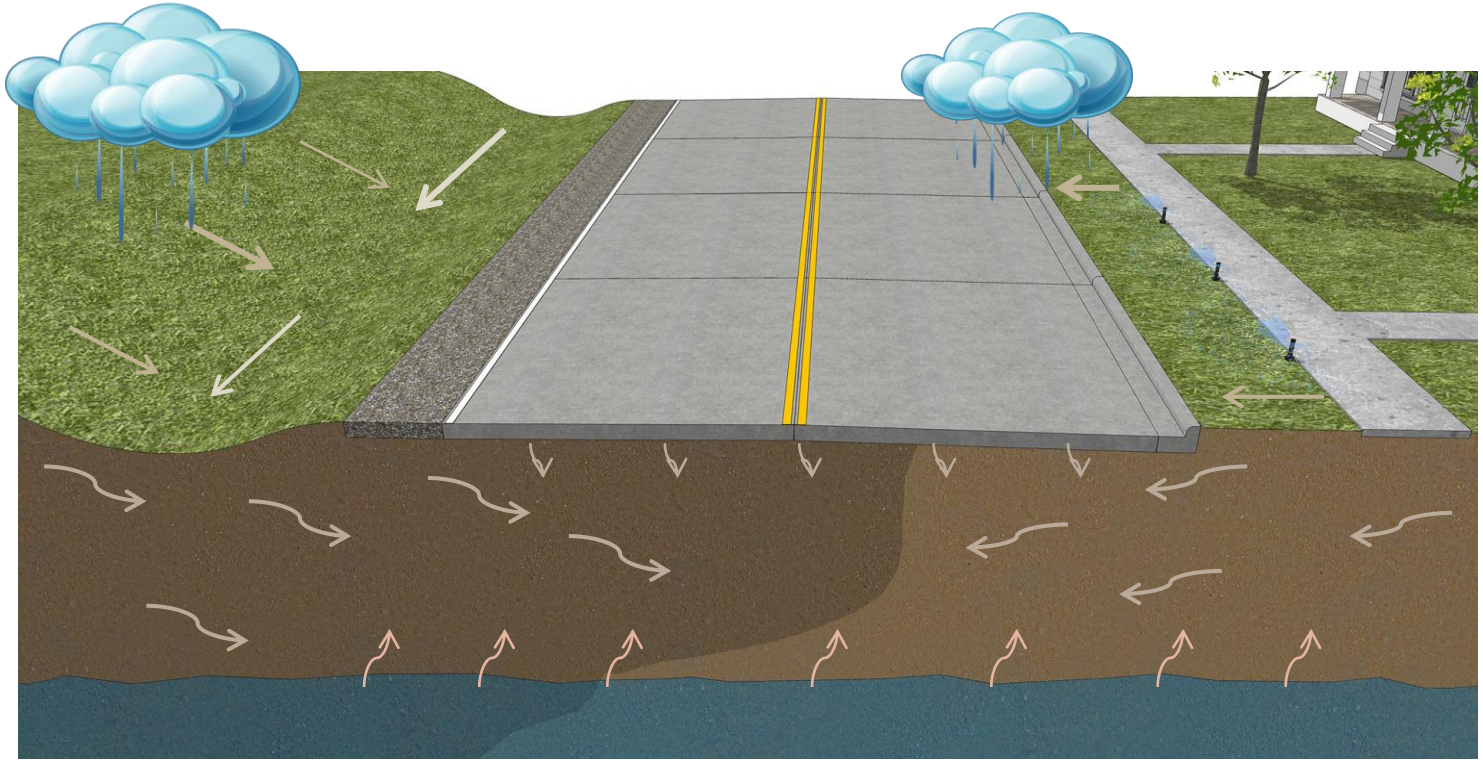
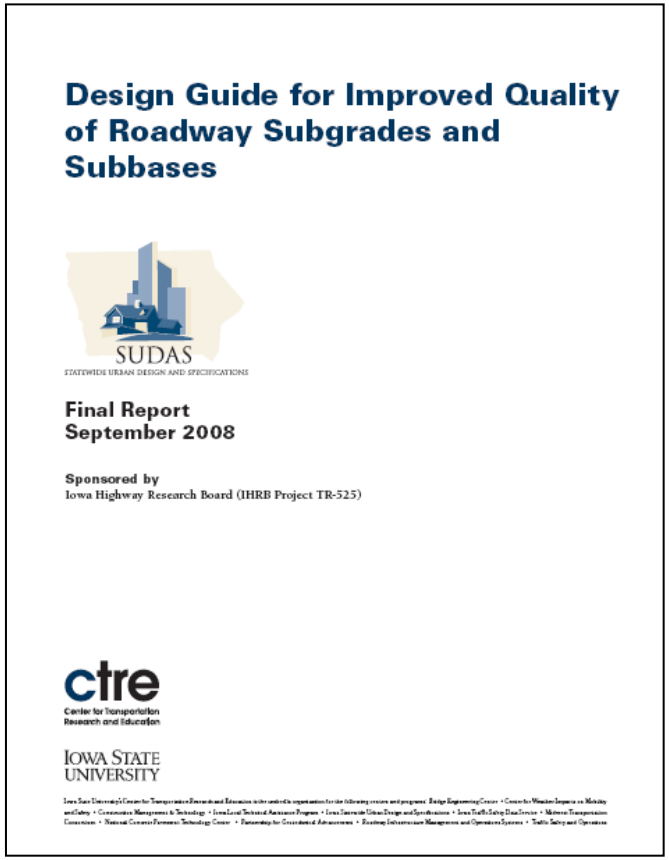
Best Practices for Design of Subgrades & Subbases

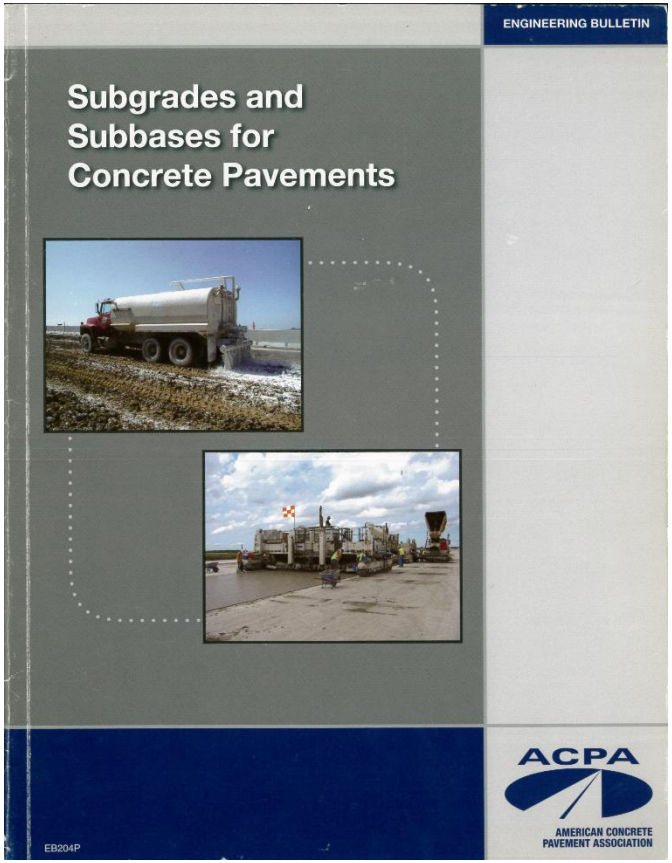


55th Annual Iowa Concrete Paving Association Workshop
February 7, 2019

Design Guidance



CHAPTER 6 - SUDAS DESIGN MANUAL



The performance of a pavement depends on the quality and drainage of its subgrade and subbase layers

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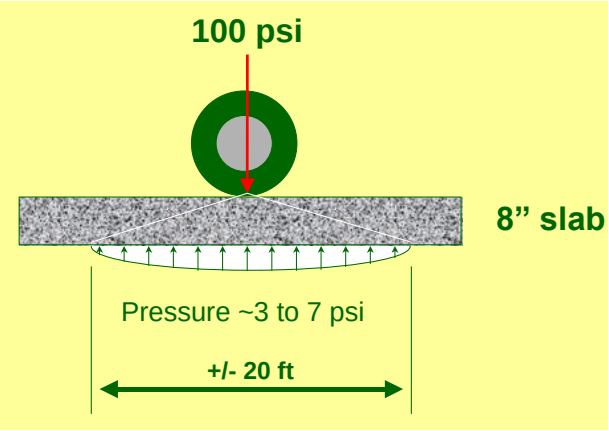
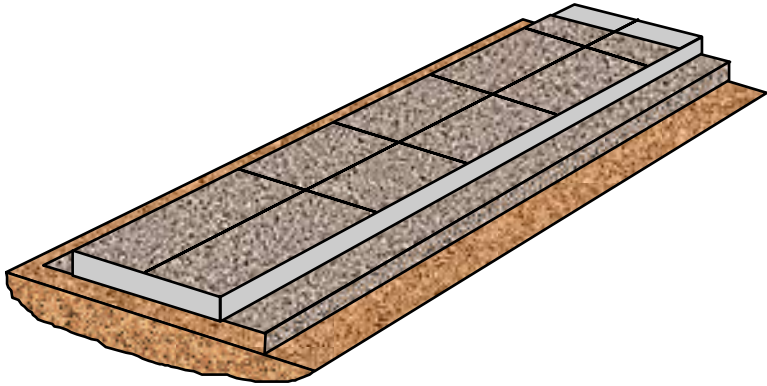
Pavement Support Basics

- 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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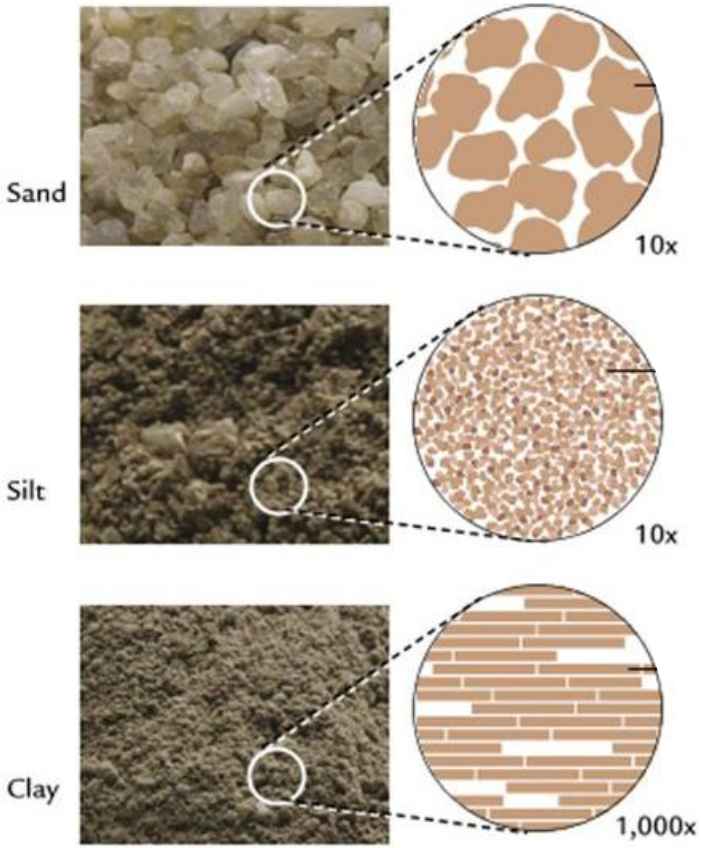
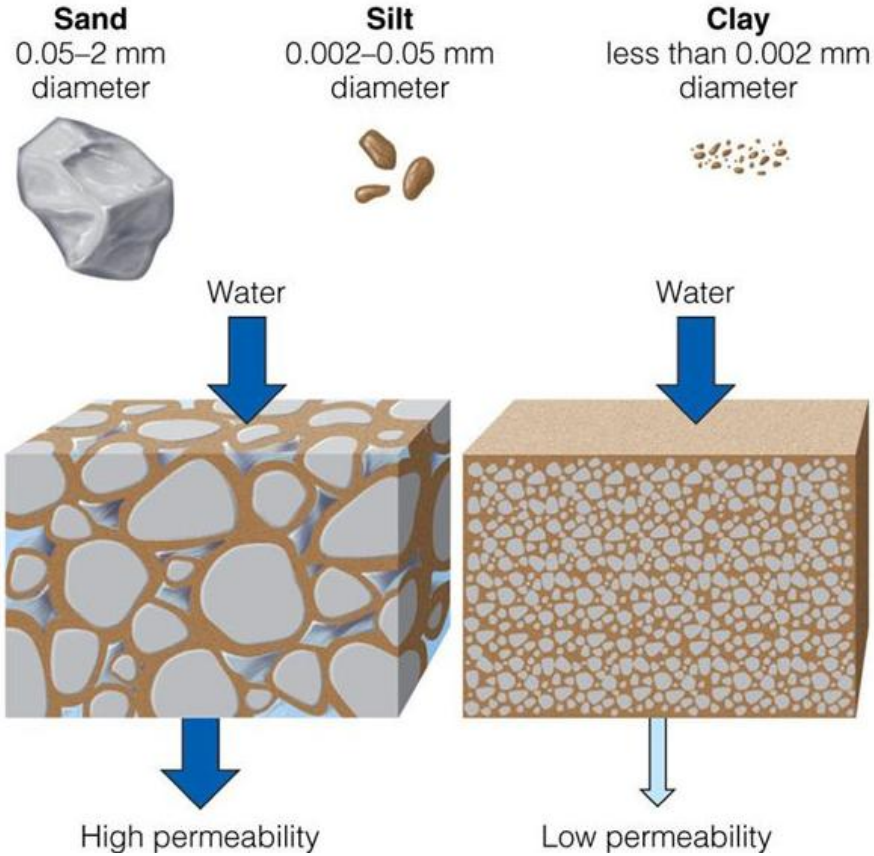
Presentation Items

1. Soils/Subgrades
2. Subbases
3. Geosynthetics
4. Soil Stabilization
5. Research

SOILS / SUBGRADES

Soil Particle Size (by themselves)





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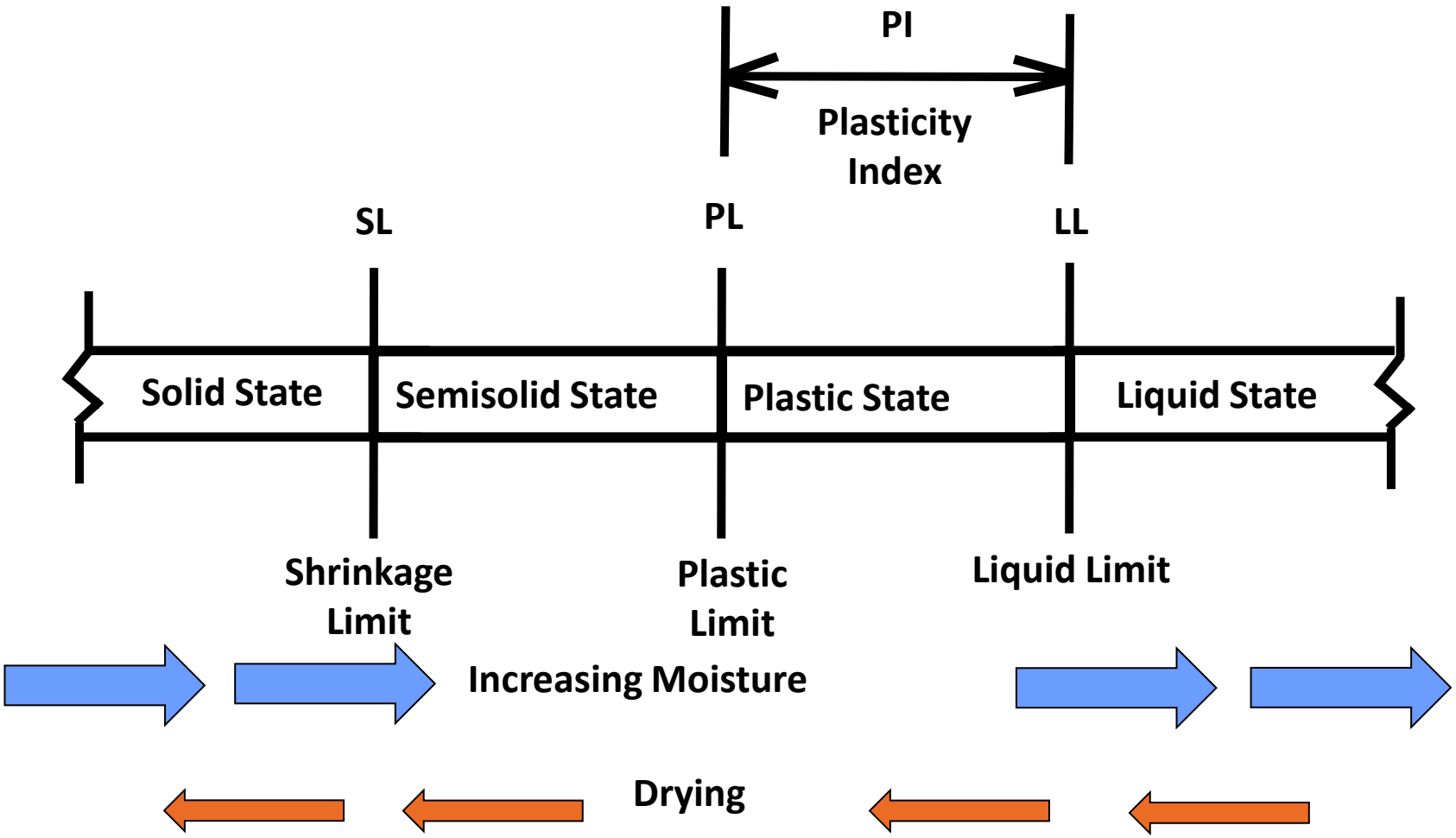
Source: Thomson Higher Education

SL=Shrinkage Limit (While drying, no more shrinkage)
PL=Plastic Limit (Beginning of Plastic State. The higher, the more swelling)
LL=Liquid Limit (Beginning of Liquid State. The higher, the greater compressibility)
PI=Plasticity Index (LL-PL) (The higher, the more plastic the soil and higher swell)



Challenges of Iowa Soils

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

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Compaction of Soils

Why compact the soil?

- Removes air and moisture
- Well compacted soils minimize the amount of moisture moving through
- Reduces settlement
- Increases bearing capacity
- Reduces frost heave if soil freezes
- Reduces expansion and contraction

What is the target?

- Compact to 95% of maximum Standard Proctor Density
- Ensure moisture content is within range of optimum moisture to 4% above optimum (SUDAS)

Subgrade Testing – Proof Roll

Proof Roll

- loaded single axle (20,000 pounds) or
- loaded tandem axle (34,000 pounds)
- <10 mph


Source; Geomax Soil Stabilization

Unstable if:

- soil wave in front of load
- rutting >2 inches

SUDAS 2010 3.06.B

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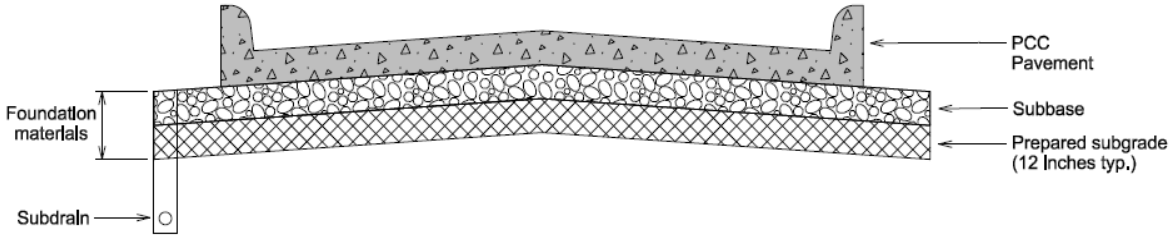
SUBBASES

Subbases

- Provides a working platform during construction
- Provides uniformity as a support layer
- Serves as a drainage system to help drain surface water away from the pavement
- Provides a cutoff layer from subsurface moisture (and risk for pumping)
- Reduces shrink and swell of high volume change soils
- A subdrain and outlet system needs to be provided



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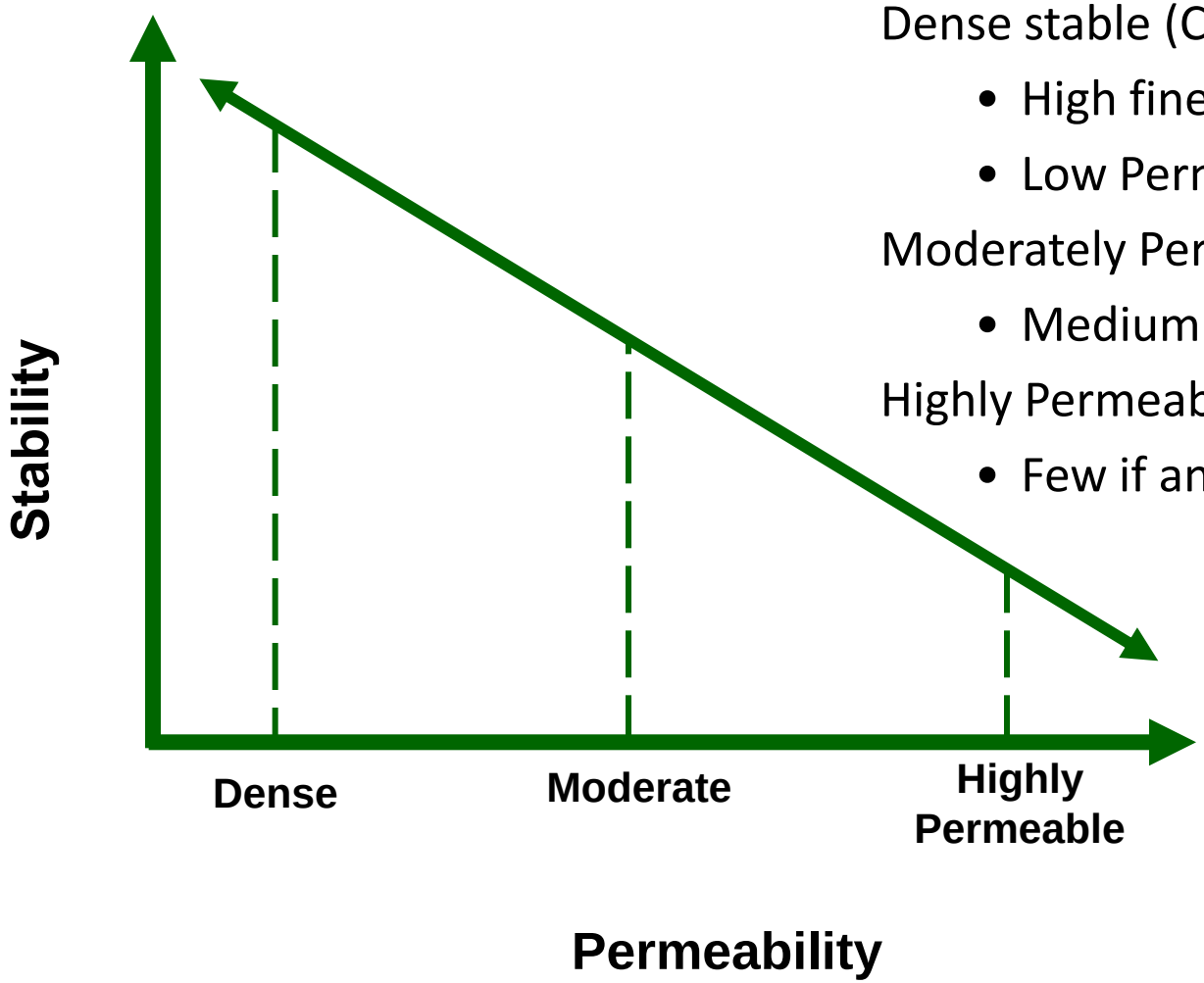
Granular Subbases Stability versus Permeability



Dense stable (Class "A")

- High fines/High Stability
- Low Permeability

Moderately Permeable (Modified Subbase)

- Medium Fines/Medium Stability

Highly Permeable (Granular Subbase)

- Few if any Fines/Low stability

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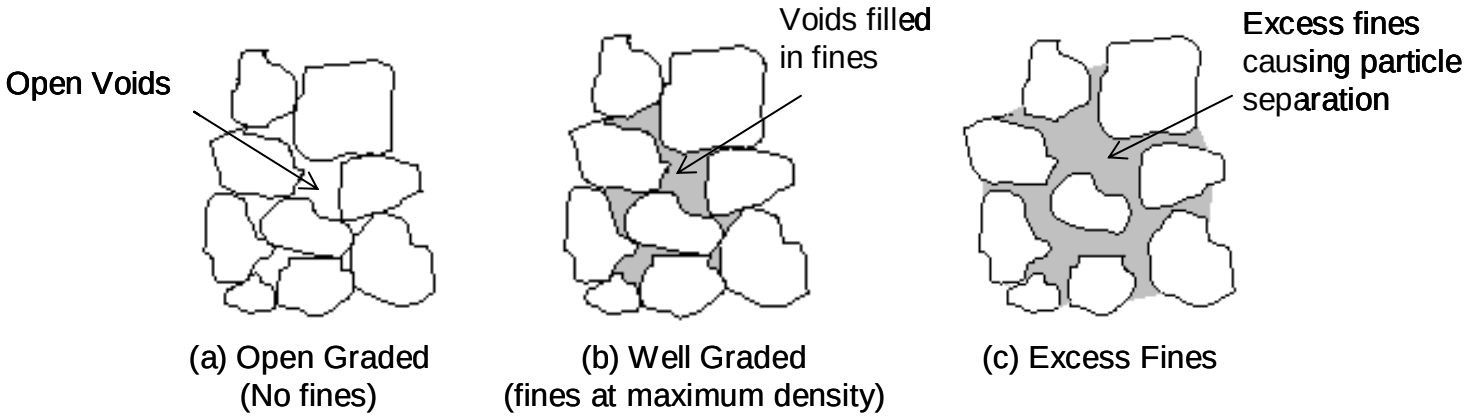
INFLUENCE OF FINES ON AGGREGATE SUBBASE



- Subbases containing no fines (a) achieves some stability through grain-to-grain interlock, resulting in lower densities but higher permeability and less frost susceptibility.
- Subbases with void spaces (b) filled with fines have higher density, and higher stability, but lower permeability.
- Subbases having excess fines (c) cause aggregate particles to float in the matrix resulting in low permeability with low stability when wet.

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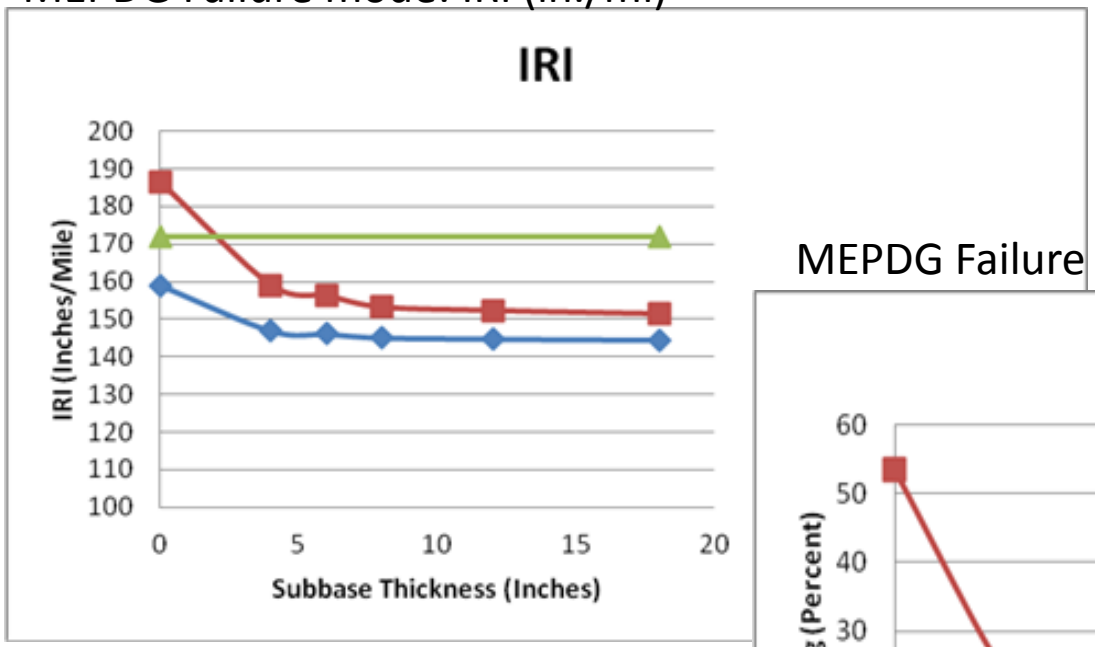
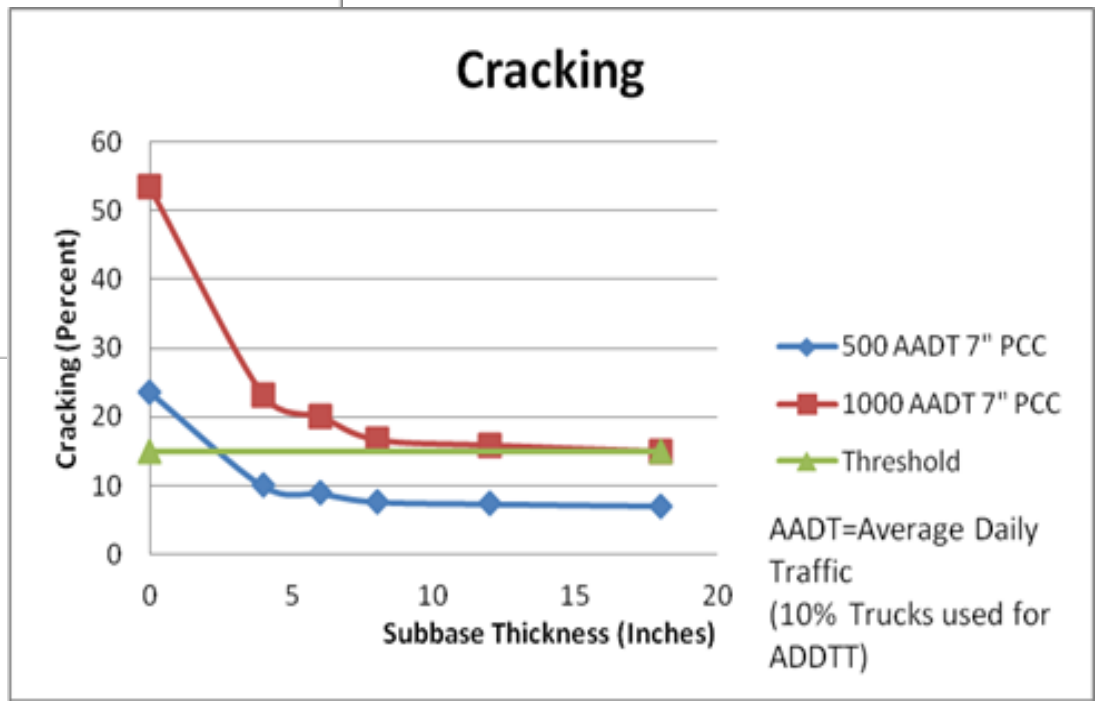
Aggregate Subbase Thickness Limitations

MEPDG Failure mode: IRI (in./mi)



MEPDG Failure mode: % Cracked Slabs



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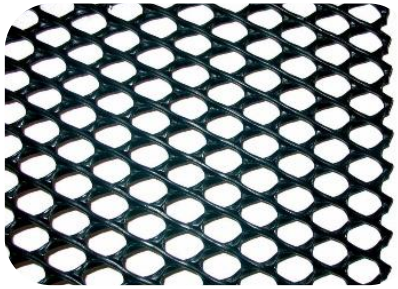
Subbase thickness over 5” does not benefit PCC

GEOSYTHNETICS

Geosynthetics

Geotextile

Geogrid



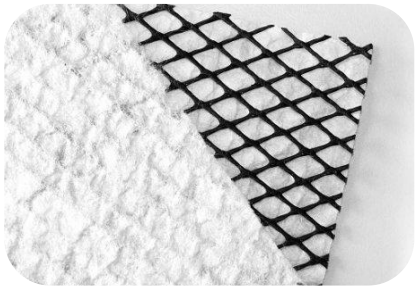
Geonet

Geomembrane

Geocell

Geosynthetic clay liner

Geofoam



Geocomposite

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When to Use Geotextiles/Geogrids

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

Source: Holtz et al. 1998

The Geosynthetic function to be provided is dependent on soil conditions

Adapted from Holtz et al. 1998 & SUDAS Design Manual Chapter 6H

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.

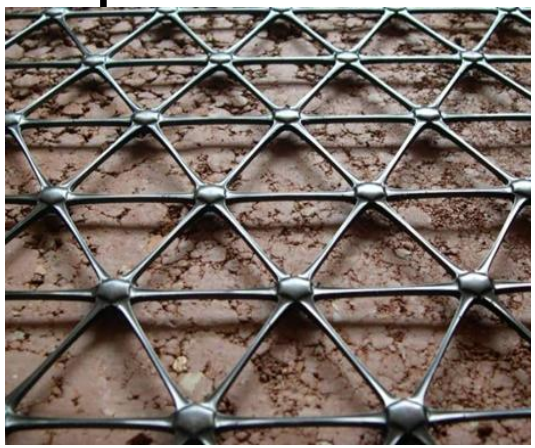
Rectangular vs. Triangular

Biaxial Geogrids

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

Triaxial Geogrids

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



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Geotextiles

<u>Woven</u>

- High strength support
- Less permeable
- Used to increase support & stabilization (and filtration and separation)

<u>Nonwoven</u>

- Felt-like
- More permeable
- Used for filtration and separation

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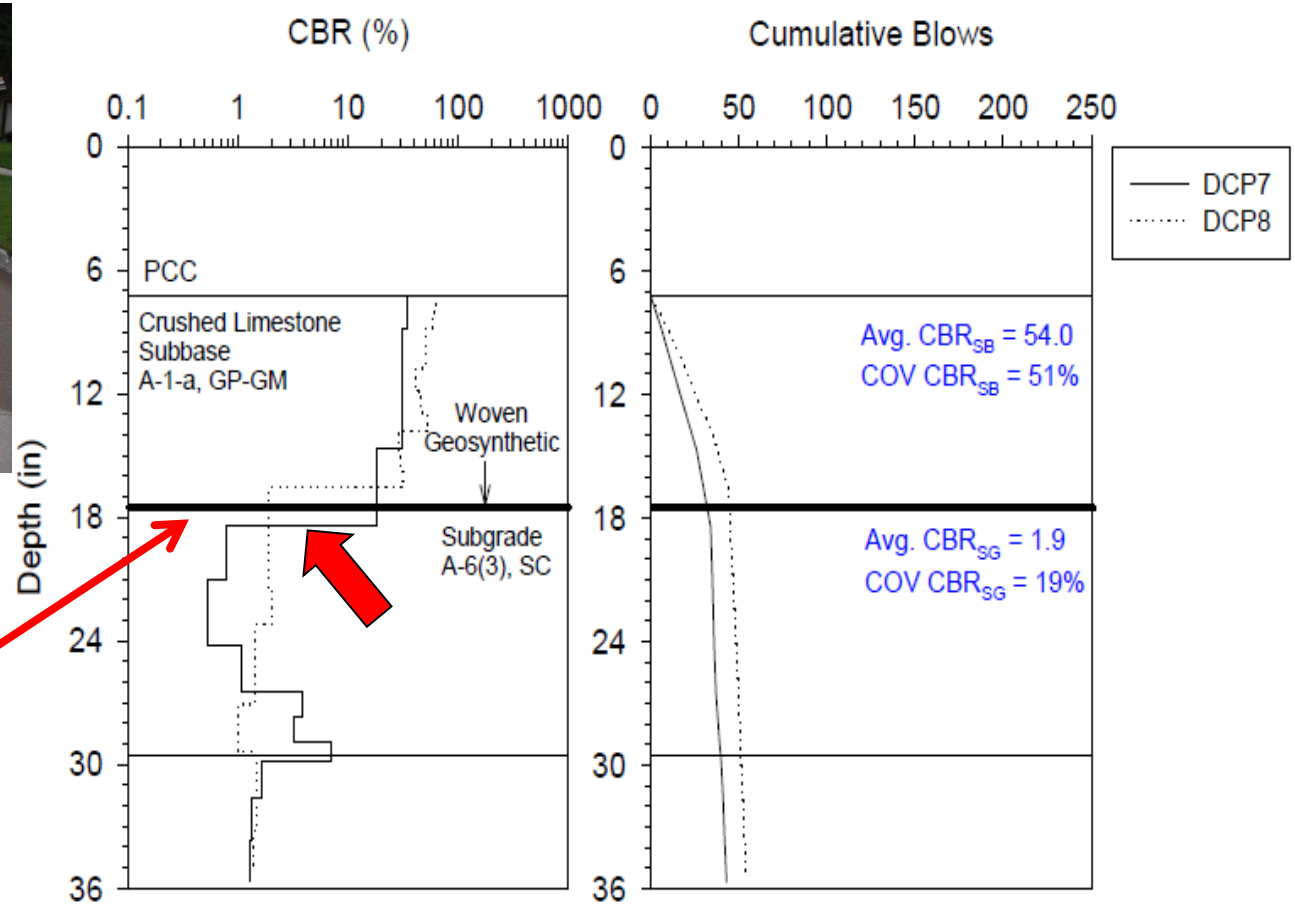
Made of Polypropylene fibers

Benefits of Geotextiles



Woven Geosynthetic Fabric

Southwest Westlawn Drive (Poor Subgrade)

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SOIL STABILIZATION

Chemical Soil Stabilization Options

Soil Stabilization:
To amend the undesirable properties of poor native soils to make suitable for construction

Fly Ash
- Class C 15-18%

Quick lime
- High quality 3-4%
- Dolomite quicklime 6-8%

Cement Modified Soils (CMS)
Cement Stabilized Subgrade (CSS) (adds compressive & shear strength)
- Cement 3-5%

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Fly Ash & Lime

Fly Ash

- Some concern for weakening in spring thaw
- May tend to group clay particles together and make more frost susceptible
- Recommend compaction within 2 hours

Quicklime

- Has slower reaction than Fly Ash
- If applied to dry soil, it can expand later

Both create a working platform

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Source: Boone County Expo Research Study

Cement Modified Soils (CMS)
Cement Stabilized Subgrade (CSS)

<u>Use 3 - 5% Cement</u>

1. Provides Uniformity
2. Provides Working Platform
3. Provides bonding of particles
4. Reduces Shrink-Swell Potential of Clay Soils
5. Wet cohesive soils may require disking to cut in cement
6. All operations in one day
7. May be applied in dry or slurry form
8. Permanent

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Source: PCA

Chemical Soil Stabilization Construction

- Recommend placement in temperatures above 40ºF otherwise it sits dormant
- Blend in soil with rotary mixer
- Use sheepsfoot roller for initial roll, then smooth drum roller
- Shape with motor grader to final crown and grade

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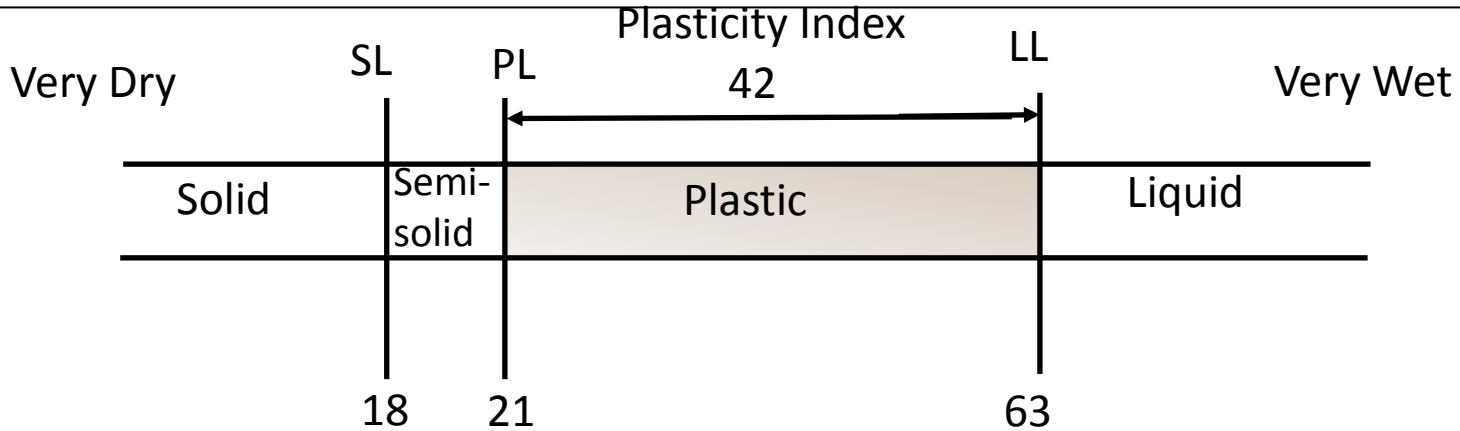
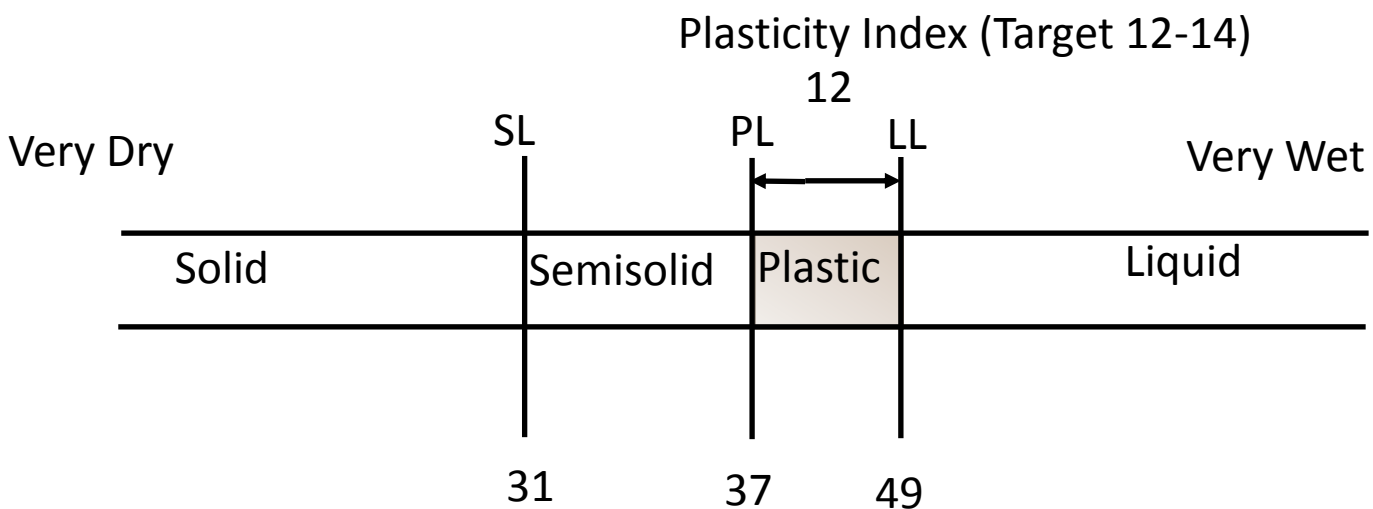
Effect of 3% Cement on Cohesive Soils

SL=Shrinkage Limit (While drying, no more shrinkage)
PL=Plastic Limit (Beginning of Plastic State. The higher, the more swelling)
LL=Liquid Limit (Beginning of Liquid State. The higher, the greater compressibility)
PI=Plasticity Index (LL-PL) (The higher, the more plastic the soil and higher swell)

Before CMS



7 days after adding 3% cement



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Effect of 3% Cement on Cohesive Soils

TB011P – Subgrades and Subbases for Concrete Pavement

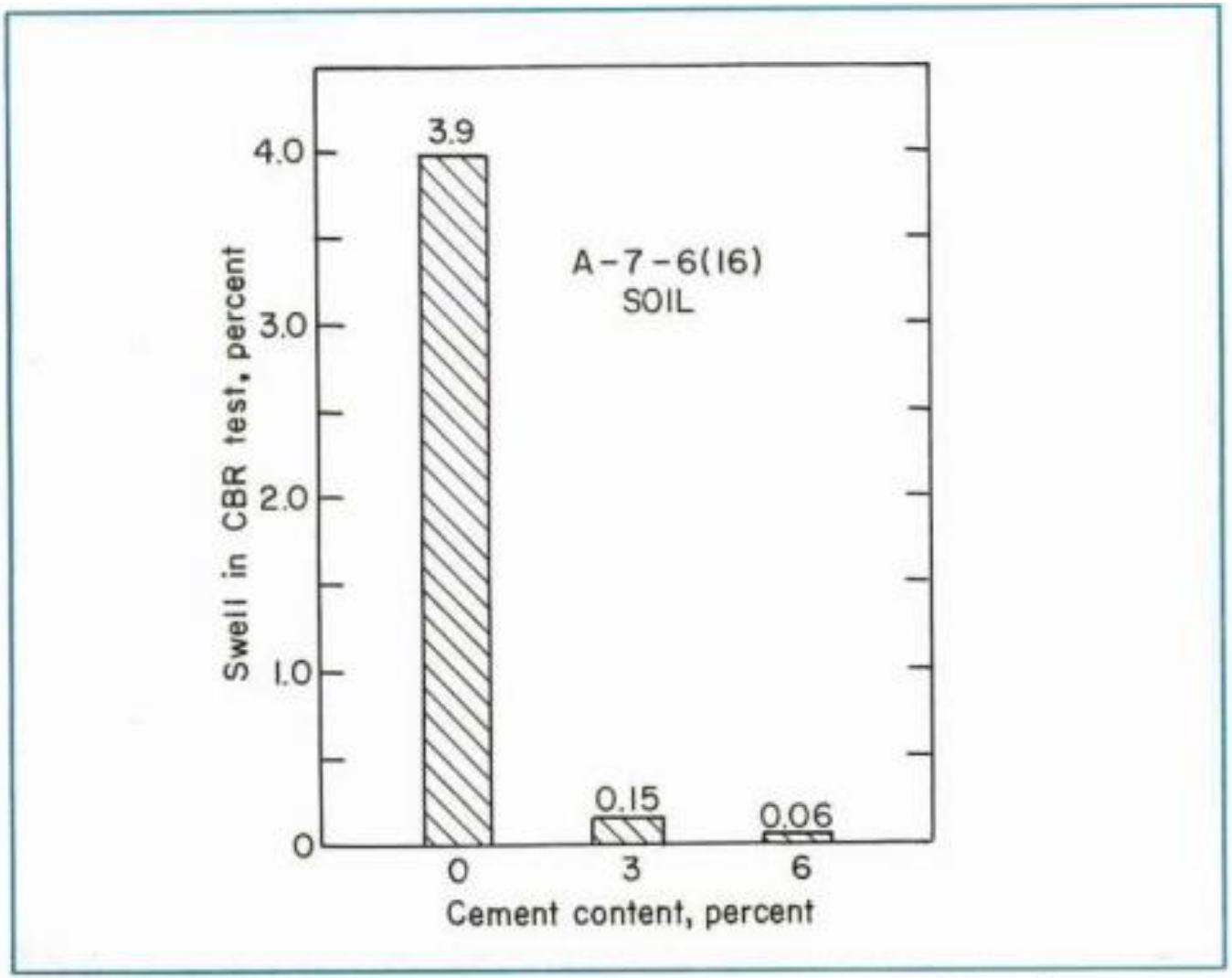

Figure 6.— Effect of cement treatment on expansive clay.

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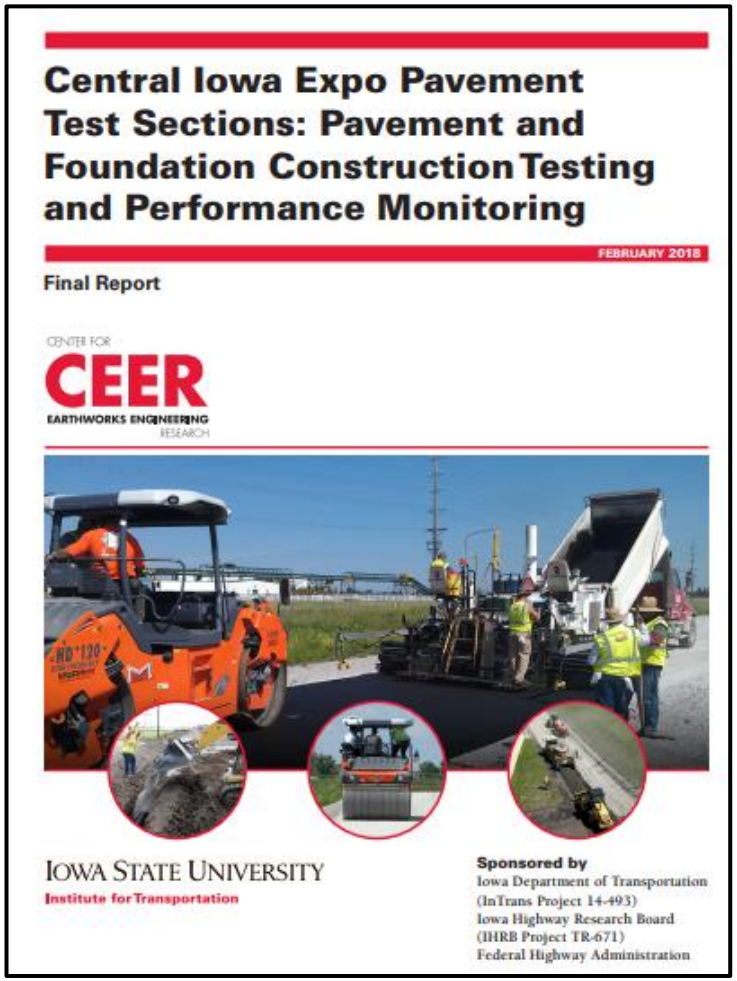
RESEARCH FINDINGS ON PAVEMENT SUPPORT LAYERS

IHRB TR-671 Performance Monitoring of Boone County Expo Pavement Sections (Phases I-III)



Central Iowa Expo Pavement Test Sections: Pavement and Foundation Construction Testing and Performance Monitoring

FEBRUARY 2018

Final Report

CENTER FOR CEER EARTHWORKS ENGINEERING RESEARCH

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Department of Transportation
(InTrans Project 14-493)
Iowa Highway Research Board
(IHRB Project TR-671)
Federal Highway Administration

RESEARCH REPORTS - DEC 2013

Tech Brief: High-Energy Impact Roller Compaction

Tech Brief: Overview of Foundation Stabilization Technologies

Tech Brief: Roller-Integrated Compaction Monitoring of Subbase

Tech Brief: Stiffness-Based QC/QA Testing

Tech Brief: Subgrade Stabilization Using Geosynthetics

Tech Brief: Fly Ash Stabilization of Subgrade

Tech Brief: Cement Stabilization of Subbase and Subgrade

Tech Brief: Cement Stabilization with Fiber Reinforcement of Subbase

Tech Brief: Mechanical Stabilization of Subgrade Layer

Tech Brief: Geocell Reinforcement of Subbase

Tech Brief: On-Site Reclaimed Material as Subbase Layer

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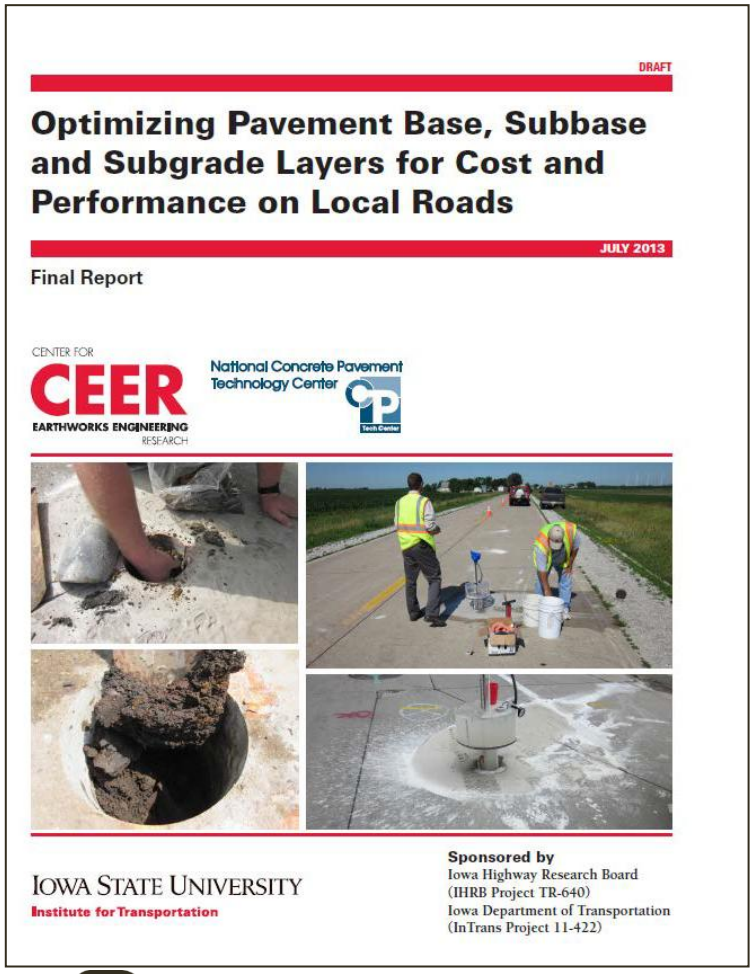
Go to: Intrans.iastate.edu & search “Performance Monitoring of Boone County Expo”

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


DRAFT

Optimizing Pavement Base, Subbase and Subgrade Layers for Cost and Performance on Local Roads

JULY 2013

Final Report

CENTER FOR CEER EARTHWORKS ENGINEERING RESEARCH

National Concrete Pavement Technology Center

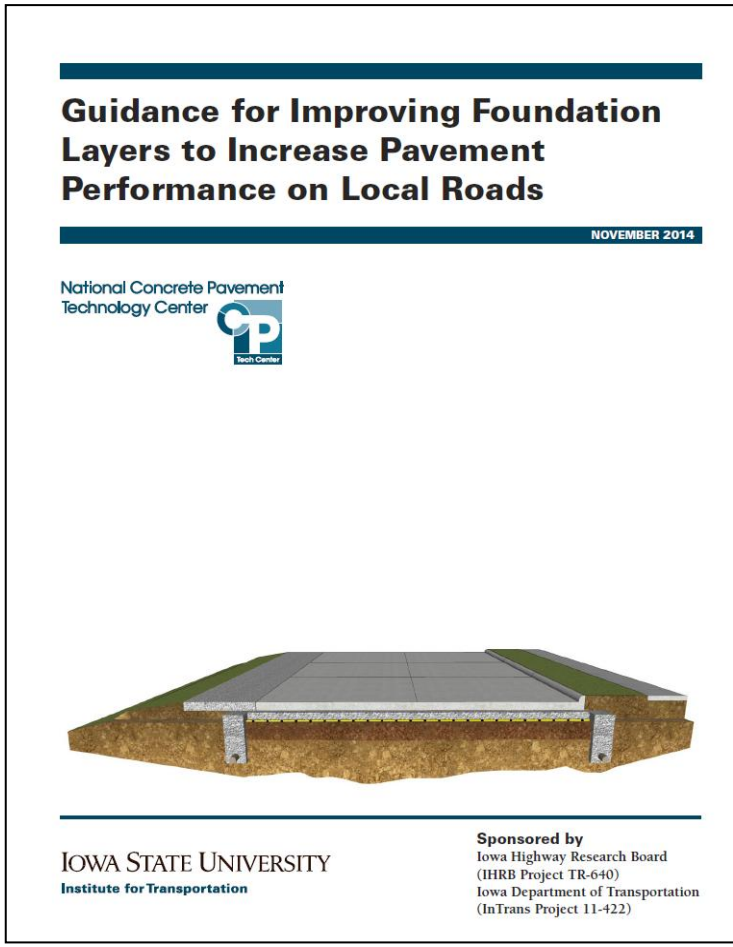
IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Highway Research Board
(IHRB Project TR-640)
Iowa Department of Transportation
(InTrans Project 11-422)

Field Investigation

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

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


Guidance for Improving Foundation Layers to Increase Pavement Performance on Local Roads

NOVEMBER 2014

National Concrete Pavement Technology Center

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Highway Research Board
(IHRB Project TR-640)
Iowa Department of Transportation
(InTrans Project 11-422)

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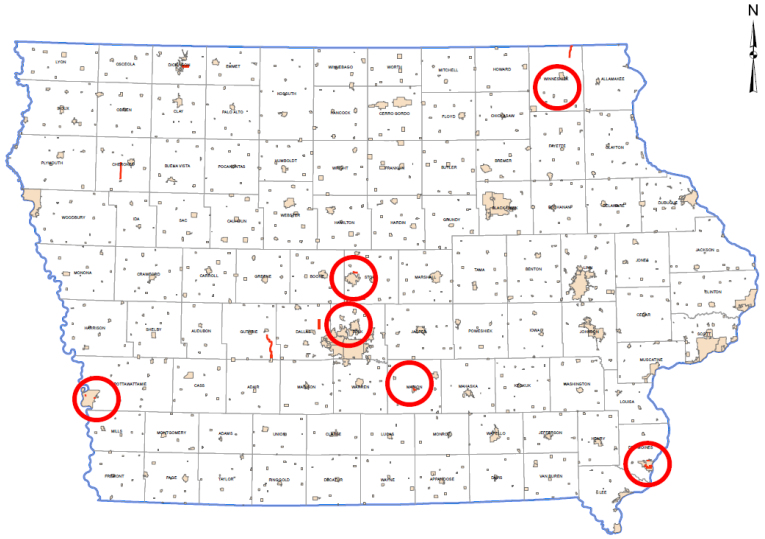
IHRB TR-640

- 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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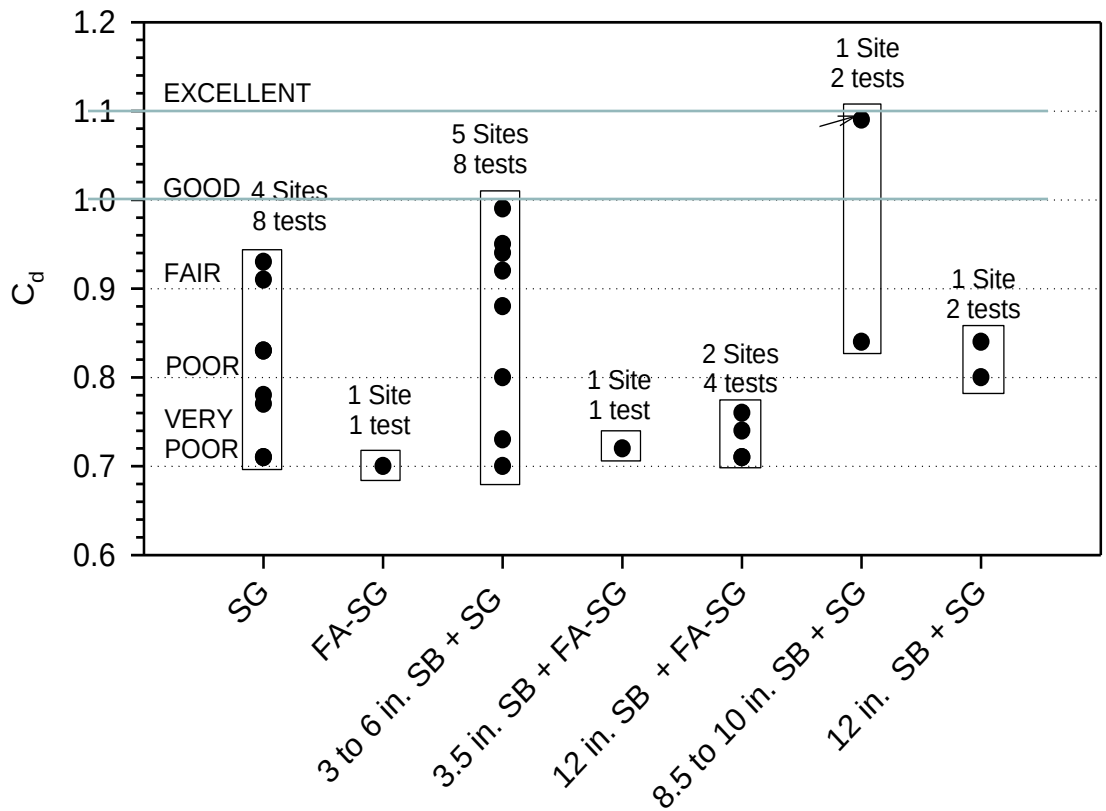
TR-640 Findings

- Low Coefficient of Drainage (Cd)
- Uniform subgrades and higher coefficient of drainage (Cd) have higher the PCI
- Increase in drainage (Cd) has the largest effect on the PCI

SUDAS
Cd =1.1 (Subbase)
Cd =1.0 (Subgrade)



David White

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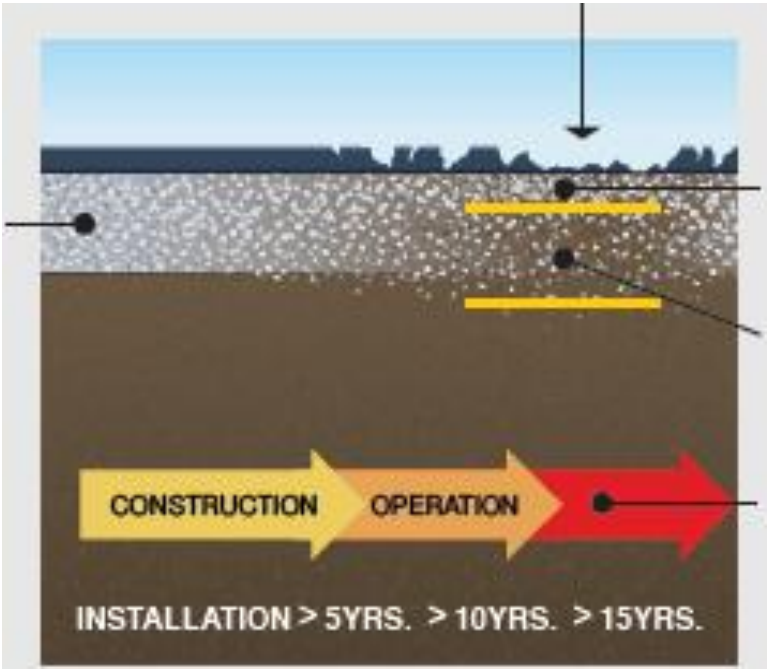
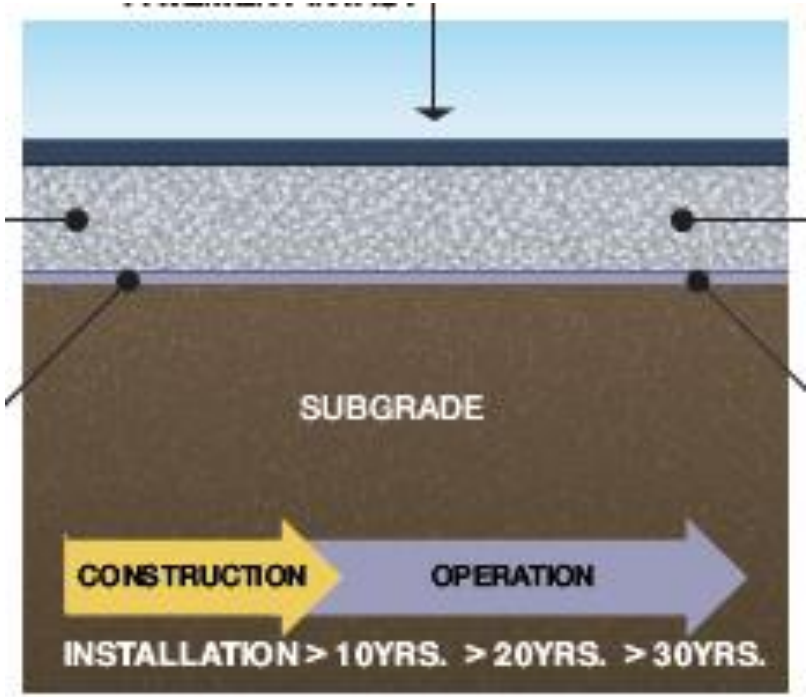
Addressing Soil Migration





<u>Aggregate Subbase Loss</u>

Pavement thickness design software programs do not reflect actual pavement foundation conditions except immediately after construction

Geotextiles provide separation and reinforcement

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Common Soil Improvement Options

Soil Conditions

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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Common Soil Improvement Options

No	Subgrade Conditions	Treatment
1	• Varying types of soil • Meets M & D tests • Passes proof roll test	• Disc and mechanically blend soils (8 in. lifts to 2 ft. depth) for subgrade • Compact to 95% standard proctor
2	• Uniformly wet soils • Does not pass proof rolling or density test	• Dry subgrade by disking • If drying weather is not available or soils are too wet, utilize geotextile, quick lime, cement or fly ash
3	• Expansive or unsuitable soils	• Chemically stabilize soil with cement (changes the PL and LL to acceptable levels. • Remove unsuitable soils and replace with select material

Cost Example for Improved Subgrade Support

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

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

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Thank you!

jgross@snyder-associates.com

cptechcenter.org