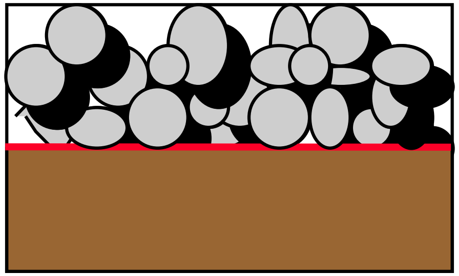

Geotextiles provide separation and reinforcement

# What Are Geotextiles?

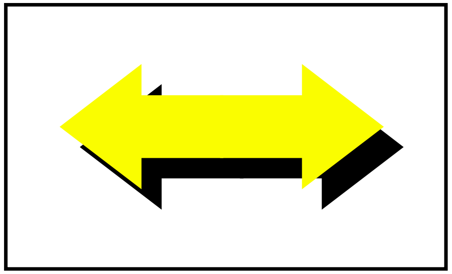
- **Definition**
  - Manufactured Fabrics used with soil, rock or other earthen materials to enhance the performance and/or reduce the cost of civil engineering projects.
- **History of Use**
  – Introduced in the 1960's
  – Use grew rapidly
  – US 2008 Civil Construction Market, 2.5 Billion SF
- **Composition**
  - Polypropylene (PP)
- **Primary Types**
  - Nonwoven
  - Woven
- **Rolled Goods**
  - Up to 17.5 ft. wide
  - 500 sy – 600 sy per roll
  - Typ. 100 – 500 lb. per roll



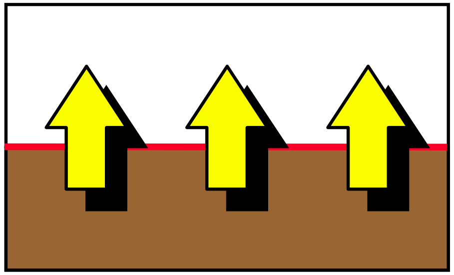
# Functions of Geotextiles



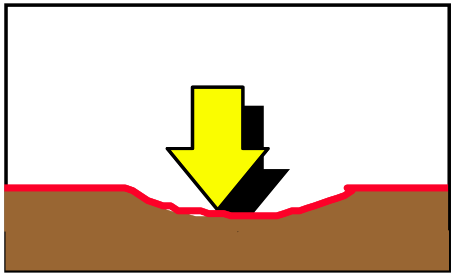
Separation



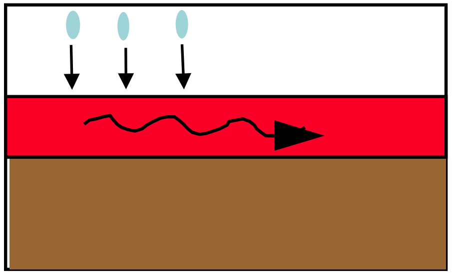
Reinforcement



Filtration



Cushion/
Protection



Drainage

# Geotextile Specs

AASHTO M288 Lists Requirements for:

1. Strength (Class 1 – 3, with 1 the highest)
2. Subsurface Drainage (permittivity, opening size)
3. Separation (permittivity, opening size)
4. Survivability (depends on subgrade conditions & construction equipment)
5. Stabilization (strength, permittivity, opening size)

SUDAS:
Manufactured of polymer fibers, meeting the requirements of ASTM D 4439.

**Permittivity** is the volumetric flow through a cross section of material

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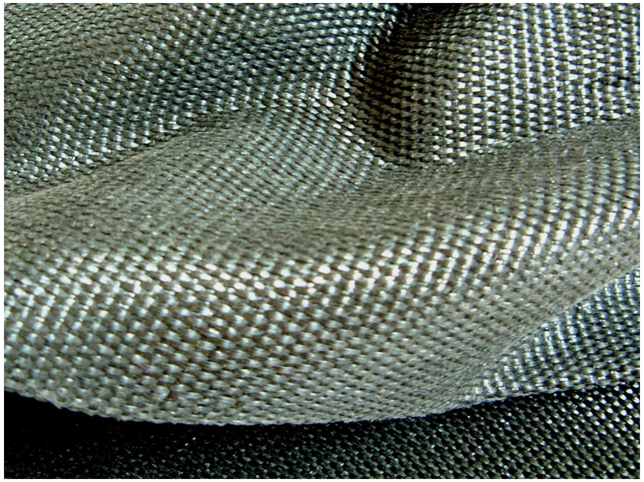
# Geotextiles

**Woven**

- High strength support
- Less permeable (4 gpm/sf)
- Used for stabilization, filtration and separation
- 10% elongation
- Cost: ~$2 per SY ($0.60/SY material)



**Nonwoven**

- Lower strength than Woven
- More permeable (100 gpm/sf)
- Used for filtration and separation
- 50% elongation
- Cost: ~$2 per SY ($0.65/SY material)

Made of Polypropylene fibers

# Woven Geotextile

*Figure 1. Woven geotextile placed on subgrade as a separation layer*

# Nonwoven Geotextile

*Figure 2. Non-woven geotextile placed on subgrade as a separation layer*

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# Cost Example for Improved PCC Pavement Performance

| Subgrade Conditions | Approach & Costs |
|---|---|
| Wet & Unstable | Chemically treated soils<br><br>6” Cement Modified Soils = $4.50/ Sq.Yd.<br>5” aggregate subbase = $6.00/ Sq.Yd.<br>**$10.50/ Sq.Yd**. |
| After compaction, slightly wet & somewhat stable but will not pass proof rolling | Dry out soil, place woven geotextile with 5” aggregate subbase.<br><br>Geotextile (woven) = $2.50/Sq.Yd.<br>5” aggregate subbase = $6.00/Sq.Yd.<br>**$8.50/Sq.Yd**. |
| Meets moisture & density control and passes proof rolling | Non woven geotextile = $1.75/Sq.Yd.<br>5” aggregate subbase = $6.00/Sq.Yd.<br>**$7.75/Sq.Yd.** |

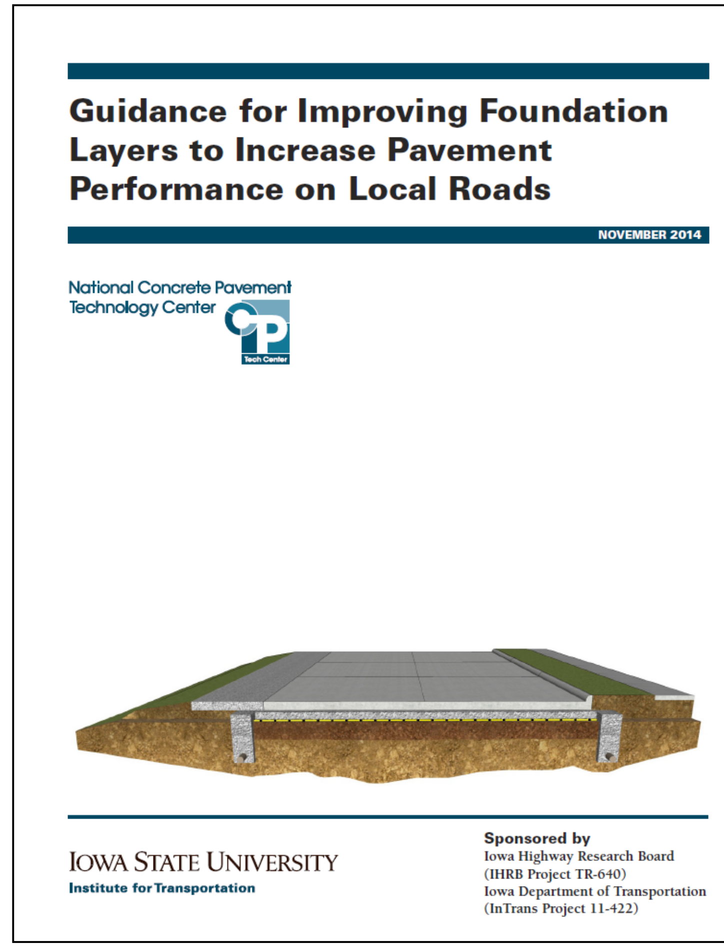
CMS or Fly Ash $0.75/Sq.Yd/in; Aggregate $1.20 /Sq. Yd/in.

# IHRB TR–640
# Optimizing Pavement Base, Subbase and Subgrade Layers for Cost and Performance on Local Roads


## Field Investigation

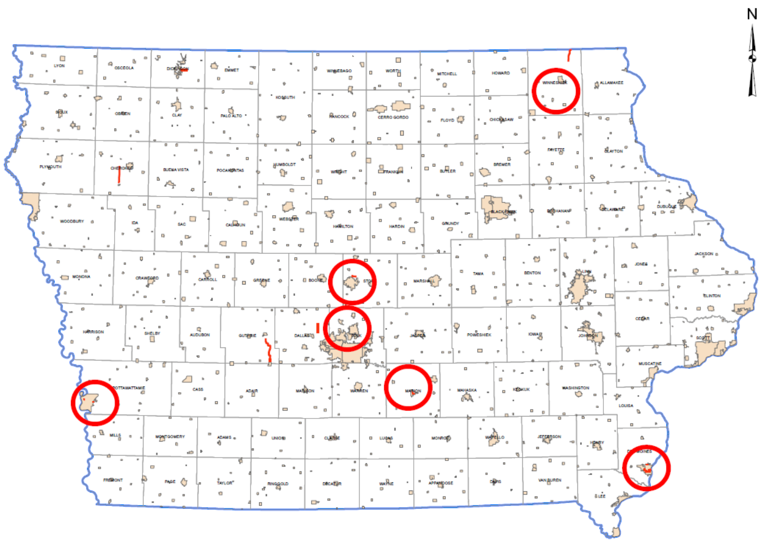
**David J. White, Ph.D., P.E.**
Associate Professor
Director, CEER

**Pavana KR. Vennapusa, Ph.D.**
Research Assistant Professor
Asst. Director, CEER



# IHRB TR-640

- PCC Pavement (16 Sites) were tested to capture range of conditions statewide
  - Pavement Age: 30 days to 42 years
  - Surface Distress Conditions: Poor to Excellent (PCI = 35 to 92)
  - Support Conditions:
    - Natural Subgrade
    - Fly Ash Stabilized Subgrade
    - 6 in. to 12 in. Granular Subbase
  - Pavement Thickness: 6 to 11 in.
  - Traffic (AADT): 110 to 8900

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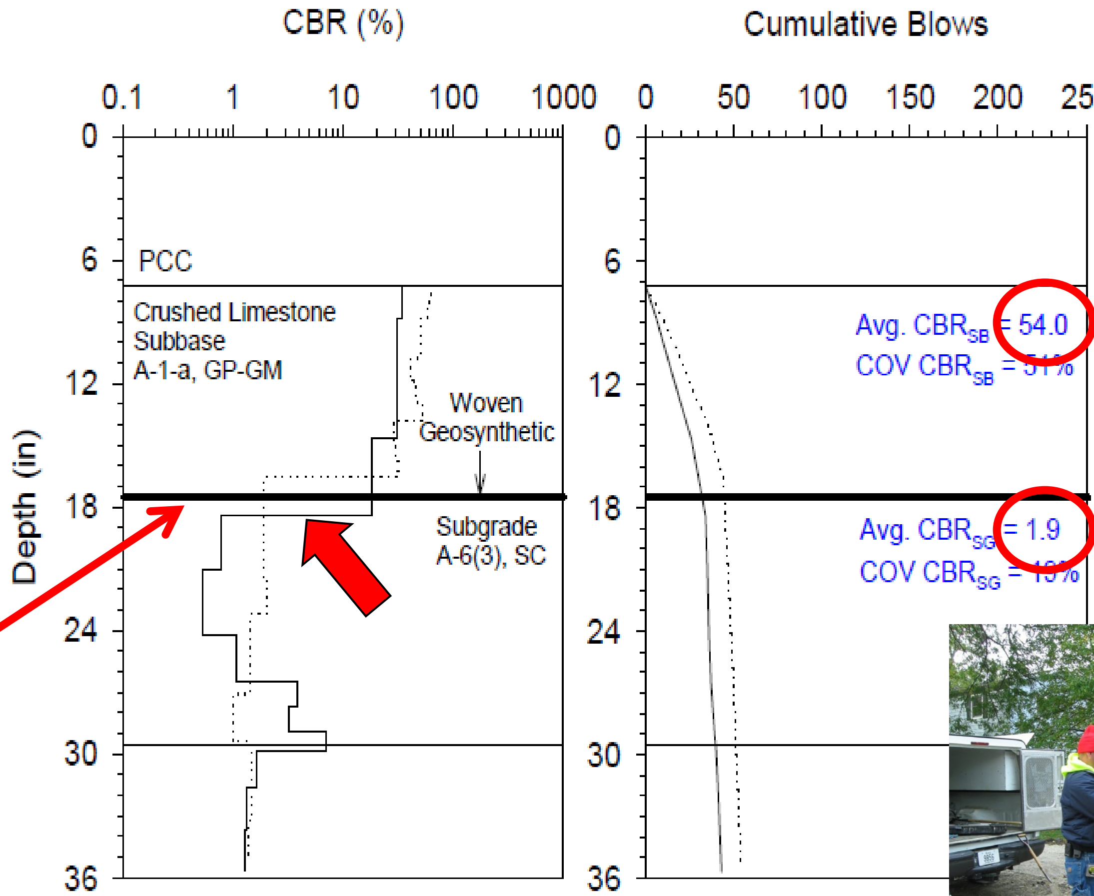
# IHRB TR-640
# Benefits of Geotextiles




Woven Geosynthetic Fabric

**Southwest Westlawn Drive (Poor Subgrade)**

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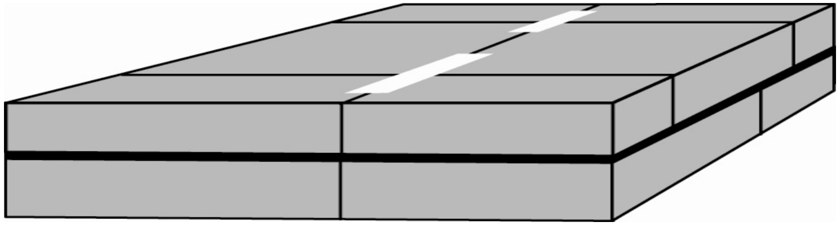
# Nonwoven Geotextile for Unbonded Concrete Overlay Separation Layer



**Isolation** (from movement in underlying pavement)

- Shear plane that relieves stress, mitigates reflective cracking and prevents bonding

**Drainage**

- Must channel infiltrating water along the cross-slope to a ditch or working subdrain system

**Bedding**

- Cushion for the overlay to reduce bearing stresses and the effects of dynamic traffic loads and prevent keying from the existing pavement

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# Nonwoven Geotextile for Concrete Overlay Separation Layer

- Practice began in Germany 20 years ago
- In 2006, a team of public/private sector rep's brought practice to US (including FHWA and AASHTO)
- 2008 – First US DOT project installed in Missouri
- 2008 – 2017
  - Over 100 projects have been specified & installed
  - Over 100,000,000 SF of Geotextile Interlayer installed
  - 14 US states have utilized Geotextile Interlayers

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# Separation Layer Type
# Nonwoven Geotextile vs. HMA

## Cost

- Geotextile: $3 per SY installed ($42k per mile)
- 1” HMA layer: $5 per SY in-place costs ($70k per mile)

    Anti-striping agent (lime) can be used

## Placement/Installation

- No need for multiple contractors or large equipment
- Fabric can be placed in more diverse conditions vs. HMA

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# Separation Layer Fabric Weight

≤ 4" Overlay – Consider 13.3 oz. / sy- Typical thickness 130 mils

5" Overlay & greater – Consider 14.7 oz. /sy – Typical thickness 170 mils

2013 MnRoad Research constructed a 3" ultra-thin fiber reinforced concrete overlay on a thin, 8 oz per SY fabric - continuing to monitor performance

# Color of Fabric

## Two Predominant Colors Used

## Black and White

•Black - carbon molecules which absorb Ultra-Violet energy
•Requires damping to reduce heat below 120º F.
•Use in spring and fall

•White - pure polypropylene resin and reflects Ultra-Violet energy
•Does not require damping to reduce heat
•Use in summer months

# IOWA DOT DS-15018

## Developmental Specifications for Pavement Interlayer Geotextile

**Effective Date**
**October 20, 2015**

Compressed 1/8” to 1/16” under dynamic load (3-4 psi)

**Table DS-15018.02-1: Pavement Interlayer Geotextile Properties**

| **Property** | **Requirement** | **Test Method** |
|---|---|---|
| Fabric Type | Non-woven Geotextile, no thermal treatment | EN 13249, Annex F |
| Mass per unit area | ≥13.3 oz/sq.yd and ≤16.2 oz/sq.yd | ASTM D 5261 |
| Thickness under load (pressure) | 0.29 psi: ≥ 0.12 inches<br>2.9 psi: ≥ 0.10 inches<br>29 psi: ≥ 0.04 inches | ASTM D 5199, modified under loads of 0.29, 2.9, and 29 psi |
| Tensile strength | ≥ 685 lb/ft | ASTM D 4595 |
| Maximum elongation | ≤ 130% | ASTM D 4595 |
| Water permeability in normal direction under load (pressure) | ≥ $3.3\times10^{-4}$ ft/s[under pressure of 2.9 psi]<br>Longitudinal drainage | ASTM D 5493 |
| Water permeability in the plane direction of the fabric (transmittivity) under load (pressure) | ≥ $1.6\times10^{-3}$ ft/s [under pressure of 2.9 psi]<br>≥ $6.6\times10^{-4}$ ft/s [under pressure of 29 psi]<br>Transverse drainage | ASTM D 6574 |
| Weather resistance | Resistance ≥ 60% | EN 12224 |
| Alkali resistance | ≥ 96% Polypropylene/Polyethylene | EN 13249, Annex B |

Note: EN is European Standard

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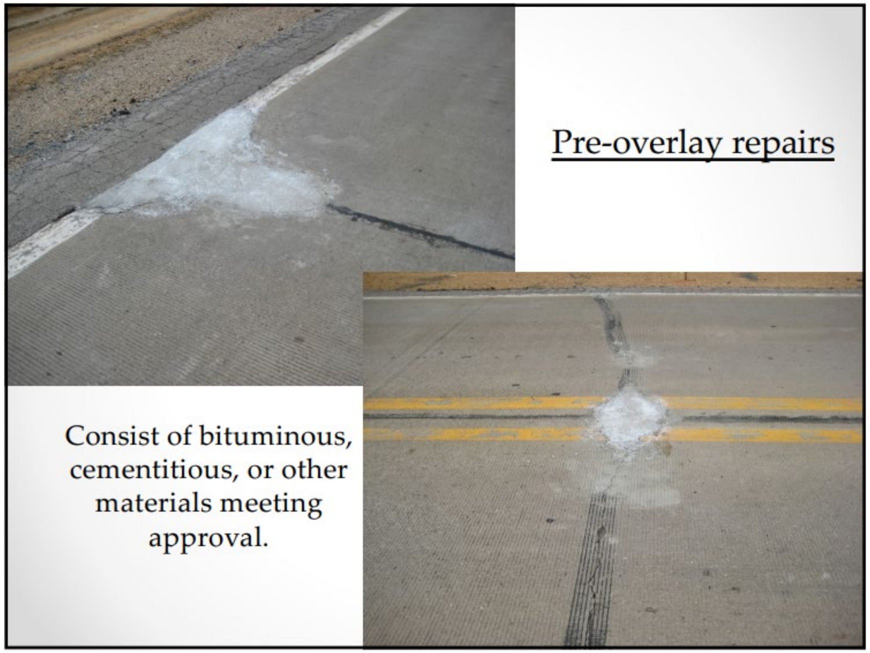
Must meet AASHTO M 288, except as modified above

# Route D Missouri




2008 Unbonded Concrete Overlay
First U.S. project with nonwoven geotextile fabric
5” min, 6’ panels
9300 AADT (5% trucks)
Severe joint distress

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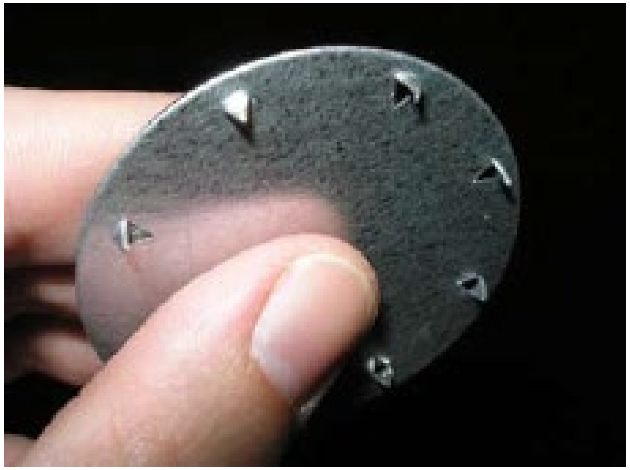
# Route D Missouri




10 years old and performing very well

# Separation Layer Installation (Nails)

To secure the geotextile, pins or nails should be punched through 2- to 2.75-in galvanized  washers or discs every 6 ft or less (Hilti Gun)



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# Separation Layer Installation (Adhesive)

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# Pins/Nails vs. Adhesive

1. **Cost**
   - Pins/Nails: $0.18 - $0.25/sy installed
   - Adhesive: $0.20 - $0.22/sy installed
2. **Placement/Installation**
   - Adhesive is much quicker than pins, requires less labor
3. **Performance**
   - Adhesive performs in 40mph wind. Geotextile pulled through pins.
   - Adhesive is "non destructive", pins penetrate into pavement

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# Paving

## Control Concrete in Front of Paver


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# Driving on Fabric

- Geotextile traffics well
- Avoid sudden changes in acceleration
- Avoid sharp or sudden turns – leave cut outs at access points
- Wrinkles should be cut out and fixed before paving

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# Nonwoven Geotextiles for Unbonded Concrete Overlays - Summary

- Cost and time savings
- Over 10 million SY placed nationally since 2008
- 10 year positive performance
- State agencies continue to optimize material and construction practices


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# Thank you!

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